Problems of People's Evacuation Modelling

A Parfyonenko 1, J Kurbatova 1

1 National Research Moscow State University of Civil Engineering, Yaroslavskoye Shosse, 26, Moscow, 129337, Russian Federation

ikbs@mgsu.ru, kurbatovajuliapb@mail.ru

Abstract. In the field of the study of the human flows traffic, there are programs appear whose developers don't have the knowledge required about fire safety and the parameters of the human flows traffic. Algorithms embedded in software and computer systems give inadequate results, which reduces the indicator of people's safety in buildings and structures. This work describes the features of using individual-flow evacuation modeling of people in buildings and structures when changing the width of the aperture of door. The main parameters of the human flow, characteristic of individual-flow modeling, are also considered. The survey of software and computer systems used in risks estimation of buildings and structures. The results of people's evacuation modeling in software and computer systems are analyzed. An assessment of the correctness of the results was made, a conclusion was drawn on the adequacy and possibility of using these software and computer systems in calculating the time of evacuation of people in buildings and structures.

1. Introduction

Evaluation of planning decisions from the point of view of the safety of people's lives [1] in case of fire in buildings and structures inherently includes the calculation of evacuation of people. This article envisages the modeling of evacuation of people in various computer software and computing systems. In the field of the study of the human flows traffic, programs are emerging for simulating the evacuation of people, which, as practice shows [2-4], give inadequate results due to a lack of understanding by the developers of the patterns of human flows traffic. Therefore, the algorithms embedded in the programs must be checked for the correctness of the data obtained, and the programs themselves for the consistency of the laws used between the parameters of human flows and the real processes of movement of people. Therefore, the analysis of the developed computing software and computer systems, which are used to estimate the evacuation time, is an urgent task, and there is an urgent need to test the software systems and obtain appropriate conclusions from competent specialists before entering the public market. The modeling of the human flows traffic was considered in the works of Parfyonenko A “Methodology for modeling human flows and the practice of programming their movements during evacuation” [5] and Kholshechevnikova “Once again on the modeling of human flows in assessing fire risk” [6].

2. Methods

The Methodology for determining the calculated values of fire risk in buildings [7] presents three computational models of human flows traffic: simplified-analytical, simulation-stochastic and individual-flow models.
Simplified-analytical model allows us to establish calculated correspondence between the parameters of the human flows traffic [8,9]. This model is the simplest and most tried and tested. It is implied that people during evacuation create equable distributed flows, the mixture of evacuated flows (mobility group, projection area, speed) is not taken into account. Therefore, this model gives adequate results only when calculating the evacuation from geometrically simple units.

The simulation-stochastic model of the human flows traffic makes it possible to accurately assess the qualitative and quantitative picture of the human flows traffic during evacuation. When calculating, the building is divided into elementary sections, for each of which a lot of settlement operations are performed per second. In this model, there are phenomena peculiar to the human flow [10-12]: spreading, reformation, merging, decompression. Both models take into account the concept of human flow, are sensitive to changes in the geometry of the building, but don't represent the possibility of considering the traffic of an individual person in the flow.

The individual-flow model involves modeling the traffic of an individual person taking into account its individual parameters (speed, projection area, mobility). This model is used to calculate evacuation from a building with a complex internal layout [13].

The mathematical model is selected based on the features of the layout of the building, the area of horizontal projections of people, as well as the parameters of people's traffic of various mobility groups.

For the analysis of software and computing systems, design schemes for the people's traffic from a room 20x2 m in size with aperture of doors of 0,8, 1,2, 1,6 m wide and traffic from a room without an aperture of doors, i.e., on a horizontal section of the path 2 m wide. For the calculation, it was necessary to place 360 people in a room with a horizontal projection area of each person $f = 0,1 \text{m}^2/\text{person}$ and a density of people's flow $D = 0,9 \text{m}^2/\text{m}^2$. According to the calculation schemes, the calculation results were obtained in accordance with the Methodology for determining the calculated values of fire risk [7]. The calculation of time was carried out according to the laws of human flows traffic:

$$t_{ck} = \frac{N \cdot f}{q_{pa,D=0,9} \cdot b}$$

(1)

where $N$ is the number of people, person; $f$ is horizontal projection area of a person, $\text{m}^2/\text{person}$; $q_{pa,D=0,9}$ is the intensity of movement through the site at a density of 0,9 or more, $\text{m} / \text{min}$; $b$ is the width of the section, upon entering which, a crowd is formed, $\text{m}$.

The intensity of traffic through the aperture of door with a width of less than 1,6 m is determined according to the dependence:

$$q = 2,5 + 3,75 \cdot x$$

(2)

where $x$ is the width of the aperture of door, $\text{m}$.

Further, it was necessary to simulate the traffic of people through various apertures in software and computing systems and compare the results of manual counting for compliance with the Methodology [7]. It was assumed that if software and computing systems take into account the laws of traffic of people in accordance with the Methodology, then the results should be close to the values obtained in the calculation according to a simplified analytical model. If the deviation of the results is significant,
then the use of these programs is unacceptable. Visualizations of modeling the human flows traffic are presented in Figures 1-5.

**Figure 1.** Pathfinder: visualization of the simulation of the human flow traffic through apertures of various widths.

**Figure 2.** Sigma PB: visualization of the simulation of the human flow traffic through apertures of various widths.

**Figure 3.** Urban: visualization of the simulation of the human flow traffic through apertures of various widths.
Figure 4. Fenix+: visualization of the simulation of the human flow traffic through apertures of various widths.

Figure 5. Fogard Pb: visualization of the simulation of the human flow traffic through apertures of various widths.

3. Results and discussions
Based on the simulation results, a comparative table 1 was compiled, which indicates the time of evacuation of people during modeling in various software and computing complexes.

Table 1. The time of evacuation of people from the units.

| No. | The width of the door aperture 0.8 m | The width of the door aperture 1.2 m | The width of the door aperture 1.6 m | Horizontal way 2 m wide |
|-----|------------------------------------|------------------------------------|------------------------------------|-------------------------|
| 1   | Manual calculating                 | 490,90 sec                         | 257,14 sec                         | 158,82 sec              |
|     | - in seconds                       |                                    |                                    | 79,99 sec               |
|     | - in minutes                       | 8,18 min                           | 4,29 min                           | 2,65 min                |
|     |                                    |                                    |                                    | 1,33 min                |
| 2   | Pathfinder                         | 503,77 sec                         | 258,50 sec                         | 159,50 sec              |
|     | - in seconds                       |                                    |                                    | 80,50 sec               |
|     | - in minutes                       | 8,39 min                           | 4,31 min                           | 2,66 min                |
|     |                                    |                                    |                                    | 1,34 min                |
| 3   | Sigma PB                           | 114,25 sec                         | 68,50 sec                          | 58,75 sec               |
|     | - in seconds                       |                                    |                                    | 57,25 sec               |
|     | - in minutes                       | 1,90 min                           | 1,14 min                           | 0,98 min                |
|     |                                    |                                    |                                    | 0,95 min                |
| 4   | Urban                              | 76,00 sec                          | 74,00 sec                          | 76,00 sec               |
|     | - in seconds                       |                                    |                                    | 63,00 sec               |
|     | - in minutes                       | 1,26 min                           | 1,23 min                           | 1,26 min                |
|     |                                    |                                    |                                    | 1,05 min                |
| 5   | Fenix+                             | 467,00 sec                         | 243,00 sec                         | 148,60 sec              |
|     | - in seconds                       |                                    |                                    | 45,40 sec               |
|     | - in minutes                       | 7,78 min                           | 4,05 min                           | 2,47 min                |
|     |                                    |                                    |                                    | 0,75 min                |
| 6   | Fogard Pb                          | 150,20 sec                         | 99,90 sec                          | 74,30 sec               |
|     | - in seconds                       |                                    |                                    | 59,50 sec               |
|     | - in minutes                       | 2,50 min                           | 1,66 min                           | 1,24 min                |
|     |                                    |                                    |                                    | 0,99 min                |
Manual calculating is a reference, as it was calculated in accordance with the Methodology. The main drawback of many programs is the deviation of the evacuation time from the reference value, so, we can conclude that the programs do not take into account the patterns of the flow traffic of people. When considering a horizontal section without a door, the Fenix + software complex showed the greatest deviation from the standard (43,24%), while the Sigma PB program showed the largest deviation with a door aperture width of 1,6 m and 1,2 m (63,01% and 73,36%, respectively), with a door aperture width of 0,8 m - Urban (84,52%). A deviation that does not exceed 5% is acceptable. Only one software-computing complex complies with this value (Pathfinder). The remaining programs give serious deviations, which are presented in table 2, and their use for calculations is undesirable.

| No. | Software and computing systems | Deviations of the evacuation time from the time calculated in accordance with the Methodology |
|-----|--------------------------------|--------------------------------------------------------------------------------------------------|
| 1   | Pathfinder                     | 0,42-2,62%                                                                                      |
| 2   | Sigma PB                       | 28,43-76,73%                                                                                   |
| 3   | Urban                          | 21,24-84,52%                                                                                   |
| 4   | Fenix+                         | 4,87-43,24%                                                                                     |
| 5   | Fogard Pb                      | 25,61-69,40%                                                                                   |

When modeling the human flow traffic, certain drawbacks of software and computing systems were identified. In the Pathfinder program, it is necessary to manually set the initial data on the patterns of human flows traffic with an aperture width of less than 1,6 m. Otherwise, the program will consider the “false aperture effect”, that is, reducing the actual width of the aperture for a short time due to the fact that people walking from the sides of the horizontal path are repelled from the corners to the center of the door aperture when passing through it, as people tend to avoid being pressed to the corners of the door aperture. In the Sigma PB software and computing complex, the laborious process of preparing the building and creating an evacuation scenario and an inconvenient interface were noted. When placing people in Sigma PB, the program does not allow you to set the necessary density of the human flow, it is also not possible to set the initial data on the laws of people's traffic. Urban combines the drawbacks of the Sigma PB program, and also with the automatic placing of people according to a given number in a given area, the program places people not only in the unit, but also “inside” the envelope building. The qualitative picture of the people's traffic is displayed inadequately, the program does not have the concepts of congestion, merging, decompaction, etc., people move at the same speed, rolling over the heads of people in front, the flow of people merges into a single whole in the door aperture. The Fenix + program does not allow you to set the parameters of the people's traffic with a door aperture width of less than 1,6 m. Fogard Pb does not clearly show the location of doors and people, only their coordinates are in a table form, there is no visualization of the calculation, therefore, it is impossible to fully evaluate the process of human flow's traffic.

Also there are such unsolved problems as the lack of generally accepted criteria for the acceptable quality of programs for evacuation modeling, the lack of qualifications for program developers, the lack of development of the fire models market, since all new developments are cloning of the previous ones, they do not add new approaches, models, or initial data.

4. Conclusions
The results of modeling the human flows traffic are analyzed, deviations are obtained that prove the incorrectness of the algorithms embedded in the software and computing systems designed to calculate the time of evacuation of people. The data obtained give the prospect of finalizing existing programs and show the need to confirm the qualifications of developers of software and computing systems. It is expected that if existing programs are brought into compliance with the Methodology, if leading scientific state organizations publish methodological manuals for developers and designers, if sets of
test cases are developed to confirm the qualifications of developers of software and computing systems, it will be possible to enter the public market programs that give adequate results in accordance with the Methodology, taking into account all the subtleties of the dependencies of human traffic.

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