ISSN 1232-3829
tts 10/2013
Technika Transportu Szynowego koleje ▪ tramwaje ▪ metro

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THE CONCEPT OF MINIMIZING EVACUATION TIME BY OPTIMIZING THE DIMENSIONS OF THE EMERGENCY ROUTES FOR PASSENGER SHIP

Abstract

The concept of dimensioning escape routs to obtain a predetermined displacement of the numbers of people from their initial position to a destination as fast as possible, will be presented at the paper. In order to present the method it was used the plan of evacuation of an exemplary passenger and car ferry. Based on a simple example, the distribution of escape was analyzed. The calculation method was applied genetic algorithms.

INTRODUCTION- THE FACTORS AFFECTING FOR EVACUATION TIME

Evacuation of buildings and transport systems (for example the passenger ships) is always difficult problem. Improving the safety systems can be a big challenge for designers, builders and operators of those objects. Preventing accidents is highly dependent on the "human factor", which is a difficult to estimating. Therefore, despite the fact that prevention is considered to be the best way to ensure safety, we should not forget about the development of methods of effective evacuation

The research in order to improve the methods of safe evacuation should include extending the time available to carry out the evacuation and shortening the process of evacuation (Fig. 1).

The systems against exceeding the life-threatening conditions (eg appropriate smoke ventilation), detection systems and alarm system are also very important factors which can affect for evacuation process.

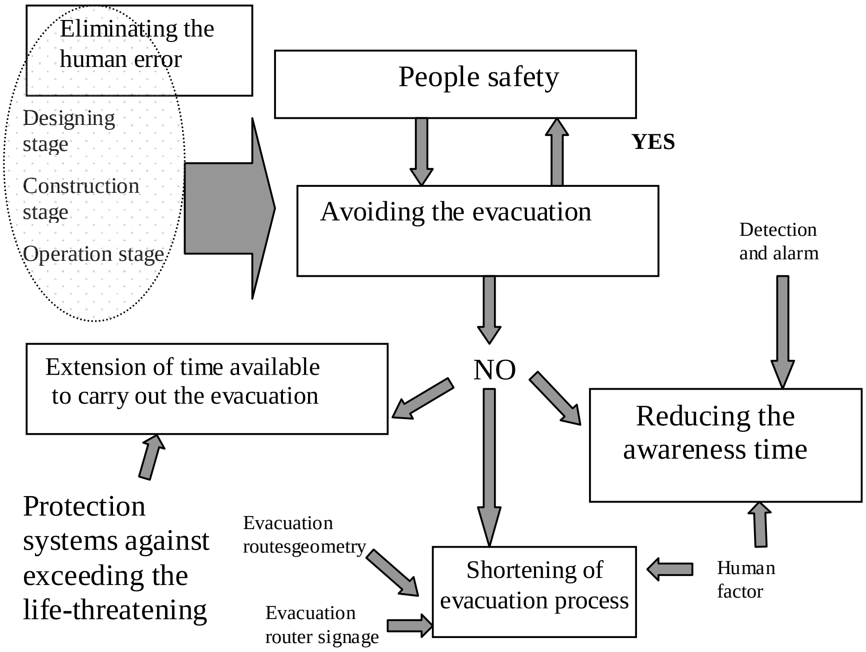


Fig. 1. Schematic recognition of the factors affecting the process of evacuation
Source: [own**]**

The geometry and layout of escape routes play an important role in shortening the evacuation time. They must meet a number of requirements, but also to effectively carry out their functions, should have sufficient capacity, signage and lighting. The next part of this article will present the concept of escape routes dimensioning, in order to obtain displacement assumed number of people from their initial position to the destination as quickly as possible.

However, the term "fastest" does not only depend on traveling time by a single individual, but also on the number of units moving this path. Therefore, to solve the task will be used a formula of quickest path problem, [1], combined with an encoding of escape networks based on graph theory [3].

1. ENCODING THE DISTRIBUTION OF ESCAPE ROUTES, THE DEFINITION OF VARIABLES, OBJECTIVE FUNCTION AND CONSTRAINTS

Assume that the network of escape routes at passenger ship can be described as a directed graph [2].

The individual vertices can represent elements of the evacuation routes. For each edge of the graph, assign weights [$\lambda(i_i, i_{i+1})$, $b(i_i, i_{i+1})$] where:

$$\lambda(i_i, i_{i+1}) = \frac{L(i_i, i_{i+1})}{S_{sr}}[s] \quad (1)$$

L- length of the escape route [m],
S_{sr}- average speed of person on the escape route (assumed for the calculation of 0.5 m / s with the ship inclination) [5], [m/s],

$$b(i_i, i_{i+1}) = Fs \cdot W\ (i_i, i_{i+1})[person / s] \quad (2)$$

W- width of the escape route [m],

F_s – specific flow (assumed for the calculation of 1.3[person/m·s]) [4].

The lengths of individual elements *L* and the width *W* can be set as variables in the analyzed problem posed.

The objective function is the time needed to send *N* passengers from i_1 to i_k along the path *P*:

$$T(N,P) = \lambda(P) + \frac{N}{b(P)} \tag{3}$$

where:

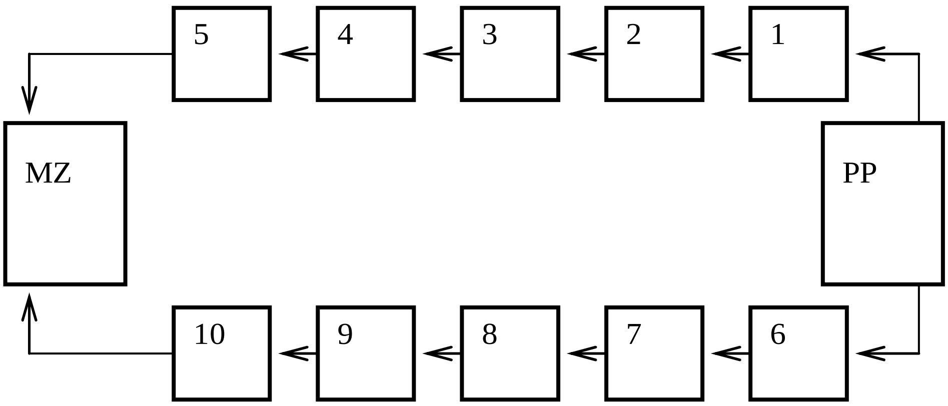
$$b(P) = \min_{1 \le i \le k-1} b(i_i, i_{i+1}) \tag{4}$$

$$\lambda(P) = \sum_{i=1}^{i=k-1} \lambda(i_i, i_{i+1}) \tag{5}$$

In order to present the established method, the plan the evacuation of an exemplary passenger and car ferry was used. It is assumed the presence of 160 passengers in the public space (bar, library, gift shop) which is located on the passenger deck (Fig. 2).

Passengers follow according to the established plan of evacuation to the assembly on the same board for simplicity, assume that a group of people divided in proportion to the available emergency exits.

Fig. 2. Sample Deck Plan of a passenger ship
Source: [http://hhvferry.com/deckplans.htm]



MZ- assembly, PP- public space,
1-10- evacuation routes

Fig. 3. Diagram of distribution of evacuation direction
Source: [own]

Define the variables as:
x_1-L(PP,1); x_2-L(1,2); x_3-L(2,3); x_4-L(3,4); x_5-L(4,5); x_6-L(5,MZ); x_7-L(PP,6); x_8-L(6,7); x_9-L(7,8); x_{10}-L(8,9); x_{11}-L(9,10); x_{12}-L(10,MZ); x_{13}-W(PP,1); x_{14}-W(1,2); x_{15}-W(2,3); x_{16}-W(3,4); x_{17}-W(4,5); x_{18}-W(5,MZ); x_{19}-W(PP,6); x_{20}-W(6,7); x_{21}-W(7,8); x_{22}-W(8,9); x_{23}-W(9,10); x_{24}-W(10,MZ)

We can describe two evacuation routes:
route: P1: PP-1-2-3-4-5-MZ
route: P2: PP-6-7-8-9-10-MZ
therefore:

$$b(P1)=\min\{(Fs\cdot x_{13}), (Fs\cdot x_{14}), (Fs\cdot x_{15}), (Fs\cdot x_{16}), (Fs\cdot x_{17}), (Fs\cdot x_{18})\} \quad (6)$$

$$b(P2)=\min\{ (Fs\cdot x_{19}), (Fs\cdot x_{20}), (Fs\cdot x_{21}), (Fs\cdot x_{22}), (Fs\cdot x_{23}), (Fs\cdot x_{24})\} \quad (7)$$

$$\lambda(P1)=\frac{x_1+x_2+x_3+x_4+x_5+x_6}{S_{śr}} \quad (8)$$

$$\lambda(P2)=\frac{x_7+x_8+x_9+x_{10}+x_{11}+x_{12}}{S_{śr}} \quad (9)$$

Fitness function is given by following formula:

$$f(x_1, x_2,\ldots\ldots,x_{24})=\max\{(\lambda(P1)+\frac{0{,}5\cdot N}{b(P1)});(\lambda(P2)+\frac{0{,}5\cdot N}{b(P2)})\} \quad (10)$$

The next step is to define the limits, which impose limit dimensions passages.

Proposed the following linear constraints, so that the dimensions of escape routes are within established limits:.

1. $x_1+x_2+x_3+x_4+x_5+x_6= 150$
2. $x_7+x_8+x_9+x_{10}+x_{11}+x_{12}=150$
3. $x_{13}+x_{19}=20$
4. $x_{14}+x_{20}=20$
5. $x_{15}+x_{21}=20$
6. $x_{16}+x_{22}=20$
7. $x_{17}+x_{23}=20$
8. $x_{18}+x_{24}=20$

Lower bound and upper bound means of which the bound the numbers symbolizing the dimension of the escape routes are random generated. The layers are represented as vectors which, for the scenario under consideration, have the following values:
Lower bound=[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1]
Upper bound=[40 40 40 40 40 40 40 40 40 40 40 40 20 20 20 20 20 20 20 20 20 20 20 20]

2. EVACUATION TIME CALCULATION EXAMPLE

In the first step of evacuation time were calculated using the formula (10) for the dimensions of the passages listed below:
x_1=5; x_2=5; x_3=5; x_4=25; x_5=25; x_6=25; x_7=45; x_8=25; x_9=25; x_{10}=45; x_{11}=45; x_{12}=25; x_{13} =10; x_{14}=10; x_{15}=10; x_{16}=10; x_{17}=10; x_{18}=10; x_{19}=10; x_{20}=10; x_{21}=10; x_{22}-W(8,9)=10; x_{23}=10; x_{24}=10
Evacuation time was 481 seconds.

Then, calculations were made using genetic algorithms using the module "Genetic Algorithm" MATLAB.

Examples of results obtained during the optimization are shown in Figures 4, 5, 6 and 7.

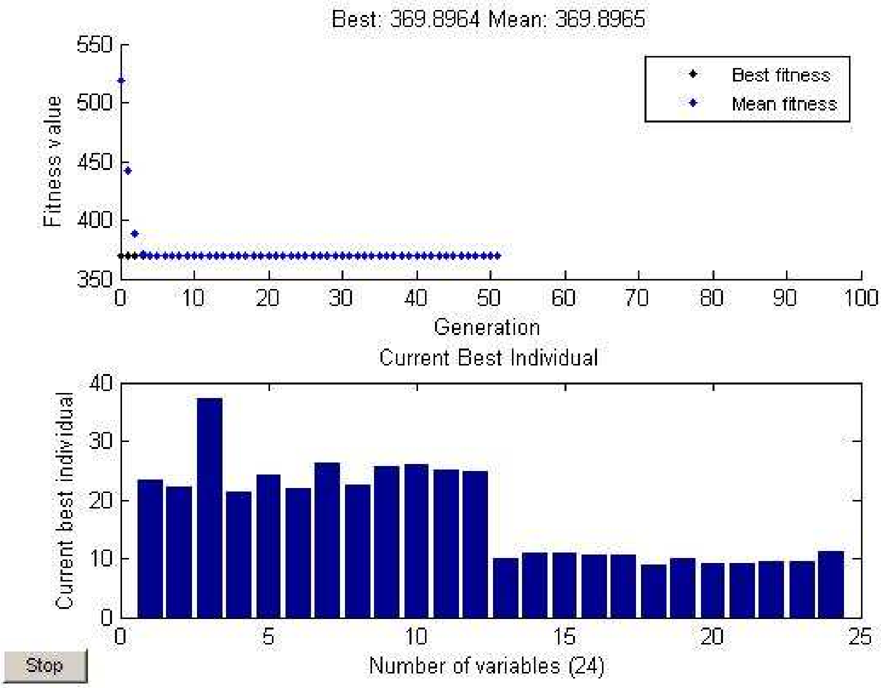


Fig. 4. The results of calculations of the resulting evacuation time 369 seconds
Source: [own]

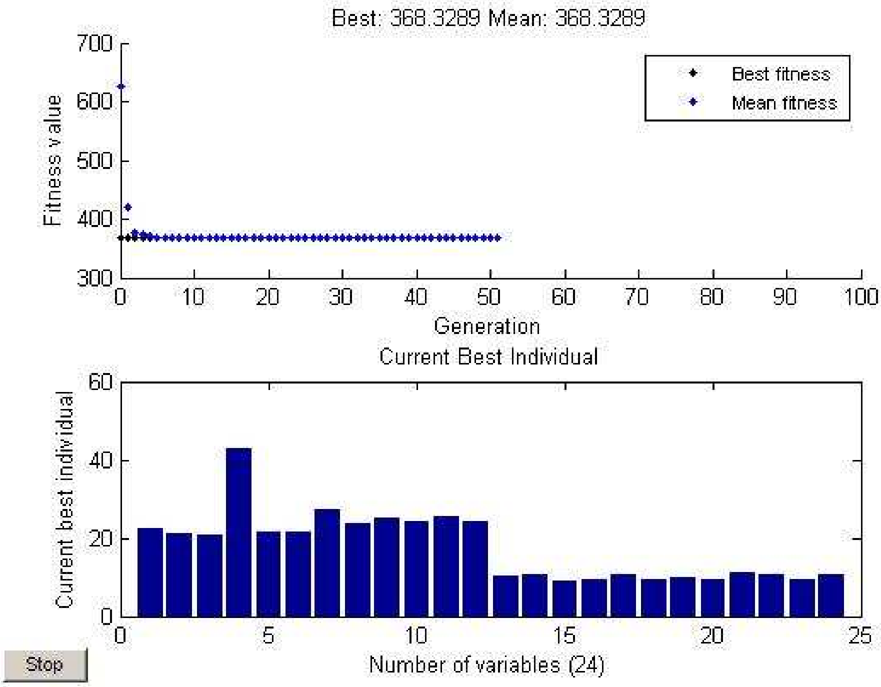


Fig. 5. The results of calculations of the resulting evacuation time 368 seconds
Source: [own]

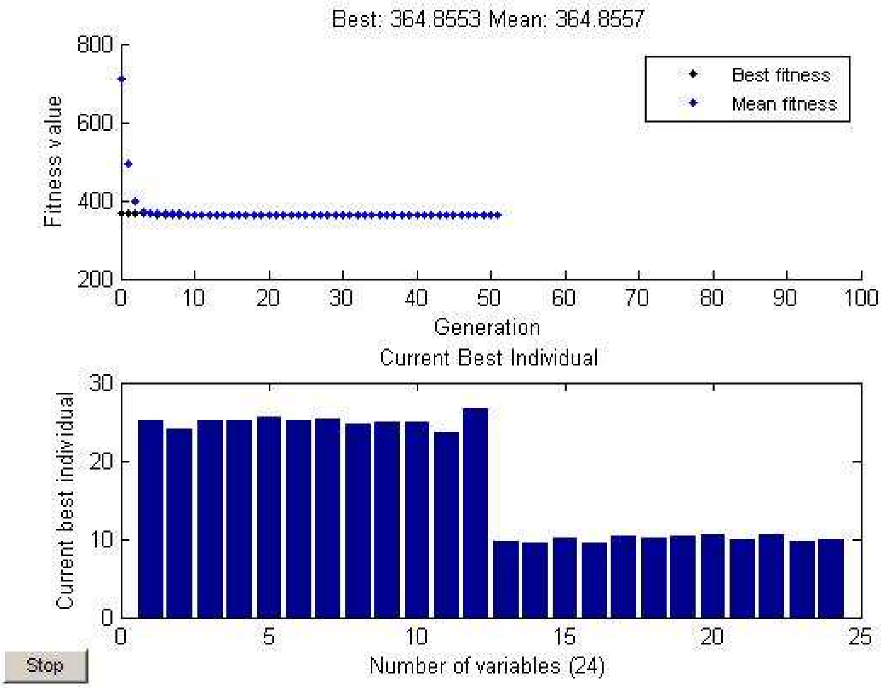


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Fig. 6. The results of calculations of the resulting evacuation time 364 seconds.
Source: [own**]**

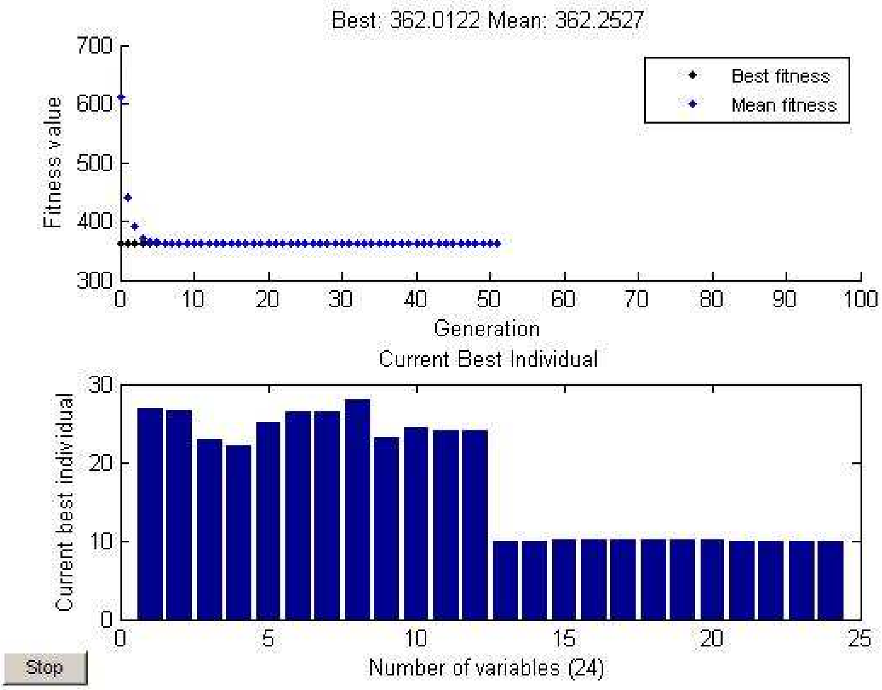

Fig. 7. The results of calculations of the resulting evacuation time 362 seconds.
Source: [own**]**

The charts show how changing the value of the average and best objective function in each iteration of the algorithm and the values of the variables (dimensions corridors) for the shortest evacuation time obtained in different simulations

SUMMARY

At the paper, it was considered a very simple case of evacuation routes distribution and small number of people taking a part in the process of evacuation. The results seem to indicate, that in the case of using the same method for large passenger ship, the evacuation time also should be reduced. However, the presented method has to be verified by using other deck plans for simulation

At mentioned example, in the case of random selection of the dimensions of escape routes, evacuation time was 481 seconds. The using of other dimensions chosen by optimizing reduced this time to 362 seconds (approximately 25%).

The genetic algorithms was applied to solve the problem. Evolutionary computations can be included into the group of artificial intelligence. Evolutionary methods including genetic algorithm give good results (sub-optimal), avoiding the time-consuming calculations. Another important advantage of this method is the resistance to finding local extremes.

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KONCEPCJA MINIMALIZACJI CZASU EWAKUACJI POPRZEZ DOBÓR WYMIARÓW DRÓG EWAKUACYJNYCH NA STATKU PASAŻERSKIM

Streszczenie

W artykule zaprezentowana zostanie koncepcja doboru wymiarów dróg ewakuacji na statku, tak aby uzyskać przemieszczenie się założonej liczby osób z ich początkowej pozycji do miejsca przeznaczenia tak szybko jak to możliwe. W celu zaprezentowania działania opracowanej metody posłużono się planem ewakuacji przykładowego promu pasażersko –samochodowego. Na podstawie prostego przykładu rozkładu dróg ewakuacji dokonano analizy wpływu zwymiarowania dróg ewakuacyjnych na możliwość uzyskania jak najkrótszego czasu ewakuacji. Do obliczeń zastosowano metodę algorytmów genetycznych.

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