THE COMPARISON OF THE RESULTS OF A FULL SCALE EVACUATION TEST TO THE CALCULATION METHOD OF HUNGARIAN REGULATIONS AND TO THE PATHFINDER SOFTWARE

Csaba Szilagyi [a]

[a] Optomm Ltd. Budapest, Csanyi L. utca 34

Abstract

Action of people in different building has large scale of uncertainty and there is poor availability of experimental data describing it. Evacuation software might be a solution of the problem, but their validation is a key issue. To analyze these key questions, a full scale test was conducted with more than 200 persons participating in it. The test was divided to two phases, first the comparison to Hungarian regulations with a numerical method taking the speed, the width of doors and stairs into consideration and then the comparison to three calculation methods of Pathfinder software. The criteria of calculation defined by the AHJ resulted two different egress scenarios. There were interesting differences between the results of the full scale test, the calculation and the three simulation methods, and also the reasons of the differences were interesting.

Keywords: evacuation, experiment, validation, pathfinder, analysing, OTSZ

INTRODUCTION

The evacuation of buildings and open air program areas in Hungary is controlled by the 28/2011. (IX. 6.) BM regulation, concerning the National Fire Safety Codes (NFSC). This regulation is a law, therefore obeying it is obligatory. Designers and authorities began to doubt the evacuation proceedings due to the development of architecture and the needs of the modern age. As a result of architectural development, bigger and bigger buildings are constructed and in such buildings the number of escape routes may rise dramatically. Due to the needs of the modern age, such technological devices are installed into the buildings some of which have a favourable effect and some of which have an unfavourable effect on the evacuation proceedings.

Evacuation aims to provide people a way to leave the building in safety. The method of analysis provided by the law is not detailed enough to reach a safe enough solution. Since the number of variants is high during the evacuation process and also, the effect of these variants on each other is rather high, the analysis without computer simulation is extremely difficult. However, using softwares may generate doubts. The question is whether we can accept these results or not.

Validations can help to answer these questions. Validation is a process during which we analyse a real scale experiment with the help of a software as well, and then the data of the analyses are compared to each other. After the assessment of the comparison we can decide how trustworthy the given software is to be considered. Today in Hungary Pathfinder is one of the most widespread evacuation simulator softwares. This program offers several calculation methods that can be used during a simulation.

There are validation documents available to the software that we all know but we wanted to gather our own experiences concerning the credibility of the program. Thus, the aim of the analysis is to find out how reliable the program is and to decide which of the three calculation methods reflects reality in its fullest, indicating the level of safety as well at the same time.

1 REAL EXPERIMENT

1.1 Describing the location

According to the evacuation calculation carried out based on the regulation, Dance Club would provide room for too few people, and this way, the club wouldn't be profitable (the owners say). Larger parties have already been organised in the club and authorities did not find the evacuation of the place problematic (only on-sight evaluation was conducted). The owners decided to start an analysis, in order to find real possible solutions that are safe. Evacuation simulations were run with Pathfinder's three simulation modes and one of the results would have been acceptable by the owners but since the results were different, it was necessary to make further calculations. After the discussions with the National Directorate General for Disaster Management, Ministry of the Interior (NDGDM) the next analysis took place on the location.

The NDGDM defined the Dance Club as a disco that can be found on the 3-4-5-6th levels of a six-storey building. Its only entrance is on the 3rd level at the meeting point of the hanging corridor surrounding the building and the overhead pedestrian crossing that leads to the railway station. Before and after the evacuation, the participants were to be found on the hanging corridor or on the overhead crossing.

The floorspace of the various levels can be seen on Tab. 1. Net floorspace doesn't include are where built-in furniture and equipment can be found.

Tab 1. Dance Club

Dance Club		
Level	Gross floorspace	Net floorspace
3.	19,76 m^2	8,35 m^2
4.	78,25 m^2	49,4 m^2
5.	98,64 m^2	50,3 m^2
6.	58,75 m^2	35 m^2

1.2 Variations

Hungarian regulations stipulate that each m^2 of built-in furniture equals (provides room for) 4 people. Therefore, the distribution of the people who is in the club is to be calculated using the most unfavourable scenario, that is, starting with the furthest point from the entrance and using 4 people/m^2 units. Owners said that if the distribution of the people would be like above described, then the club wouldn't be able to work so they set a number limit for the maximum people to be let in. This way, they ensure a comfortable atmosphere on all the levels and the club cannot be overcrowded.

Fig. 1 The Dance floor

1.2.1 OTSZ variation

According to Tab. 1, appendix 22 of NFSC the building has to be evacuated in 90 seconds. When defining the number of people to be allowed in, we have taken net floorspace and the number of people allowed/m^2 into account (Tab. 3, appendix 22 in NFSC). In the case of discos, pop concerts and programs that take place in the open (and no seats are provided) this value is 4 people/m^2 (the number of employees wasn't taken into account). We couldn't fill all the levels of the club because only 243 students participated in the analysis. 1022 participants would have been required to fill the whole place (if we count with 4 people/m^2) so we could only fill the upmost floor (see table).

Tab. 2 2nd part of the analysis

Level	Gross floorspace	Visitors	Employees
3.	19,76 m^2	0	Were not taken into account
4.	78,25 m^2	0	Were not taken into account
5.	98,64 m^2	103	Were not taken into account
6.	58,75 m^2	140	Were not taken into account
Total:		243	Were not taken into account
Total number of participants:		243	

1.2.2 Pre-arranged variation

During the analysis we calculated with those numbers (on the three top levels) that were set by the owners (see Tab. 2). We assumed that there are 14 employees and 206 guests can be found in the building (220 total). Participants that were employees had pre-defined points of location. Participants could only begin to leave the building after everyone else has left the level they were on.

Tab. 3 1st part of the analysis

Level	Gross floorspace	Visitors	Employees
3.	19,76 m^2	0	1 (cloakroom attendant)
4.	78,25 m^2	47	1 barman + 2 security guards
5.	98,64 m^2	94	1 DJ + 2 barmen + 2 security guards
6.	58,75 m^2	65	2 barmen + 2 security guards + 1 business manager
Total:		206	14
Total number of participants:		220	

1.3 Results of the variations

Tab. 4 Results of the variations

Simulation	Number of simulation	People in the club	Simulation		Number of people exiting in 90 second	Total time required for evacuation
			Beginning	End		
I. Owner	1.	220	10:48	10:50	164	137
	2.	220	11:02	11:04	170	120
II. NFSC	1.	243	11:15	1:17	158	136
	2.	243	11:25	11:27	176	120

2 CALCULATIONS OF THE NFSC (ANALYSIS OF THE 1ST AND 2ND PART)

In Hungary, NFSC is responsible for regulating the evacuation procedures of buildings. Evacuation analyses have two parts: first, they examine the process of leaving the room, and then the exiting of the building is analysed. In the current scenario, only the first section is regulated because the different levels have one airspace (people are outdoors after exiting it).
The analysis of the 1st section consists of two parts. First, the length of the escape paths is examined, and then they determine how many people can exit the doors in a given period of time. The width of the entrance door is 1.6 m.
Tab. 1, appendix 22 of NFCSS stipulates that rooms with “C”-“E” flammability class in a building with III fire resistance rating it is required that people are evacuated within one and a half minutes.
NFSC calculations are as follows:

$$t_{1b} = \frac{N_1}{kx_1}$$

where t_{1b} is the evacuation time of the first section (given in minute, considering how many people can exit the doors)
N1 is the number of people in the room
k is the permeability coefficient (value set to determine how many people leave the exit in a given time period) of the exit that has a constant value of 41,7 people/m/m^2
x_1 is the width of exit N_1, given in meter

On the basis of this, a maximum of 100 people (who can reach the exit in one and a half minutes) may exit the narrowest cross-section.

- Time required to evacuate 220 people: 3.29 minutes (198 s)
- Time required to evacuate 240 people: 3.59 minutes (216 s)
- Time required to evacuate 243 people: 3.64 minutes (219 s)

3 SOFTWARE

3.1 Introducing the software

Pathfinder is a simulator program (simulating evacuations and human motion) developed by Thunderhead Engineering.
Pathfinder supports two pathing simulation modes. In “steering” mode doors have no effect on the pathing of the participants; this simulation mode uses a steer-control based system instead. This can ensure an optimal distance between the participants present in a simulation. In SFPE mode participants do not attempt to avoid each other (the small circles, representing participants may overlap) but doors do have an effect on their pathing and velocity is affected by the size of the group of exiting participants.
One may change freely between the different simulation modes in the user’s interface, so the results can be compared this way.
In steering simulation mode Pathfinder combines path design, navigation and the collision of participants to coordinate the movement of the participants.
In SFPE mode Pathfinder uses a flux-based evacuation model, which was published in SFPE Handbook of Fire Protection Engineering (Nelson and Mowrer, 2002) and the SFPE Engineering Guide: Human Behaviour in Fire (SFPE, 2003).

3.2 Comparing the results of the three methods of analysis

The mathematic model, run by the computer models evacuation scenarios, which is basically the computerised analysis of a given case. Several difficulties may arise during traditional analysis methods. When carrying out an analogous analysis, it is not possible to examine the

joint effects of geometry, mass or waiting in a line (taking all the details into consideration). This way, all the factors can be analysed that haven't been taken into consideration before.
The simulation was made with Pathfinder, which was developed by Thunderhead Engineering.
Two distribution scenarios were analysed. One of these was the one defined by the NFSC (4 people/m^2) and the other was the one defined by the owners. The simulation aimed to examine what kind of results are produced by the software compared to reality.

3.3 Default data of the model

3.3.1 Geometry

The levels of the club were considered rooms in the simulation (as it is given in Pathfinder's user's guide). Thus, we've examined 4 levels as rooms and additional 4 rooms were required as flight of stairs. The rooms were connected by 10 stairs. The size of these stairs was 17.78 cm – 27.94 cm. An entrance door was also modelled on the entry level. The model was built based on the drawings of the building. This model had 4 levels (entry level and three other), The exit was also to be found on the entry level.

3.3.2 Properties of the participants, calculation mode

Width of shoulders: 45.58 cm
Maximum velocity: 1.19 m/s
Calculation mode: steering, SFPE
Evacuation begins at 0.0 s
Number of people to be evacuated:

- 220 (owner's distribution)
- 243 (NFSC scenario)

Tab 5 1st simulation (owner's distribution)

Level	Gross floor space	Visitors	Employees
3.	19.76 m^2	0	1 cloakroom attendant
4.	78.25 m^2	47	1 barman + 2 security guards
5.	98.64 m^2	94	1 DJ + 2 barmen + 2 security guards
6.	58.75 m^2	65	2 barmen + 2 security guards + 1 chief business manager
Total		206	14
Total		220	

Tab. 6 2nd simulation (NFSC scenario)

Level	Gross floor space	Visitors	Employees
3.	19.76 m2	0	were not taken into account
4.	78.25 m2	0	were not taken into account
5.	98.64 m2	103	were not taken into account
6.	58.75 m2	140	were not taken into account
Total		243	were not taken into account
Total		243	

In the owner's scenario the staff (14 people) began to leave the building with a 60 seconds delay. The reason behind this is the fact that they helped other people during the evacuation.

4 CONCLUSION

Tab. 8 Number of people evacuated in 90 s

	Owner’s		NFSC		Ratios
	Simulation I.	Simulation II.	Simulation I.	Simulation II.	
Real experiment	164	170	158	176	
Calculations by NFSC	100	100	100	100	1.64 x 1.58
Pathfinder steering	90	90	78	78	1.82 x 2.02
Pathfinder SFPE	90	90	64	64	1.82 x 2.46
Pathfinder SFPE$^+$	94	94	63	63	1.74 x 2.50

Tab. 9 Full-time evacuation

	Owner’s		NFSC		Ratios
	Simulation I.	Simulation II.	Simulation I.	Simulation II.	
Real experiment	137	120	136	120	
Calculations by NFSC	198	198	216	219	1.44 x 1.58
Pathfinder steering	218	218	261	263	1.59 x 1.91
Pathfinder SFPE	255	255	313	316	1.86 x 2.32
Pathfinder SFPE$^+$	250	250	318	338	1.82 x 2.33

It is observable that the 60 seconds latency of the staff in the owner’s scenario results in different behaviour on the various levels. There aren’t any people on the lower levels but the staff is still at its original spot. On the upper levels, however, the staff begins to exit the building when the area is still crowded. It would be a lot better if they started to exit a given level when it’s empty. On the basis of the results, we can safely claim that the evacuation simulations with Pathfinder take more time than the evacuations themselves (in all 3 modes). Calculations take place with 1.82 x safety level in steering and SFPE modes and 1.74 x SFPE$^+$ mode during the 90 s simulation. When the whole evacuation process is analysed, calculations have a safety level of 1.59 in steering mode, 1.86 in SFPE mode and 1.82 in SFPE$^+$ mode. The deviation of the simulation modes isn’t high but somewhat greater differences are observable between steering mode and the other two modes. This is the result of the two different mathematic models. SFPE modes are flux-based models, where cross-sections of the doors and the level of crowdedness (affecting the pace of advancement) play a major role. Steering mode on the other hand provides a more detailed way of analysis. This is provided by the evasive model, which is a lot more sensitive to a decrease in crowdedness. Due to this sensitivity, an evacuation simulation can speed up to a greater extent (than in SFPE mode) when a decrease takes place. NFSC calculation results fell between real experiment values and simulation values. This leads to the conclusion that the three modes can be considered stricter than the NFSC requirements, thus resulting in more representative results.

REFERENCES

Hickernell B. K., Hickernell E. H., Hickernell A. B., Author's Manual for Preparation of Manuscripts for Conference Proceedings, Composite Constructions IV, 2000.

Dickert D., Book Proceeding: Preparation of Manuscripts, ASCE Publications, 2002.

Thunderhead Engineering Pathfinder 2011 User Manual

Thunderhead Engineering Pathfinder 2011 Technical Reference

Thunderhead Engineering Pathfinder 2009.1.0417 Verification and Validation

Tadahisa Jin Visibility and Human Behavior in Fire Smoke The SFPE Handbook Of Fire Protection Engineering, . National Fire Protection Association,Quincy, Massachusetts, 3rd edition, 2002. 2-42 – 2-53.