Evacuation as a Way of Fire Protection in the Health Institutions

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Fire presents very often occasion, even in the modern world and can cause human victims and very serious destruction in the sense of material properties. So, it is very important to undertake every available potential to protect human lives and material properties. One of the most important procedures in the case of fire and not only fire is evacuation. Generally, evacuation is the safest, the shortest and the fastest way of moving humans, animals and material properties from endanger object/area to the secure location. The evacuation, as a very important way of protection presents always complex and open task that must be constantly improved. The evacuation will not be the same for the different objects, because there are objects with special properties that demand special procedures and actions. One of those objects are health objects. This review paper is written to show the examples of evacuation from different health objects and to present the use of simulation software as a inevitable tool in the evacuation object design.

Key Words: *evacuation, fire, health, protection, prediction*

1. INTRODUCTION

There are lot of definition and understanding of the evacuation term. The origin of the evacuation term, related to some sources, at the beginning, purported a military term and the meaning was the leaving of the battlefield. Generally, evacuation presents planed and organized relocation of humans, animals and material properties from endanger place, object or location to the safe and secure place or location. „In etymological sense, the word ‘evacuation’ is not complicated and has a similar meaning to scientific term for vacuum, empty space without any parts or elements. The words „vacuum“ and „evacuation“ originate from Latin adjective vacuus - empty, neuter gender, vacuum“ [1, 2].

The evacuation must be realized for different reasons, such as: fire, earthquake, flood, war, nuclear accidents, chemical accidents, terrorism threat, hurricanes etc. The evacuation as a task can be very complex and hard, in the dependence of many different factors. Of course, one of the most complex evacuation tasks is the evacuation of the object in the presence of lot of people inside. Those objects are, for example, health objects.

Health objects present a very large group of different objects intended to help humans in the prevention, maintenance and preservation of their health. Those objects are hospitals, clinics, emergency centers, community health centers, objects for rehabilitation and postoperative period, ambulances, sanatoriums, and similar. The vast majority of these objects, due to their own characteristics and services that they provide, available 24 hours with the presence of lot of humans inside. One of the most important facts related to the evacuation from health objects is the fact that many of health objects have a lot of immobile or hard mobile humans inside. Also, evacuation of clinics or objects with infective patients are particularly complex and demanded.

Fires in hospitals or similar objects are not rare occurrences (fire in Gaziantep in the south of Turkey during COVID epidemy, large fire in hospital in Madrid (Spain), large fire in 2009 in the CHC „Dr. Dragiša Mišović Dedinje“ – Belgrade, and many others.

Although all of objects in use, so as health objects, have proper permissions and licences with evacuation plan and clear showed evacuation routes, evacuation still presents complex and hard task for realisation. The most important fact is that great presence of people purports different and very unpredictable behaviour

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under stress, panic and fear. Stress, panic and fear cause different reactions at different people bringing them into situations where they probably have never been in or thought about it. That purports unpredictable behaviour such as faster moving or running, selfishness, ignoring of others in the sense of help to injured, creating jams with addition stress and panic. In the case that the reason for evacuation presents fire, it is very possible situation that evacuation of people is realising at the same time with fire extinguishing what can cause to increased disorganisation and additional jams. Besides, some of fire extinguishers can cause very bad effects on human`s health or even death.

So, related to noted facts, every evacuation can go wrong and cause additional human victims and other damages if it was calculated related to standard methods. It is certainly very hard to predict every potential evacuation scenario, but it would be of a great help and use to somehow predict different evacuation events.

Checked engineer way for precise, safe, secure and cheap prediction of evacuation from different objects, so as health objects, presents the use of simulation software.

The aim of this paper was to propound and explain the importance of simulation software use in the realisation of evacuation in health objects with concrete real examples realised in Pathfinder simulation software [3, 4].

2. PATHFINDER SIMULATION SOFTWARE

This computer software presents powerful simulator for humans' movement and evacuation. The main intention is the calculation of evacuation times so as analyse of potential evacuation events, with possibilities to use 2D and 3D visualisation tools for results analyse and presentation.

Pathfinder presents the product of Thunderhead engineering and demands the licence for using. It is possible to get the free trial in the duration of one month. There are different types of licences that can be arranged. As every simulation software, for its optimal functioning, Pathfinder demands strong hardware configuration. Related to extant information [5] „the minimum hardware configuration purports 32 or 64-bit Windows or higher, at least processor in the Intel i5 rank, at least 4 GB of RAM, graphic support for OpenGL 1.2." Of course, stronger hardware configurations with stronger processor and more RAM would enable much faster and more comfortable work.

Pathfinder enables drawing of complete objects with every of their elements: walls, doors, stairs, elevators, different obstacles and location of different number of occupants (humans) inside. The movement environment presents 3D triangulated mesh and it can be designed manually or it can be imported as already designed model.

The very important thing in this software are the modes of simulation. Pathfinder supports two different modes of simulation. The first one presents so-called „Steering" mode which purports that „humans" use steering system of movement and interaction. This implies the emulation of the human behaviour as much as possible. The second one presents so-called „SFPE" mode. This mode purports that occupants can interpenetrate each other and do not attempt to avoid each other. The main characteristic of this mode is that the speed of occupants is controlled by density.

One of the very good and very important things related to Pathfinder software is the fact that complete object can be designed in some other software (Auto Cad for example) and can be imported into Pathfinder software, what is great advantage related to efficiency. Fig. 1 shows an example of evacuation moment from the resident building simulated in Pathfinder software [5].

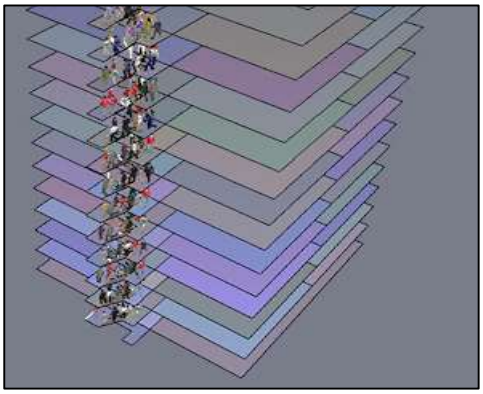

Figure 1 - Evacuation moment from the residential building simulated in Pathfinder software

3. EVACUATION FROM STATIONARY HEALTH INSTITUTION

The analysed stationary health institution is Hotel Radon, which is very important health object and it is the part of the hotel complex of three hotels in the property of the Institute „Niška Banja". This object has a lot of different purposes and presents great and important healthy potential for different patients. It is located literally in the centre of Niška Banja, surrounded with lots of different trees. It is also supplied with thermal water from the nearby spring.

This stationary health object presents large object with large base floor and eleven other floors. The potentials of the hotel in the sense of accommodation present 300 beds with followed contents and enable stay of more dozens of people at the same time with complete medical assistances. Hotel also possess many

other modern contents. One of that content presents the pool with thermal and radioactive water. This pool is also available for patients, so as for ordinary citizens. Also, stationary capacities provide many different medical meetings, congresses, seminars, conferences and similar events. Large parking enables space for great number of cars. Hotel Radon is presented on figure 2.

Figure 2 - Stationary health institution Hotel Radon in Niška Banja

The evacuation from object like this definitely presents hard, demanded complex task. There was simulation of six different evacuation scenarios realised. There are many reasons for this, such as patient's condition, location, movement speed, fear, panic etc.

The complete number of occupants/humans with the participation in simulations in the Hotel Radon was 363. This number of occupants/humans was adopted for simulation analyse because of the analyse of objects capacities, that included patients with additional medical stuff and other human resources. Of course, it doesn't mean that the complete number of the occupants/humans cannot be bigger or smaller. For an example, during COVID virus pandemic, the number of occupants/humans in the hotel was different from day to day, but it was bigger than 363 [6].

The simulation conditions for all of six evacuation scenarios, what purported speeds for different occupants/patients are presented on table 1.

Table 1. The conditions for all of six evacuation scenarios

Scenario	Speed of occupants at fifth and sixth that need assistance floor [m/s]	Speed of all other occupants [m/s]
I	0.15	1
II	0.15	0.75
III	0.15	0.6
IV	0.15	0.5
V	0.15	0.3
VI	0.15	0.15

Simulation model of the stationary health institution with some of evacuation moments and complete simulation results are shown on figures 3 to 8.

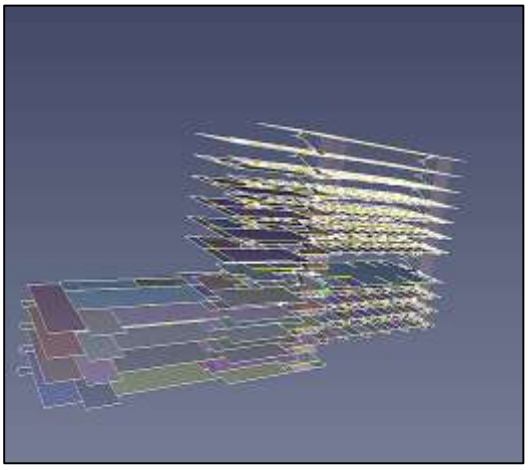

Figure 3 - Hotel Radon simulation model in Pathfinder 2012 software (figure source:[6])

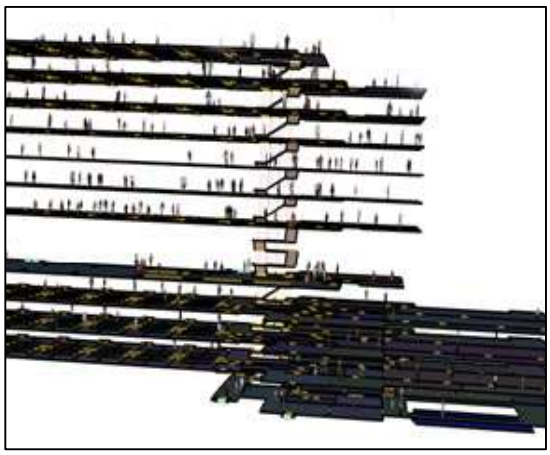

Figure 4 – Evacuation moment for the first case scenario in the 5 seconds after the start of the simulation

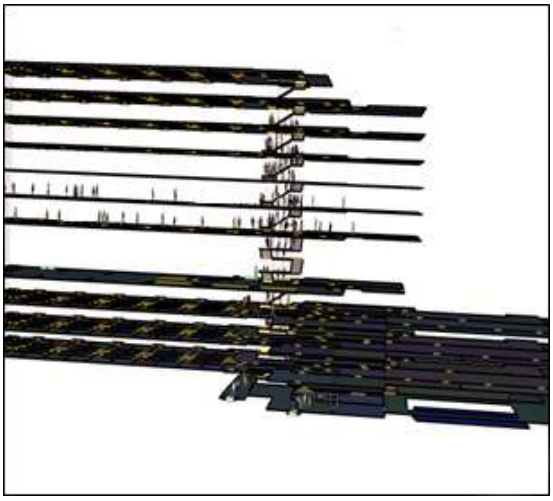

Figure 5 - Evacuation moment for the first case scenario in the 50 second after the start of the simulation

Figure 6 - Evacuation moment for the first case scenario in the 225 seconds after the start of the simulation

Figure 7 - Evacuation moment for the first case scenario in the 400 seconds after the start of the simulation

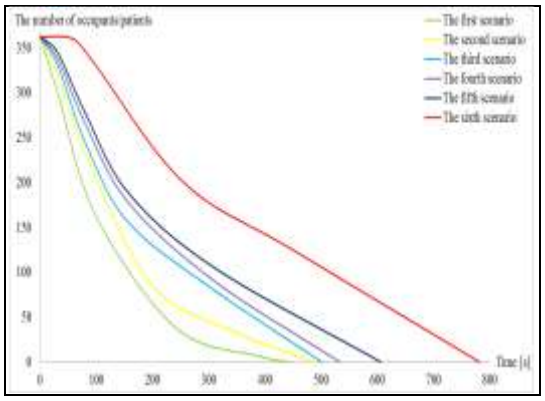

Figure 8 – Results of simulations presentation for every of six scenarios

4. EVACUATION FROM HOSPITAL WITH THE PRESENCE OF IMMOBILE OCCUPANTS

Health objects generally purport the presence of many occupants/humans inside in the form of patients, doctors, medical and technical stuff, visitors etc. They are circulating through connection elements such as corridors, stairs, hallways and other construction elements which at the same time mostly present potential evacuation routes.

This objects purports patients in rooms, in ordinary beds or medical beds. Their moving can be free or with assistance. Many of them cannot move themselves but with the assistance of one or more humans, in the dependence from the fact that they are in the wheelchair or in the medical bed. Generally, every type of health clinic is very hard for evacuation. For example, in the case of infective clinic or infective object, evacuation must be realised related to special procedures, with aims to save the occupants/patients and not to spread the infection.

The simulated object for this example is the hospital with several (five) floors. The dimensions of this health institution in the base were 47 m x 11 m. Every floor has a height of 3 m. There were ten rooms for patients at every floor. As construction elements between floors, there were: ordinary and emergency stairs, as well as elevators between floors. The complete number of elevators in the hospital was five, two big ones and three small ones with different speeds-0.7 m/s for big elevators and 1,1 m/s for small elevators. Also, this health object possesses two different exits.

There were 285 occupants inside the health object, related to the simulations. There were two or three patients in each room and there were 20 patients' rooms per floor (100 in total). There were five scenarios realised for this health object. These scenarios and conditions for them are presented in table 2.

Table 2. Conditions for realised simulation scenarios

Evacuation scenario	Potential connections				
	Ordinary Stairs available	Emergency Stairs available	Elevators available	All stairs available, but not elevators	All stairs and elevators available
I	■				
II		■			
III			■		
IV				■	
V					■

Every of five scenarios purported that the speeds of mobile occupants were 1,2 m/s, 1,5 m/s, 2 m/s and 2,5 m/s while the speeds of immobile occupants were for wheelchairs 0,69 m/s.

The simulation model of the hospital with some evacuation moments are presented on figures 9 to 11[7].

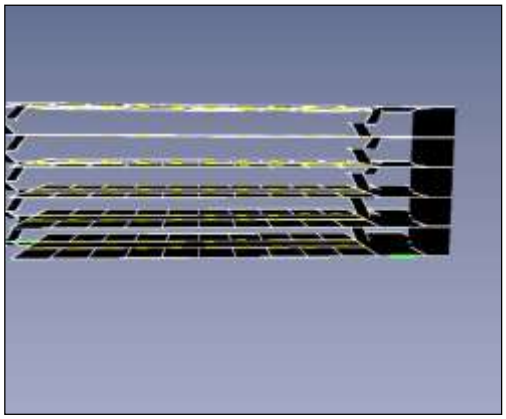

Figure 9 - The simulation object of the hospital with immobile patients in Pathfinder presentation (figure source:[7])

Figure 10 - The evacuation moment for the scenario I (the mobile occupants/patient's speed 1.5 m/s, wheelchairs speed 0.69 m/s)

Figure 11 - The evacuation moment for the scenario V (the mobile occupants/patient's speed 2 m/s, wheelchairs speed 0.69 m/s)

The simulation results for the „fastest" and for the „slowest" scenarios are presented on figures 12 and 13.

It is important to note that also one more scenario was planned to be realised (only elevators were available for evacuation), but, because of used hardware configuration, it wasn't possible.

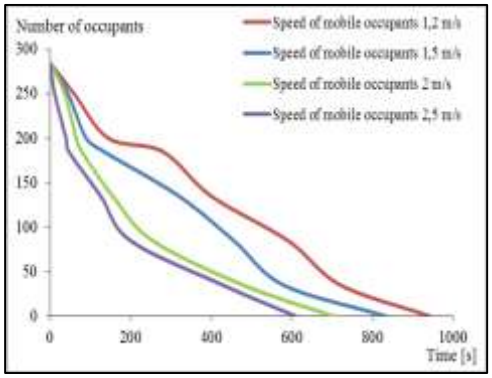

Figure 12 - Realised results for the "fastest" scenario

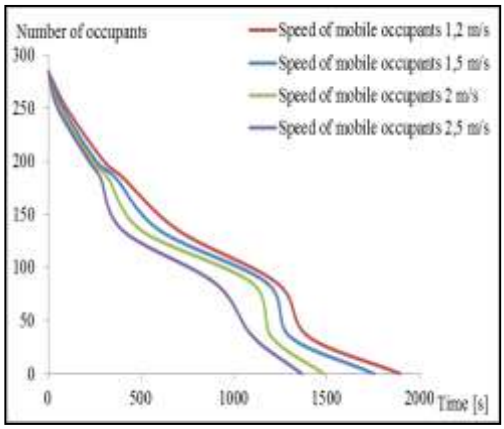

Figure 13 - Realised results for the „slowest" scenario (figure source: [7])

5. EVACUATION FROM THE HEALTH GERONTOLOGY INSTITUTION

Gerontology institutions are special health institutions with a lot of mostly immobile and hard mobile occupants/patients. Evacuation of this kind of objects can be very complex and hard to realise. Immobile and hard mobile patients in this object can be move by wheelchairs, medical beds and stretchers. This can significantly limit the speed and the movement of this kind of patients with a great possibility for crowding. So, it is very important at this kind of object to predict the potential evacuation scenarios and routes.

The simulation model of Gerontology institution analyzed and realized for this paper was the object with contented of five floors: ground floor and four additional floors. The object was simulated in its real dimensions.

Location of the personal was in the ground where also were several rooms with different purposes. Immobile persons were located at two first floors, where the first floor was equipped with medical beds

which were used by immobile patients, and the second floor was used by immobile patients in wheelchairs. Mobile patients were located at the two top floors (3rd and 4th). Each floor intended for patients had 16 rooms. It is important to note that immobile patients in medical beds were able to move but only with assistance of two members of medical staff, while immobile persons in wheelchairs were able to move but only with assistance of one member of medical staff. The remaining patients were able to move without any assistance. Dimensions for medical bed were 2 m x 0,90 m x 0,75 m, while the dimensions of wheelchair were 1,1 m x 0,65 m x 0,92 m and these dimensions were accepted as standard dimensions. The complete number of occupants in object was 172 (immobile patients in medical beds and wheelchairs 128 and 44 remaining). The Gerontology centre as simulation object are presented on figures 14 and 15; the conditions for all of four scenarios are presented in table 3 while the dependence of occupant's speed from scenario are presented in table 4.

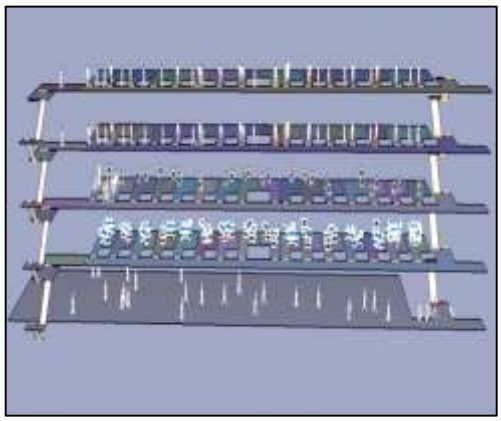

Figure 14. Simulation model of the Gerontology center in Pathfinder simulation software with occupants inside-front view (figure source: [8])

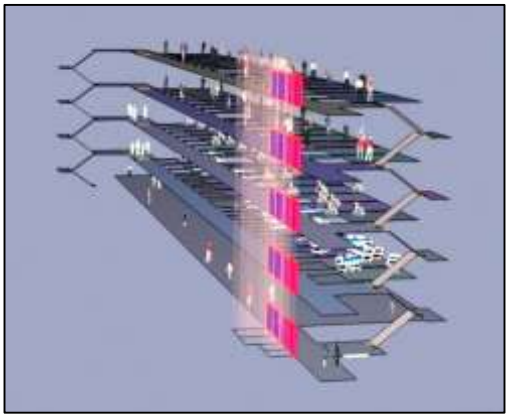

Figure 15. Simulation model of the Gerontology center in Pathfinder simulation software with occupants inside - side view (figure source: [8])

Because of the paper limitation, only few figures are presented to show some evacuation moments (figures 16 and 17) and realized results (figures 18 and 19)[8].

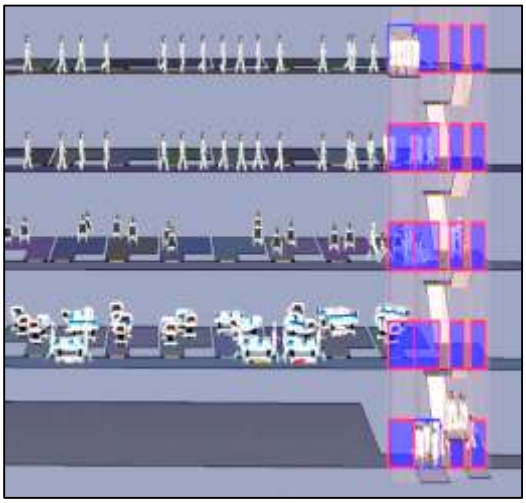

Figure 16 - Evacuation moment for the first scenario, 34 seconds after simulation start in Pathfinder software

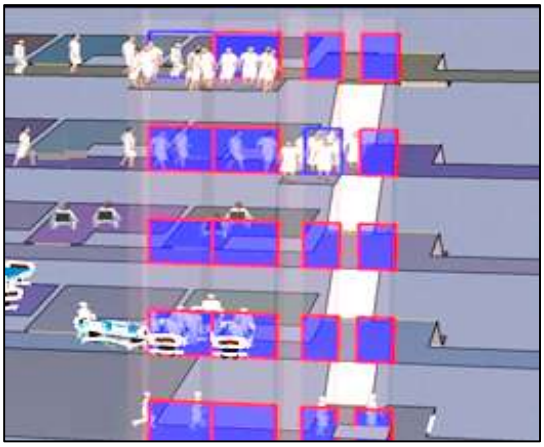

Figure 17. Evacuation moment for the first scenario, 273 seconds after simulation start in Pathfinder software

Table 3. Conditions for realised simulation scenarios

Evacuation scenario	Availble connections			
	All elevators and all stairs available	All elevators disabled and all stairs available	Only emergency stairs available	Only ordinary stairs available
I				
II				
III				
IV				

Table 4. The dependence of occupant's speed from scenario

SCENARIO/ SPEED	The first scenario	The second scenario	The third scenario	The fourth scenario
mobile patients [m/s]	0.55	0.65	0.75	0.85
patients in wheelchairs [m/s]	from 0.55 to 1.35	from 0.55 to 1.35	from 0.55 to 1.35	from 0.55 to 1.35
patients in medical beds [m/s]	0.25 to 0.95	from 0.25 to 0.95	from 0.25 to 0.95	from 0.25 to 0.95
medical and administrative personal [m/s]	1.15	1.15	1.15	1.15

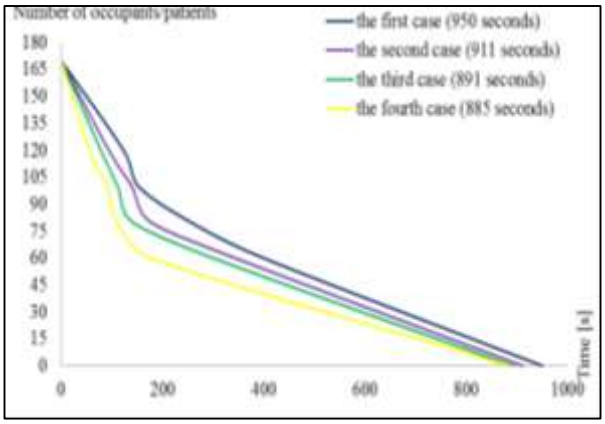

Figure 18 - Realized results for the „fastest" scenario (the first scenario with all four cases)

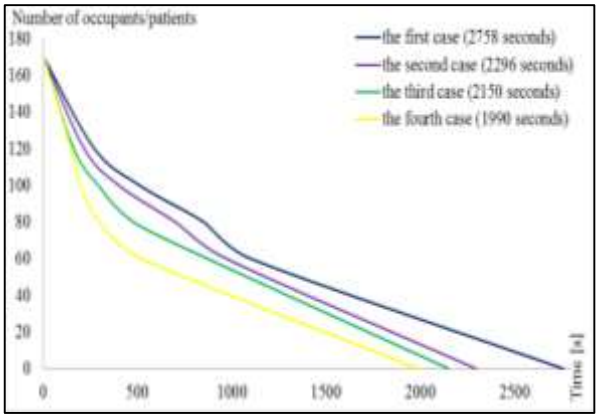

Figure 19 – Realized results for the „slowest" scenario (the third scenario with all four cases)

6. CONCLUSION

Evacuation as a very complex, hard and potentially unpredictable task demands all possible professional and scientific help that can get because the main aim is the protection of human lives. The role of simulation software in evacuation presents very important shift with unthinkable possibilities in the sense of safety reasons, technical reasons, organisation reasons and financial reasons. Simulation software enable analyse and prediction of a lot of various evacuation scenarios with potential of different parameters and conditions variation and of course, as a final result, the selection of the best evacuation scenario.

Because of all this noted and many other reasons and advantages, simulation software must be very important and inevitable engineering tool in different engineering and other fields, so as in the health [9-12].

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REZIME

EVAKUACIJA KAO VID ZAŠTITE OD POŽARA U ZDRAVSTVENIM USTANOVAMA

Požar predstavlja veoma čestu pojavu, čak i u modernom društvu i može prouzrokovati ljudske žrtve i veoma ozbiljne destrukcije u materijalnom smislu. Zato je veoma važno preduzeti sve raspoložive mogućnosti da bi se zaštitili ljudski životi i materijalne vrednosti. Jedna od najvažnijih procedura u slučaju požara i ne samo u slučaju požara je evakuacija. Generalno, evakuacija predstavlja najsigurniji, najkraći i najbrži način premeštanja ljudi, životinja i materijalnih sredstava iz ugroženog objekta ili područja na sigurnu lokaciju. Evakuacija, kao veoma važan vid zaštite predstavlja veoma kompleksan i otvoren zadatak koji se mora stalno unapređivati. Evakuacija neće biti ista za različite objekte zato što postoje objekti sa specijalnim namenama koji zahtevaju posebne procedure i postupke. Takvi objekti su zdravstveni objekti. Ovaj rad je napisan sa ciljem da prikaže primere evakuacije iz različitih zdravstvenih objekata i da predstavi upotrebu simulacionog softvera kao neizbežnog alata u projektovanju evakuacije.

Ključne reči: *evakuacija, požar, zdravstvo, zaštita, predikcija*