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evacuation of people, conditions for preventing risk to life and health

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IDENTIFICATION OF FACTORS HAVING AN IMPACT ON THE MOMENT OF COMMENCING THE EVACUATION OF PEOPLE FROM A VESSEL

Summary. In the paper factors having an impact on the time imperative to recognize the situation and to make decision to undertake action are discussed. It will be shown how the right moment to start evacuation is determined nowadays in normative documents for evacuation analysis and what methods of exact determination of such time are suggested. The moment of starting the evacuation can significantly influence the fact the very process of the evacuation will not be kept within the time limits available for carrying it out and the conditions for preventing risk to life and health will be exceeded.

IDENTYFIKACJA CZYNNIKÓW WPŁYWAJĄCYCH NA MOMENT ROZPOCZĘCIA EWAKUACJI LUDZI ZE STATKÓW

Streszczenie. W artykule przeanalizowane zostaną czynniki wpływające na czas niezbędny do rozpoznania sytuacji i podjęcia decyzji o działaniu. Przedstawione zostanie, w jaki sposób obecnie ustala się moment rozpoczęcia ewakuacji w dokumentach normatywnych analiz ewakuacji oraz jakie są propozycje metod dokładnego wyznaczania tego czasu. Moment rozpoczęcia ewakuacji może w znaczący sposób wpłynąć na to, że sam proces ewakuacji nie zmieści się w czasie dostępnym na jej przeprowadzenie i przekroczone zostaną warunki zagrażające zdrowiu i życiu ludzi.

1. INTRODUCTION

Time indispensable for a complete process of evacuation from the vessel can be divided into a number of components:

- time indispensable for a recognition of the situation,
- time indispensable for making a decision,
- time indispensable for movement to assembly stations,
- time for getting access to and launching life-saving appliances.

Each of the components is affected by many factors, outlined in Figure 1.

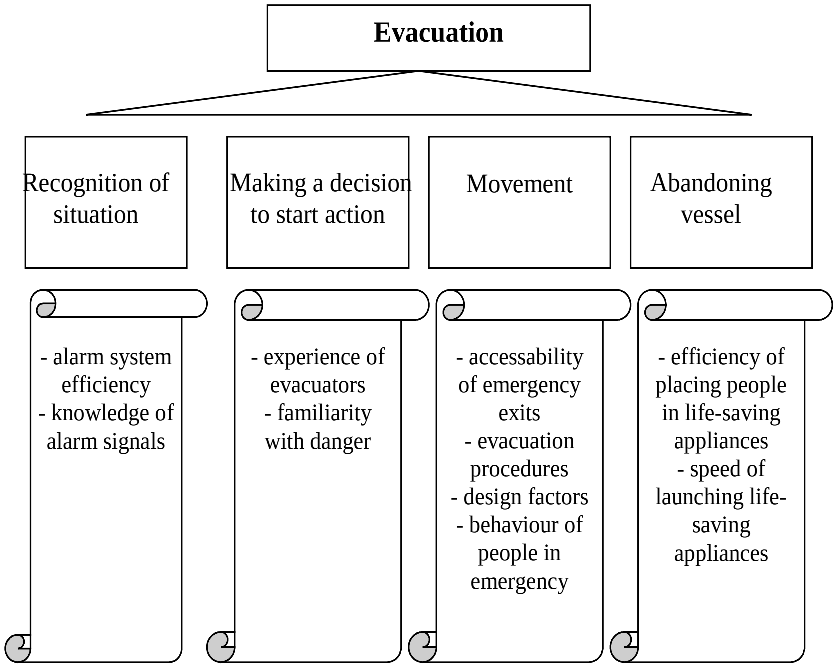

Fig. 1. An outline of indispensable time components for carrying out the evacuation
Rys. 1. Schematyczne ujęcie składowych czasu niezbędnego na przeprowadzenie ewakuacji

This paper will analyze factors having an impact on the time imperative to recognize the situation and make a decision to undertake action. It will be shown how the right moment to start evacuation is determined nowadays in normative documents for evacuation analysis and what methods of exact determination of such time are suggested.

The moment of starting the evacuation can significantly influence the fact that the very process of evacuation will not be kept within the time limits available for carrying it out and the conditions for preventing risk to life and health will be exceeded (Fig. 2).

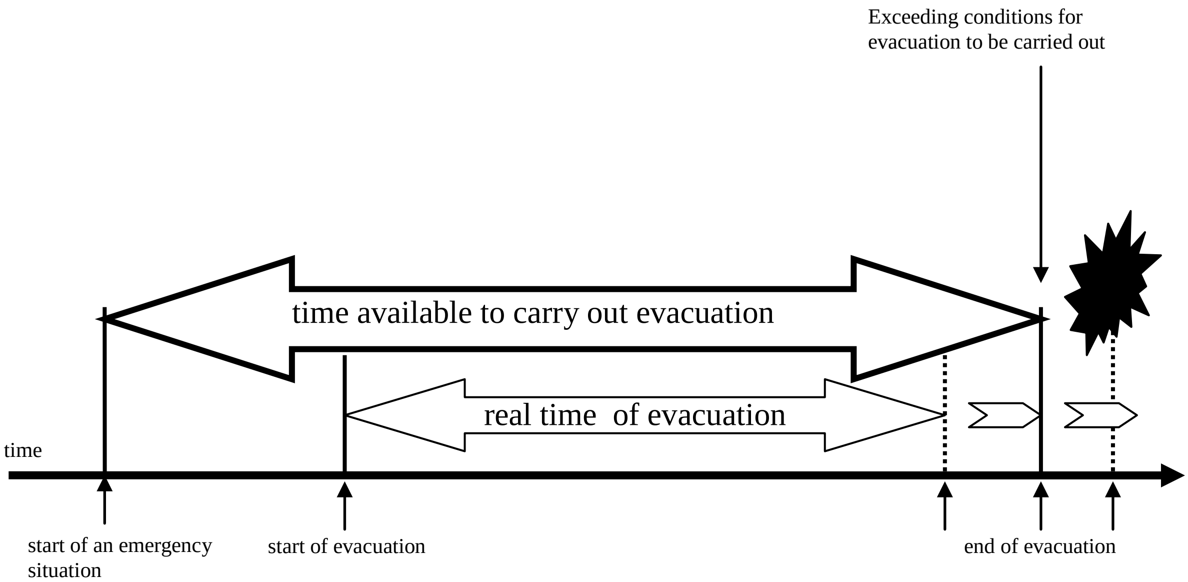

Fig. 2. Outline of the relation between real time of evacuation and available time of evacuation
Rys. 2. Schematyczne ujęcie relacji pomiędzy czasem rzeczywistym ewakuacji a czasem dostępnym ewakuacji

History knows many cases when a delayed evacuation has resulted in fatal accidents. Sime [6] draws attention to the significance of the moment the actual evacuation commences, particularly in case of a fire. He gives an example a house fire back in 1973 on the Isle of Man, in which due to a 20 minute delay 50 people lost their lives. During that period of time the fire spread over to areas where people were staying. A fire at sea is a far more dangerous phenomenon because on land after leaving house evacuees can already feel safe whereas for ship passengers the evacuation still goes on.

2. THE MOMENT OF STARTING THE EVACUATION IN THE IMO NORMATIVE DOCUMENTS OF IMO PASSENGER VESSEL EVACUATION ANALYSIS

The following IMO (International Maritime Organisation) normative documents were drawn up for the purpose of carrying out analyses:

- Interim Guidelines for a simplified evacuation analysis of ro-ro vessels (Msc/Circ. 909)
- Interim Guidelines for a simplified evacuation analysis of high-speed passenger craft (Msc/Circ. 1001)
- Interim Guidelines for an evacuation analysis of new and existing passenger vessels of the ro-ro type (Msc/Circ. 1033) [2].

Guidelines according to Msc/Circ. 1033 supersede Msc/Circ. 909 and should be applied for ro-ro type of vessels as obligatory and for other passenger ships optionally.

For the purpose of calculation of the evacuation time an assumption is made that all persons start the evacuation at the same time and move in the direction set by the escape routes, without overtaking and interaction during the movement;
Total time of evacuation is calculated on the basis of the formula:

$$t_0 = 1{,}25(t_a + t_i) + 2/3(t_e + t_l) \tag{1}$$

where: t_a – time of passengers' response (delay of beginning the movement after the alarm signal),
t_i – time of translocation (movement) of the passengers to the assembly stations, t_e – time for getting access to life-saving appliances, t_l – time for launching life-saving appliances.

The values t_e and t_l are determined according to tests of similar systems of evacuation and data from the manufacturers of life saving appliances ($t_e+t_l<30$ min). The response time values are assumed to be constant (10 minutes for daytime and 15 minutes for the night). In calculations of t_0 it is assumed that time t_i and (t_e+t_l) can be partially concurrent in the range of $1/3(t_e+t_l)$.

The evacuation analysis according to the guidelines is based on simplified assumptions (stochastic models), and the evacuation time calculated can considerably differ from the real time (obtained from the tests). Therefore guidelines are updated pursuant to theoretical investigations and real tests.

3. FACTORS HAVING IMPACT ON THE ACTIVITY OF PEOPLE WHILE STARTING THE EVACUATION

The reason for a delay in commencing the evacuation can be generally categorized as

- related to the danger detection time and alarm system,
- related to the human factor.

Detection and alarm systems are constantly improved, their reliability is higher and higher, however the human factor still poses a problem because it is difficult to evaluate. There are attempts though to systematise and describe human behaviour because, thank to the results of the tests, attempts can be made to withstand the phenomena which can adversely affect the safety level during the evacuation.

Pires [5] points out to the following factors influencing the activity of people during the evacuation:

- level of stress,
- importance of the task which is carried out by the evacuator (the more important it is, the less attention (s)he pays to the surroundings),
- noise and fatigue.

The influence of stress was shown in [9].

The description of behavioural response to a fire can be found in [8]. Avoiding action belongs to this type of responding. People feel they can protect themselves by so called negation of the danger actually happening. This type of behaviour results in people ignoring the existing emergency situation. Avoidance often takes place in the first few moments of a fire. Another phenomena is "involvement" which means that people involved in activities they are carrying out at the moment of danger often continue what they have been doing in spite of the threat. "Affiliation" is one of the reasons for delays. People often do not start the evacuation until the whole group is ready. It is a well known fact yet that the speed of the slowest people determines the evacuation speed of the whole group. Also social roles or the status of the evacuated person determines her/his response to the existing danger. It can be quite important for instance whether a given person is a passenger or a crew member.

In [4] the theory of behaviour is divided into the following categories:

- panic,
- making a decision,
- danger level.

In those theories a number of references can be found on factors having impact on the moment of commencing the evacuation.

In the „panic theory" the main assumption is that when people notice a danger their usual conscious activity is replaced by subconscious activity which can lead to irrational behaviour. The "theory of decision making" claims that a person even in a dangerous situation can make rational decisions. In the "theory of danger level" the moment to start the evacuation depends on the danger level. The consequences resulting from not leaving the endangered place have an impact on the time of response.

In [4] the system of human behaviour classification on three levels can be found as well:

- individual,
- interaction between people,
- interaction with the environment.

A crowd is a group of individuals, so to comprehend the behaviour of a crowd, an individual way of behaviour should be studied in the first place. From a psychological point of view the behaviour of individuals is a result of making decisions. An individual process of making decisions has an impact on the moment the evacuation commences. It can be divided into two groups:

- following the instinct,
- following the experience.

Making a decision takes place in three steps: recognition of a situation as similar to that which happened in the past, recalling the way of problem solving, acting in accordance with the experience. Decision making like that is limited because in most cases previously not all solutions were known and not all of the consequences of given actions can be assessed. When in danger a human does not always have time for making a rational decision and acts by instinct or in accordance with his/her earlier experiences.

4. STUDIES OF THE IMPACT OF THE MOMENT OF COMMENCING EVACUATION ON EVACUATION TIME

In the study by Pires [5] the moment of commencing evacuation by a given person is considered by means of probabilistic methods. To this end a network for the analysis of the time of commencing the evacuation was created as a logical diagram that identifies sequential relationships. The diagram starts with a given condition, and next subsequent conditions are indicated in order to create proper scenarios.

The problem which arises in the designed method is the lack of sufficient data for the model. Collecting the required data is subject to some difficulties. The following methods of gathering data are mentioned:
- expert methods,
- experiments,
- analytical methods.

The probabilistic risk assessment of the evacuation has also been presented in the study of Chu Chen [1]. The time of evacuation RSET consists of the following parts:

$$RSET=t_d+t_a+t_p+t_m \tag{2}$$

where: t_d – time of detection (from the ignition to the moment of detection), t_a – time of giving the alarm (from detection to the moment of raising the alarm), t_p – time of starting evacuation (from hearing the alarm to the start of evacuation), t_m – time of movement to safe places.

The assessment of t_a is carried out by a simulation of the smoke spreading and the characteristics of the detecting system.

Further t_p is divided into the time of recognition and time of the response. At this stage people respond in different ways (reactions like: protecting one's money, gathering children and other family members, checking the situation, fire fighting, searching the way, alerting others, etc.). Time t_p is difficult to evaluate for each individual person, therefore a random value of distribution of that time is taken into consideration.

Mac Lennan [3] proposed Weibull's distribution. In [1] normal distribution was suggested.

$$f(t_p)=\frac{1}{\sqrt{2\pi\sigma_p}}\exp\left[-\frac{(t_p-\mu_p)^2}{2\sigma_{p^2}}\right], t_p>0 \tag{3}$$

where: $f(t_p)$ – probability of density t_p, μ_p – mean value t_p [s], σ_p – standard deviation t_p.

In simulation models of evacuation the start of evacuation is accounted for in different ways. For example in ASERI [7] first activities and perception of first signs by people can be modelled both by attributing individual times of alarm and response or by incorporating the interim positions of stopping. These positions are meant to be the areas towards which the evacuated person moves, waits, and after certain time starts escaping. ASERI uses a matrix of estimated times of delays that depend on the initial activities corresponding to these actions or behaviour (Table 1).

Table 1

Matrix of estimated times of delays in ASERI model

	Awarness [s]	**Time of response [s]**	**Preparation (dressing) [s]**	**Information [s]**
Watching TV	0 to 30	4 to 8	5 to 120	0 to 30
Shower	60 to TS	4 to 10	30 to 300	0 to 60
Social activities	0 to TS	4 to 10	5 to 240	0 to 60
Sleeping	10 to TS	6 to 14	20 to 300	0 to 60
Reading, writing	0 to TS	4 to 8	5 to 120	0 to 45
Smoking	0 to 300	4 to 8	10 to 120	0 to 45

The attributes assigned to certain activities can be defined as follows:

- Awareness – time that starts at the moment of perceiving the first signs of hazard and ends when a person fully realizes the situation which has arisen.

- Time of response – the mean time of reaction to the perceived signs of hazard.
- Preparation – time needed for people to get dressed and collect their valuables.
- Information – time needed for people to find information about the occurrence and informing other people about this situation.

ASERI Model uses a Monte Carlo simulation method to analyze the evacuation results through stochastic changes of individual reactions, while leaving the initial and final conditions unchanged.

5. SUMMARY

In recent years all forms of relaxation at sea have become immensely popular. The present day trends to build very large vessels necessitate the safety systems of these vessels to be constantly improved. Up till now there have been a lot of problems which have not been solved in the field of ship technical systems and construction safety. This state has been confirmed by passenger ship accidents that happen from time to time.

The design of escape routes in passenger vessels should enable passengers and crew members to leave the hazardous areas safely if need arises to evacuate the ship.

Designing and developing adequate methods and tools for computing the evacuation time is crucial for making the relevant analysis. The knowledge concerning the movement of people in case of a possible evacuation is necessary for the evacuation routes to be designed so that in case of an emergency evacuation they will allow to leave safely the hazardous area.

One of the ways of creating more precise methods of evaluation of the evacuation time is an accurate analysis and taking into account as great a number of parameters as possible that could affect the process of evacuation. The parameters affecting safe evacuation are the subject of research in many national institutions as well as those abroad. The knowledge of many fields is needful to perform such analyses. A comprehensive approach enables a more accurate evaluation of the evacuation time and should take into consideration the parameters which can adversely influence the evacuation process.

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