

# EVACUATION SIMULATION FOR DISABLED PEOPLE IN PASSENGER SHIP

Keiko MIYAZAKI, Mitujiro KATUHARA,  
Hiroshi MATSUKURA and Koichi HIRATA

National Maritime Research Institute, JAPAN

---

## SUMMARY

Means of escape of transportation facilities should be effective for evacuees including disabled persons. It is, therefore, important to develop methods for evaluating the effectiveness of means of escape for such persons to maintain evacuation safety. One way for the evaluation is an evacuation simulation. We already developed an evacuation simulation in passenger ships for general passengers. It can estimate evacuation time and optimal evacuation routes. Now we are improving it taking disabled people into account. We are carrying out some experiments to investigate data and algorithms for describing the behaviors of a wheelchair user and related persons. In several experiments, we observed the behaviors that pedestrians and a wheelchair user escaped in basic conditions on land. A numerical simulation model for movement of pedestrian group overtaking a wheelchair user has been developed. Then we are investigating how crewmembers escort a simulated wheelchair user onboard. Focusing the behavior of a wheelchair user during ship listing and dynamic ship motion conditions, we have made a motion platform. Through those experiments we are getting information for the evacuation simulation. The improved simulation will estimate evacuation time and optimal evacuation routes for all passengers including disabled people.

## 1. INTRODUCTION

Means of safe evacuation is still very important for ships even though ships have become safer, and various studies on evaluation and modeling of means of escape in ships have been conducted (Galea, 2001), and guidelines has been developed (IMO, 2002). Ships shall also provide safety for disabled persons in their normal use and emergency occasions (DPTAC, 2002). Therefore, safe evacuation measures for disabled persons from transportation facilities including ships should be ensured. As evacuation simulation is one way to evaluate evacuation safety, we already developed an evacuation simulation in passenger ships for general passengers (Katuhara, 1996) and are improving it taking disabled people into account. In this paper we introduce how crewmembers escort a simulated wheelchair user in their fire drill. Then aiming to add data and algorithms to the simulation, we have been carrying out several experiments, which were basic evacuation experiments on land, crew-escorted ones onboard and motion platform ones. Through those experiments we are obtaining useful information to examine evacuation in passenger ships and to improve the evacuation simulation.

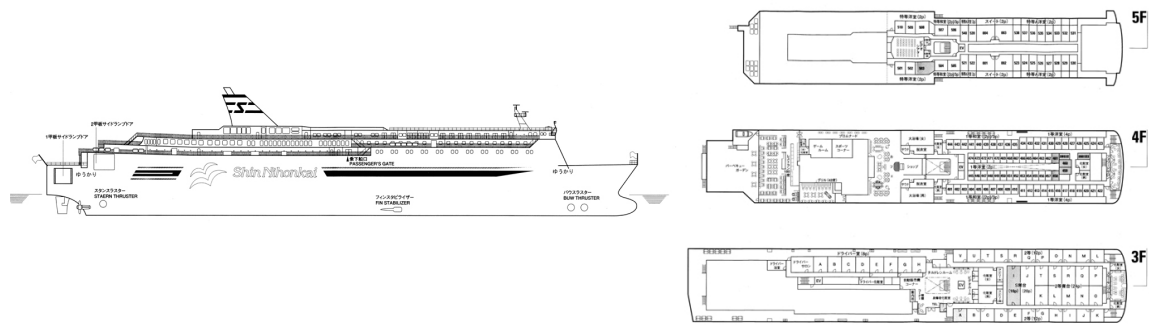


Figure 1 “yuukari” appearance and its deck plan

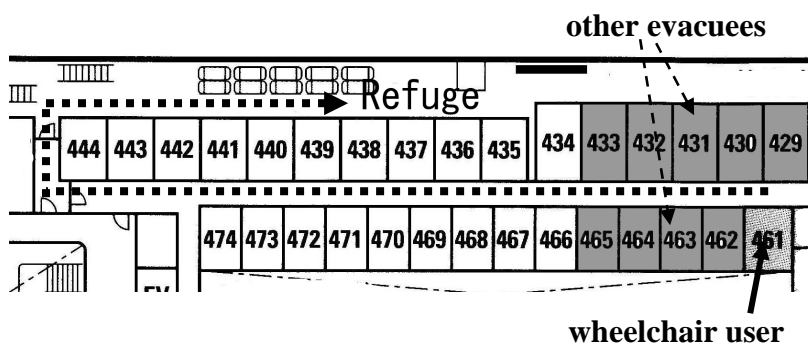


Figure 2 Arrangement of evacuees

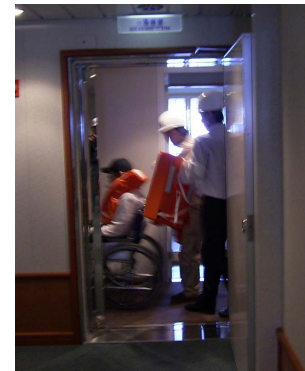


Figure 3 Scene of the drill

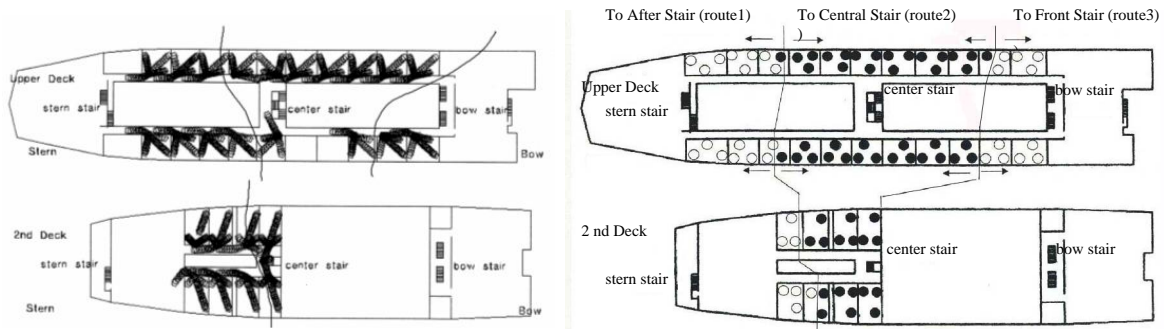
## 2. FIRE DRILL ONBOARD

A fire drill was held in a ferryboat “yuukari” on September 22nd in 2003 at Niigata port in Japan. A simulated wheelchair user and 20 college students attended this drill. Crewmembers behaved as they were trained. We observed the drill and got information of evacuation with a wheelchair user onboard. The “yuukari” appearance and its deck plan are shown in figure 1. Figure2 expresses an arrangement of evacuees' initial positions on the 4th floor as a colored area. One of crewmembers was attended to this area. In the drill he told the evacuees to wear life-jackets and helped the wheelchair user to wear it. At the same time he asked one evacuee to play a role of sub leader. When he guided a group of evacuees to a refuge on the 4th floor, he and the wheelchair user were at the head of the group. The others followed them and the sub leader was the last. A dotted line in figure 2 was the evacuation route. The evacuation with a wheelchair user on a flat floor was executed smoothly. Figure 3 shows a scene of the drill.

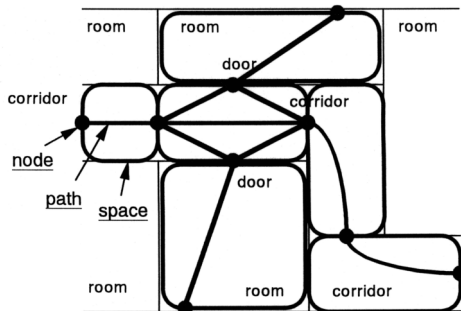
## 3. EVACUATION SIMULATION

### 3.1 Outline of Evacuation Simulation

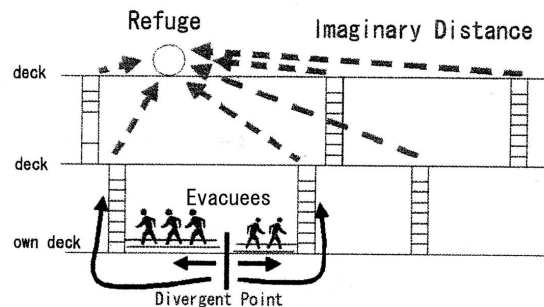
We already developed an evacuation simulation in passenger ships. The simulation was verified by demonstrations onboard (Katuhara, 1996). It can estimate evacuation time and optimal evacuation routes. Furthermore it can treat several types of evacuees such as different moving speed and various response times. So it can show an influence of elderly persons who have a slow walking speed to the evacuation time if we obtain their data. Figure 4 shows an example of the optimum escape routes in a case of minimum evacuation time on both the simulation and the demonstration onboard in a case of general evacuees.



**Figure 4 Example of results of the simulation and the demonstration**



**Figure 5 Network of node-path-space**



**Figure 6 Escape route selections**

### 3.2 Network Model

The interior of a ship is described by the network, which is constituted from nodes, paths and spaces as shown figure 5. Each component has attributes such as width, length and area. Evacuee's movement is defined according to the opening width of node and path, and the density of space. Prepared files of node, path and space are input files and a route-make program produces possible escape routes in advance. This possible escape route files and evacuees' initial positions files are the next input files. The evacuation simulation calculates the minimum evacuation time and its optimum escape routes.

### 3.3 Escape Route Selection Model

Evacuees are considered to judge the optimum route at all times and their evacuation action is considered to be group behaviors. The route selection model based on group psychology is as follows:

- 1) Evacuees desire to reach a refuge earlier.
- 2) Evacuees get all information on their own deck using every sense of sight, hearing and smell.
- 3) Evacuees only imagine the situation of other decks except their own deck.
- 4) Group psychology is dominant.
- 5) Moving speeds and response times depend on types of evacuees.

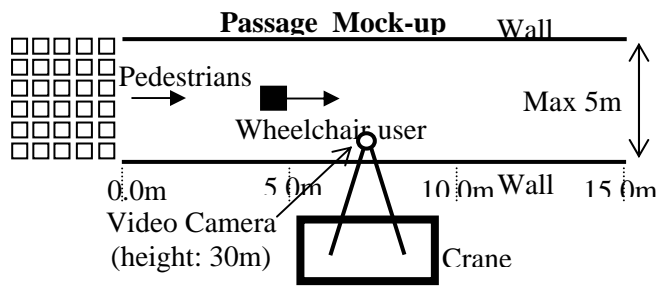
As an amount of psychology imaginary distance is defined as the distance on the imagination from stairs to refuges as shown in figure 6. Each evacuee chooses a route that takes minimum time calculated by a formula (1). Group psychology means that a certain imaginary distance of each evacuee is the same value.

$$T_{mowd} + T_{wowd} + T_{motd} \quad (1)$$

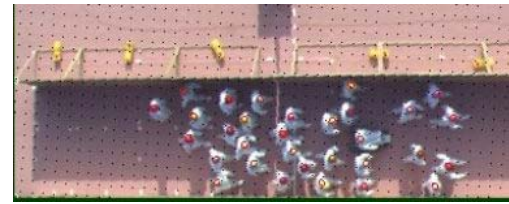
$T_{mowd}$ : moving time on own deck

$T_{wowd}$ : waiting time at congestion point on own deck

$T_{motd}$ : moving time along the imaginary distance of other decks



**Figure 7 Outline of experiments**



**Figure 8 Example image data of video picture**

## 4. EXPERIMENTS FOR EVACUATION SIMULATION

As described above the evacuation simulation in passenger ships for general evacuees has been completed. Now we are improving it taking disabled people into account. It is required that data describe behaviors of disabled persons. Then we are carrying out some experiments to investigate data and algorithms for describing the behaviors of a wheelchair user and related persons. In this chapter the main results of pedestrians and a wheelchair user experiments are explained. Since crew-escorted experiments on stairs and motion platform experiments are ongoing ones, they are shown just their outlines.

### 4.1 Interference of Pedestrians and Wheelchair User Experiments

#### 4.1.1 Outline of Experiments

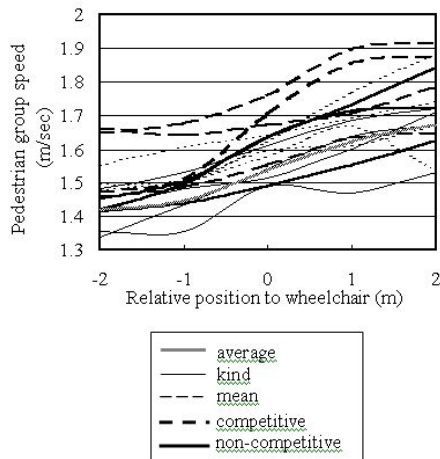
We conducted experiments on the movement of pedestrians and a wheelchair user using 30 pedestrians (27 males and 3 females of college students) and one wheelchair user, who wore colored helmets for identification purpose and moved together in a corridor mock-up of 15 m in length, as shown in figure 7 (Miyazaki, 2003). The movement of them was recorded by a video camera set at about 30 m high above the corridor. A position of a pedestrian was determined by the position of the pedestrian's helmet on the image data of video pictures. Figure 8 shows an example of the image data.

The wheelchair was an electrical operation type and capable of keeping its traveling speed. The conditions of the experiments were (1) width of the corridor, (2) with or without a doorway put in the middle of the corridor, (3) initial density of the pedestrians, (4) wheelchair conditions, and (5) psychology of pedestrian group such as competitiveness and kindness.

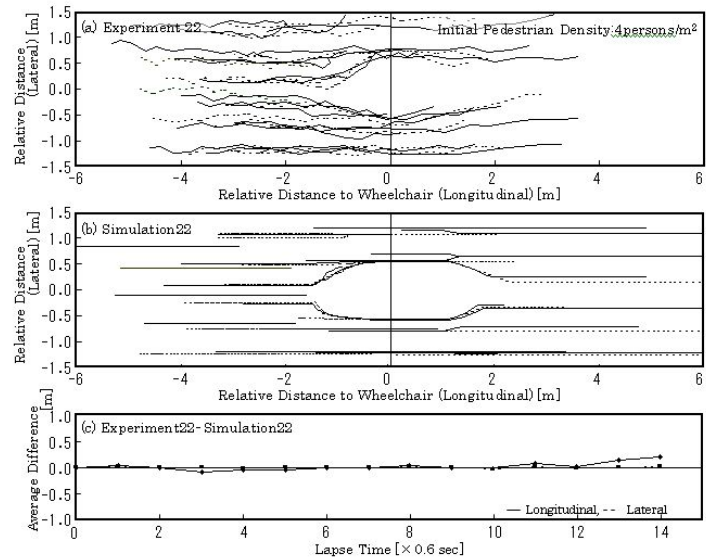
#### 4.1.2 Results of Experiments

It was observed that behaviors of both the wheelchair user and the pedestrians influenced each other, while both basically tended to keep their speed, and once changed the speed they tended to recover their speed to that of original. Figure 9 shows the pedestrian group speed in various group psychological conditions. When the pedestrians had competitive spirits or mean mental state, the pedestrian group speed was faster than that in the other mental conditions. On the other side when the pedestrians had no-competitive spirits or kind mental state, the pedestrian group speed was slower than that in the other psychological conditions. However, the speed was recovered almost to the initial speed after overtaking.

In cases of doorway-put-in the walking speed of some pedestrians, who went through the doorway together with or just after the wheelchair user, dropped considerably at the



**Figure 9 Pedestrian group speeds in relation to mental conditions**



**Figure 10 Comparison of the results**

doorway. By the calculation of the flow rate (persons/sec.) at the doorway, it can be said that a wheelchair user seems to correspond to 2 or 3 pedestrians in regard to flow rate at doorway.

#### 4.1.3 Numerical Simulation of Overtaking Wheelchair User

We investigated the behavior of the pedestrians who overtook the wheelchair user and identified 5 rules that explained features of the pedestrians' behaviors (Matsukura, 2003).

- Rule 1. Rule for dividing walking zone by selections
- Rule 2. Course change rule
- Rule 3. Speed adjustment rule
- Rule 4. Avoiding action rule
- Rule 5. Cognitive activity cycle : Expect-Estimate-Modify-Execute

Figure 10 shows an example that is a comparison of the results of the experiments and the simulation. Both results have similarity.

#### 4.2 Crew-Escorted Experiments

We conducted experiments that got the information of escort a wheelchair user using stairs. Usually one crewmember escorts both a group of pedestrians and a wheelchair user at a time in domestic ferryboat in Japan. Therefore a more specific plan is needed to treat all passengers safely in emergency. On the other hand the investigation of a suitable way to escort a wheelchair user on stairs should be investigated as a usage of elevators is limited in emergency. Ways of escorting a wheelchair user on stairs are various. Figure 11 shows an example of the ways using an evacuation-chair. Further examinations are being done.

#### 4.3 Motion Platform Experiments

We prepared a motion platform shown in figure 12. We took data of pedestrians in during dynamic ship motion conditions. We are analyzing the data using motion capture software. The influence of rolling to walking is evident. In the next step behaviors of a wheelchair user on the motion platform is investigated systematically.



**Figure 11 Wheelchair user moving on stairs by crew-escorted**



**Figure 12 Appearance of motion platform**

## **5. CONCLUSION**

In this paper we introduced the current ways treating a wheelchair user by crewmembers in emergency. Then it is explained that the simulation models and the procedure of the evacuation simulation in passenger ships. To improve the evacuation simulation for disabled persons we are conducting several experiments. The data that we are obtaining though the experiments should be examined further. After that those data can improve the evacuation simulation. As the evacuation simulation program can treat all various types of evacuees, some data such as wheelchair users' moving speeds though stairs and their response times can be reflected to the simulation. The improved simulation will estimate evacuation time and optimal evacuation routes for all passengers including disabled people. And it can be an effective method to maintain evacuation safety for them in passenger ships.

## **REFERENCE**

- Disabled Persons Transport Advisory Committee (DPTAC) (2000). Design of large passenger ships and passenger infrastructure: Guidance on meeting the needs of disabled people. UK: DPTAC
- Galea E., et al. (2001). Predicting the evacuation performance of passenger ships using computer simulation. UK: CMS Press Publications
- International Maritime Organization (IMO) (2002). Interim Guidelines for Evacuation Analyses for new and Existing Passenger Ships, MSC/Circ.1033. UK: IMO
- Katuhara M., et al. (1996). Simulation and Demonstrations of Human Evacuee Escape on Board. RINA Conference (with The Nautical Institute), Escape, Evacuation and Rescue. UK:
- Matsukura H., et al. (2003). A study on human model of pedestrian group overtaking wheelchair user. Journal of Japan Institute of Navigation (JIN) Vol.108. JAPAN: JIN
- Miyazaki K., et al. (2003). Behaviors of Pedestrian Group Overtaking Wheelchair User. Proceedings of Pedestrians and Evacuation Dynamics. UK: CMS Press Publications