ANALYSIS OF PEOPLE’S EVACUATION FROM SHIPS AS A WAY OF IMPROVING SAFETY AT SEA

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Abstract: Present method of evacuation time estimation and evacuation process modelling are analysed. Full scale trials are made at similar ships and evacuation computer models are often used. Author reviews the computer models and systematizes them in dependence of different factors.

1. Introduction

Ship voyages as a means of travelling were made only in the case of necessity even 200 years ago. Sea voyages were dangerous, unhealthy and monotonous. Only in the mid-19th century were they made faster and safer by new technologies. There have been, however, a lot of unsolved problems in the scope of the ships’ technical safety even until today, which is evidenced by numerous sea disasters happening from time to time.

Attention should be focused, first of all, on passenger ships suited for the carriage of a large number of persons – passengers and crew members. This can be exemplified by cruise ships such as “Carnival Victory”, built in 2000 for 3480 passengers and 1080 crew members, or the “Explorer of the Seas” (2000) for the carriage of 3860 passengers and 1180 crew members. The length of passenger ships in many cases exceeds 300m, as in the case of “Queen Mary II” (345 m length, 2620 passengers and 1253 crew members).

A series of spectacular sea accidents with numerous casualties were noted in the 19th and 20th centuries. Amongst them can be counted the sinking of the “Titanic” in 1912, and of the “Empress of Ireland” in 1914, or the sinking of the “Donna Paz” in 1987 caused by the collision with a tanker and a fire (ca. 4000 casualties).

Among the most menacing emergency situations requiring passenger evacuation from the ship there can be counted the vessel’s loss of stability leading to its sinking, fire which could cause the loss of a vessel in a comparable time period, collision, running ground, collision caused by unfavourable weather conditions.
In order to calculate evacuation time it is indispensable to work out suitable methods and tools for analysis. Knowledge concerning people’s traffic during possible evacuation is necessary for designing escape routes, which will make it possible for passengers to abandon the threatened regions in the event of an emergency situation.

The real time of evacuation should not exceed the time at our disposal for carrying it out. In that time, no factor menacing human life (e.g. temperature, visibility, toxicity of combustion products, oxygen want or damage to the object in the case of fire on board) should exceed values dangerous for human life. This problem has been treated comprehensively by Sychta (2002).

In the event of the ship’s collision the time of sinking, which determines the carrying out of evacuation, depends on numerous factors and may amount to only a few minutes in extreme cases. Estimating evacuation time is an important stage permitting to check if the arrangement of escape routes will make it possible to abandon the threatened object.

Both in civil engineering and in ship construction attempts are made to find suitable methods of estimating evacuation time. Transferring research results obtained for land building for their application on ships, the following specific conditions prevalent on ships have to be taken into consideration:

- the distribution of corridors and escape routes is unknown to passengers; it is different for every ship and for every passenger it is more unusual than one encountered ashore,
- movement may be hampered by unstable and sloping surfaces (even up to 20°),
- the ship is alone at sea; abandoning the ship does not ensure safety,
- passengers and crew are multilingual, they come from various cultures, so there may be communication problems impeding the evacuation.

2. Full scale trials

A full-scale trial can be made on evacuation, using existing buildings and ships with the participation of dummies. Such trial can give a picture of evacuation efficiency, route flow capacity etc., yet they do have certain limitations. The volunteers cannot be subjected to fear, panic, physical damage, poisoning, which affects the results obtained, which cannot be repeated even with the participation of the same dummies.

In a report prepared by an Italian team for the 45th session of the International Maritime Organisation (IMO) Fire Protection Committee, there were presented mock evacuation results from four high-speed passenger craft (FP 45/3/3). Table 1 presents the results of the experiment.

Yoshida et al. (2001) presented the results of test evacuation, which was carried out on
a passenger ferry for the carriage of 514 passengers and 28 crew members on 20th October 1997. 356 volunteers participated in the trial. People traffic was watched by 26 video cameras located along escape routes, at the point of boarding the rescue means and in a boat located at 150 m from the craft.

Table 1. Results of evacuation trials on high-speed passenger craft

<table>
<thead>
<tr>
<th>No</th>
<th>Number of passengers</th>
<th>Number of crew members</th>
<th>Total evacuation time</th>
<th>Time of reaching rescue means</th>
<th>Time of abandoning the unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1800</td>
<td>27</td>
<td>15’50”</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>2.</td>
<td>608</td>
<td>9</td>
<td>11’11”</td>
<td>2’37”</td>
<td>7’39”</td>
</tr>
<tr>
<td>3.</td>
<td>538</td>
<td>6</td>
<td>15’18”</td>
<td>2’42”</td>
<td>12’36”</td>
</tr>
<tr>
<td>4.</td>
<td>780</td>
<td>12</td>
<td>14’30”</td>
<td>no data</td>
<td>no data</td>
</tr>
</tbody>
</table>


The International Council of Cruise Lines (ICCL) presented the results of evacuation trials on passenger ships and the description of 5 sea accidents (collision, running aground or fire), during which the passengers were evacuated to assembly points (FP 45/3/1). Moreover, a number of abandon-ship trials were carried out in order to determine the time indispensable for moving people from assembly points to places of boarding the rescue means, locating people in rescue means and launching them. During trial evacuations the assembling time of passengers at assembly points was recorded to be 7 to 20 minutes from the moment of commencing the action; during real evacuation, on the other hand, it amounted from 17 to 28 minutes. The passengers took 7 to 25 minutes to abandon the craft from the moment they had gathered on board at assembly points.

3. Analytical methods of determining evacuation time

There is a search for less costly methods of estimating possible evacuation time from the ship. Work in this range has been conducted by IMO specialists for many years. This has resulted in agreements and guidelines for estimating evacuation time from passenger ships (MSC/Circ. 1001, MSC/Circ 1033). At present, IMO recommends two following methods of evacuation analysis:

1. Simplified method, where passenger and crew flow is considered as a homogeneous mass.
2. Advanced method, which consists in computer simulation of movement of particular persons.

Both methods are considered as temporary ones. Due to a series of simplifications and faults, further work on their improvement is recommended. Analyses conducted for newly
built ships serve the purpose of improving escape route construction, whereas the analyses of existing ships are aimed at making evacuation procedures more efficient.

4. Computer modelling of evacuation

A convenient and ever more widely used form of analysing the evacuation course is the application of computer evacuation models. The following can be counted among the best known: EVACNET (Kisko and Francis 1985), EGRESS (Ketchell 1995), EXODUS (Owen et al. 1996) (Fig. 1) SIMULEX (Thompson and Marchant 1999) (Fig. 2), CESARE (Grandiscak et al. 1999), BYPASS (Schrenkenberg et al. 2002) (Fig. 3).

Fig. 1. Visualisation of results in EXODUS model (Owen et al., 1996)

Fig. 2 Simulation of people’s evacuation by means of SIMULEX model (Thompson et al., 1999)
With respect to the way of modelling people’s flow, computer evacuation models can be divided into: macroscopic, microscopic. In macroscopic methods the translocation of people as a homogeneous mass is taken into consideration. The direction and speed of evacuation are determined only by physical values (size of population, patency of emergency passages). The details of evacuation are determined not by individual features, but by the number of escapees. An approach like this is suggested by Melinek et al. (1975). He analyses people traffic on corridors, stairs and evacuation exits. On this basis, he establishes dependencies between corridor width, the flow of people, and between population density, and the speed of their movement.

In microscopic models translocation is combined with behaviour. Not only are physical conditions analysed, but each person is treated individually; his responses to external stimuli are taken into consideration (personal reaction time, choice of escape route). In these models, personal attributes in translocation and in the process of making decisions are taken into consideration. This process is independent of other people’s behaviour, who take part in the simulation, and takes account of individual trajectories. In the CRISP model (Fraser-Mitchell et al., 1996) each person is treated individually. They are aware of their surroundings, exposed to the effect of toxic gases. In the beginning, they gather information about the fire, smokiness, their location and other people’s activity. Then, on the basis of this data, they make their own decisions. The action to be taken depends on the type of behaviour, and may include, e.g. fire-fighting, warning others, escape. Having the required information about the surroundings, people decide how to respond. The behaviour depends on the role played by the person (passenger, crew member). In the BYPASS model, (Schrenkenberg et al., 2002) traffic of people is described by the direction and speed of movement. These values can be changed with certain probability resulting from various psychological and sociological factors. In the CESARE model
(Grandiscak et al., 1999) the animation presenting people’s movement is worked out on the basis of polls conducted among participants of true fires.

In order to present the decision-making process of people involved in evacuation in the model, a suitable method of simulating people’s behaviour should be adopted. In the work of Gwynne et al. (1999) the classification and division of various evacuation models was presented depending on many factors which characterize those models (way of modelling people’s behaviour, of the evacuation environment etc).

All models must present the evacuation environment, i.e. the geometry of the interior (distribution of corridors and spaces). This space is subdivided into sub-spaces and each subspace is connected with neighbouring ones. As a rule, two methods are used:

- the space is usually covered with regular plates of various size and shape depending on the model,
- each plate represents the space or corridor and does not correspond to real dimensions.

The former method is applied in microscopic methods. It permits the locating of each passenger at a given evacuation moment. This can be exemplified by the BYPASS model (Schrenkenberg et al., 2002), in which the floor is divided into squares 0.4 m wide. Each square can be empty or filled with one man.

The latter method is applied in both macroscopic and microscopic models. Particular plates are connected with arcs representing the current connections inside the structure. People move from segment to segment, their exact location is poorly defined, people can only move from one space to another, but not inside the space. An example of such solution is the model suggested by Lovas (1998). The building is divided into section-rooms, which are interconnected with arc-doors. Evacuation models division is presented at fig.3.

There is now a tendency to apply models which take into consideration ever more behavioural details. The development of models is limited by computer technology. Yet with an increase of processor power and the memory of modern computers it will be possible to simulate large populations including, in a complex way, the environment, people’s behaviour etc. Applying the smallest possible number of simplifications and taking account of the largest possible number of parameters affecting the evacuation process will permit the prediction of its course in the event of real menace and may minimize the number of fatalities.
5. Conclusions

The current state of knowledge permits the statement that huge progress has been made in the matter of learning the human factor based on the psychology of human behaviour during evacuation. Certain types of human behaviour in the evacuation process have been systematized in literature, which permits the working out of more accurate methods of estimating evacuation time. Research on people’s movement in various conditions continues to be carried out, including the occurrence of loll (excessive list) and spreading fire. Most of the work being currently carried out focuses on computer simulation of people’s movement and evacuation course. The models worked out tend to take account of the largest possible number of factors likely to affect evacuation time, the human factor in particular.

![Evacuation models division](image)

Fig. 3 Evacuation models division

On the basis of literature survey it can be stated that among the main situations enforcing passenger evacuation are fire and loss of stability leading to the ship’s sinking. The speed of these processes directly affects the time available for safe evacuation.

Models for calculating evacuation time should take into account the parameters discussed, which affect the speed of people’s movement:
- conditions of the surroundings in which evacuation is taking place (ship’s rolling, smokiness),
- presence of obstacles,
- the human factor (age, sex, training, knowledge of the surroundings, physical condition etc.).

Knowing and taking into consideration these factors in further analyses makes it possible
to create more accurate models of evacuation time, making it easier to design safer evacuation systems.

Improving methods of analysing evacuation time is indispensable for ensuring safety of passengers during sea voyages, the more so, since they have recently become not only the means of translocation, but also a way of spending one’s leisure time attractively.

References

8. International Maritime Organisation (IMO), Interim Guidelines for a simplified evacuation analysis of high-speed passenger craft, MSC Circular n. MSC/Circ.1001, 26th June 2001