UDK BROJEVI: 614.841.33
699.812:364-788

THE EVACUATION POSIBILITIES OF SANITARY OBJECTS

Radoje Jevtić

ЕВАКУАЦИОНЕ МОГУЋНОСТИ ЗДРАВСТВЕНИХ ОБЈЕКАТА

Радоје Јевтић

Summary

Sanitary objects present, in architectural, safety and evacuation sense, special objects with lots of humans inside for all of 24 hours. These objects could be hospitals, ambulances, emergencies, medicine academies, rehabilitation objects, clinics and similar. It implies great attention to theirs design, especially to design of theirs fire protection systems and design of evacuation routes because it is very difficult to evacuate these objects in case of some disaster or critical situation. This paper was written to show the importance of evacuation software usage in simulation of potential evacuation scenarios of sanitary object for rehabilitation, hotel Radon in Niška Banja.

Key words: *evacuation, simulation, sanitary object.*

Сажетак

Здравствени објекти представљају у архитектонском, сигурносном и евакуационом смислу, специјалне објекте у којима непрекидно борави доста људи. Ови објекти могу бити болнице, амбуланте, хитне помоћи, медицинске академије, рехабилитациони објекти, клинике и слично. Пројектовање оваквих објеката захтева много пажње, посебно пројектовање њихових система за заштиту од пожара и пројектовање евакуационих рута зато што је веома тешко реализовати евакуацију оваквих објеката у случају неке катастрофе или критичне ситуације. Овај рад је написан да покаже важност употребе софтвера за евакуацију у симулацији потенцијалних евакуационих сценарија здравственог објекта за рехабилитацију, хотела Радон у Нишкој Бањи.

Кључне речи: *евакуација, симулација, здравствени објекат.*

[1] Radoje Jevtić, PhD in technical sciences (дипломирани инжењер електротехнике), School for electrical engineering „Nikola Tesla“, Niš, Srbija.

INTRODUCTION

The object evacuation, generally, presents very complex task and always open problem that need better and better solutions. The evacuation is especially complex problem for object with lots of humans inside, such as, for example, sanitary objects: hospitals, rehabilitation objects, clinics and similar. Because of their purpose, sanitary objects usually have, for all of 24 hours of day, lots of humans inside. It is very often case that many of them are immobile or with weak movement. Also, very often situation in the evacuation case is panic, which is very hard, almost impossible to be predicted. The reasons for evacuation could be different: fire, gas, bomb threat, earthquake, overflow, civil disorders, terrorism etc. For example, only in last several years, many fires in sanitary objects were occurred: in 2009 in Belgrade – Dragiša Mišović hospital (presented in figure 1); in 2010 in Subotica, in 2013 in Bihać (Bosnia and Hercegovina), in 2013 in Russia (Lukovo village), in 2014 in Pirot, in 2015 in Prokuplje, in 2015 in Athens (Greece)…

Figure 1*. Great fire in hospital Dragiša Mišović in Belgrade in 25.10.2009 (figure source: http:// www.politika.rs/rubr-ike/Drustvo/Pozar-u-bol-niciDr DragishaMishovic.lt .html).*

These objects are constantly open so there are lot possibilities for someone without permission to come and case some kind of disaster: fire, kidnapping, terrorism, murder and similar. Because of all that reason, these objects must have very good evacuation strategy, realized through correct projecting of evacuation routes (primary and secondary) and analyze of potential evacuation scenarios.[1, 3]

The evacuation of every object should be fast, safe and effective. Every object has ways for its fastest evacuation. These ways were called evacuation routes. Evacuation routes present directions where occupants should move in case of some kind of disaster and they were projected as primary and secondary. Primary evacuation route is the most frequently, route for normal communication in object. For example, these routes could be stairs, hallways, corridors and other surfaces used for communication in object or in separate floor. They are with the different dimensions for every type of object. These routes are the routes that fire services used for, in case of fire. The secondary routes depend on objects purpose. These routes could involve windows, roofs etc. Both types of evacuation routes must satisfied many standard and no standard demands, according to the number of people, type and purpose of object, speed of people moving, necessary time of evacuation etc.[4]

The successful evacuation implies usage of modern technologies, different types of monitoring and supervision, sensors, communication instruments, simulation software and all other necessary things and equipment that were defined by proper standards and laws, no matter on its financial aspects.

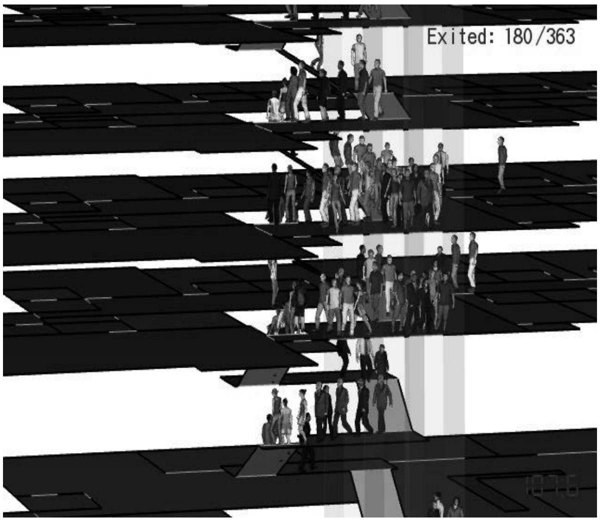
PATHFINDER 2012 SIMULATION PROGRAM

One of the often used simulation software for evacuation is Pathfinder. Pathfinder is an agent based egress and human movement simulator. There are several different versions of this program. Pathfinder provides a graphical user interface for simulation design and execution as well as 2D and 3D visualization tools for results analysis. The movement environment is a 3D triangulated mesh designed to match the real dimensions of a building model.

This movement mesh can be entered manually or automatically based on imported data (e.g. FDS geometry). Walls and other impassable areas are represented as gaps in the navigation mesh. These objects are not actually passed along to the simulator, but are represented implicitly because occupants cannot move in places where no navigation mesh has been created. Doors are represented as special navigation mesh edges. Every door has its own length. In all simulations, doors provide a mechanism for joining rooms and tracking occupant flow. Depending on the specific selection of simulation options, doors may also be used to explicitly control occupant flow. Stairways are also represented as special navigation mesh edges and triangles. Occupant movement speed is reduced to a factor of their level travel speed based on the incline of the stairway. Occupant speed could be defined for different evacuation scenarios. Each stairway implicitly defines two doors. These doors function just like any other door in the simulator but are controlled via the stairway editor in the user interface to ensure that no geometric errors result from a mismatch between stairways and the connecting doors.

Occupants are modeled as upright cylinders on the movement mesh and travel using an agent-based technique called inverse steering. Each occupant calculates movements independently and can be given a unique set of parameters (maximum speed, exit choice, 3D model, etc). Pathfinder supports two movement simulation modes. In "Steering" mode, doors do not act to limit the flow of occupants; instead, occupants use the steering system to maintain a reasonable separation distance. In SFPE mode, occupants make no attempt to avoid one another and are allowed to interpenetrate, but doors impose a flow limit and velocity is controlled by density. Simulator users can freely switch between the two modes within the Pathfinder user interface and compare answers.[5] The example of occupant's movement in particular object is presented on figure 2.

Figure 2. *Modeled occupants in the simulation model of hotel Radon in Niška Banja.*



One particularly appropriate software possibility is importing files created in 3D CAD, FDS and PyroSim. These files have its own geometry which can be used in Pathfinder and significantly save time need to complete the whole evacuation and fire project. The imported geometry is sent as-is to 3D Results, resulting in a clean and fast graphical representation of the data. The used version of Pathfinder for paper results was 2012 version.

SIMULATION MODEL

Hotel Radon is on of three hotels that belong to the Institute of Niška Banja. Each of these hotels is a unique complex that possesses accommodation capacities, complete therapy blocks (hydro, electro, kinezzy and mud therapy), several halls for individual or group therapy, recreation and fun. Hotel Radon is located about 100 meters far from promenade in Niška Banja. It is high building with basement and 11 floors. Hotel Radon has capacity of 300 beds, commodious rooms, apartments and luxury apartments, amphitheater with 300 seats, plenum hall with 60 seats, hall for VIP guests, restaurant with 300 seats, café restaurant, bar, summer garden, swimming pool with thermal water, wellness center and parking at the back side.

The wide range of therapeutics services contains: the gym for rehabilitation of cardiovascular patients, the block for manual massage, the room for electro therapy, the room for mud application, inhalation room, hydro block (swimming pool, jacuzzi pool, pearl baths, underwater massage, hydro jet, local application, sauna and vibrant-sauna), coronary care unit – intensive and semi-intensive care, diagnostic center – central laboratory, Rö cabinet, MRI screen of peripheral joints, echocardiography with color Doppler, stress echocardiography test, color Doppler of the neck blood vessels, 24 hour Doppler monitoring, ergometry ultrasound examination of the joints and soft tissue.

The arrangement in hotel Radon was formed according to the condition and possibilities of patients. For example, at the basement, there are swimming pool, wellness centre and reception part. At the first floor, there are baths, ambulances, amphitheater and similar rooms. At the second floor, there are store room, offices, waiting rooms and rooms for patients. At the third floor, there were kitchens, restaurant, small hall, X ray rooms, laboratory and offices. At the fourth floor, there are also reception, library, several stores, café and several exits to the large terrace with great view. The fifth floor contents rooms for patients, offices, intensive and semi-intensive care and similar rooms. The sixth, seventh, eighth, ninth, tenth and eleventh floors the most contain rooms for patients. The patients were disposed according to their healthy condition and level of illness. Hotel Radon is presented on figures 3 and 4.

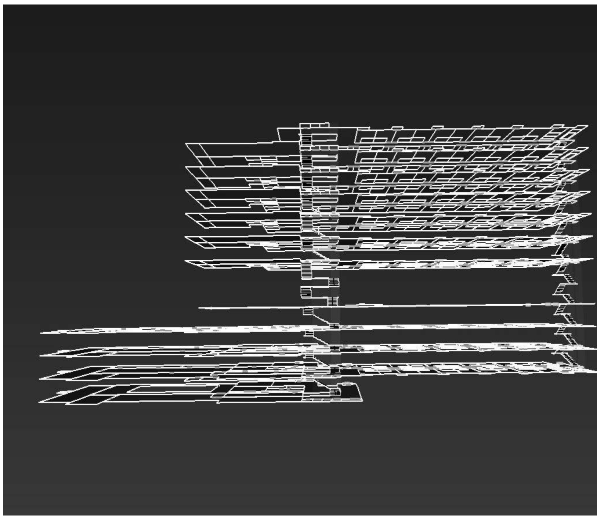
Figure 3. *Hotel Radon in Niška Banja, air view (figure source:* http://wikimapia.org/11425042 /*sr /РАДОН).*

Figure 4. *Hotel Radon in Niška Banja, front side.*

Hotel Radon has three lifts for patients and personal and one cargo lift. One lift has capacity of 10 persons while other two have capacities of 8 persons. In the hotel, there are main stairs and secondary stairs. Hotel surrounding presents beautiful park until special attraction presents huge waterfall with cascades, projected as a component of hotel.

According to hotel dimensions and evacuation diagrams presented on every floor of the hotel, the simulation model in Pathfinder 2012 was constructed. There were lots of things that had to be realized in order to construct as much as possible real model. The most important were about momentary occupant's number in the hotel and their properties, the most in sense of their movement speed and their dimensions. The reason for number of 670 occupants was in fact that the maximum of hotel's capacity is 300 beds and the presumption was that each of them was occupied. Also, there was a presumption that the amphitheater with 300 seats and plenum hall with 60 seats were also occupied. The limits of this paper don't allow to present every of them.(6, 7) The simulation model of Hotel Radon in Niška Banja, in Pathfinder 2012 program is presented on figure 5.

Figure 5. *Hotel Radon in Niška Banja, Pathfinder 2012 presentation.*



SIMULATION

The simulation of hotel occupant's evacuation was realized for four scenarios. The reason for that was in fact that different types of patients have different movement speed, according to the degree of their illness conditions. The first scenario considered that occupants on fifth and sixth floor had speed from 0,15 m/s and need help in evacuation. The other occupants from all of the rest other floors had speed from 1 m/s. The second scenario considered that occupants on fifth and sixth floor had speed from 0,15 m/s and need help in evacuation, while other occupants had speed from 1,5 m/s. The third scenario considered that occupants on fifth and sixth floor had speed from 0,15 m/s and need help in evacuation, while other occupants had speed from 2,5 m/s. The fourth scenario considered that occupants on fifth and sixth floor had speed from 0,15 m/s and need help in evacuation, while other occupants had speed from 3,2 m/s. The occupants from fifth and sixth floor must use the elevators, while the occupants from higher and lower floors, beside lifts, could use stairs, main and fire stairs. The occupants from fifth and sixth floor must use the elevators, while the occupants from higher and lower floors, beside lifts, could use stairs, main and fire stairs. All lifts could be used, three passenger lifts and one cargo lift. The occupants from the basement didn't have to use the elevators (swimming pool and wellness centre). Also, the occupants on the fourth floor didn't have to use elevators because they were in the upper ground level.

There were lots of specifications which the simulation realization based on. The limits of this paper don't allow showing all of them, but some of them are presented in table 1.

Table 1. *Some specifications used in Pathfinder 2012 simulation model of Hotel Radon.*

Occupants arrangement	by floors
Main stairs length	170 cm
Fire stairs length	95 cm
Tread	30 cm
Riser	15 cm
Occupations height	1,8 m and 1,5 m
Occupations reduction factor	0,7
Occupations comfort distance	0,3 m
Occupants persist time	1 s
Occupations slow factor 0,1	
Speeds of occupants	according to the noted scenarios
Number of passenger elevators	3
Open and close delay time	about 5 seconds
Number of cargo elevators	1
Number of used behaviors	4
Number of possible exits	6

Some scenes from the second scenario are presented on figures from 6 to 12, while the complete simulation results are presented on figure 13.

Figure 6. *Simulation example for the second scenario after 16.4 seconds from the start of the simulation.*

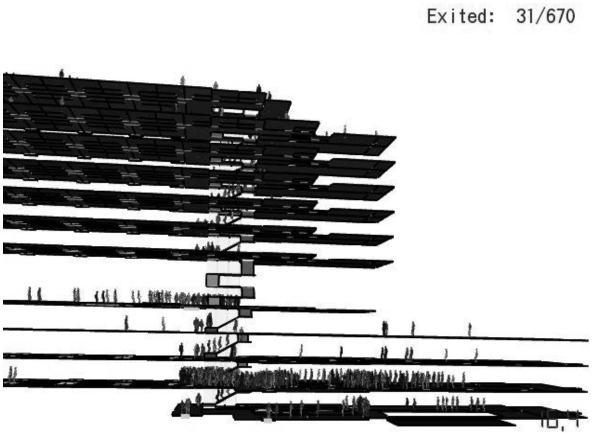


Figure 7. *Simulation example for the second scenario after 20.8 seconds from the start of the simulation.*

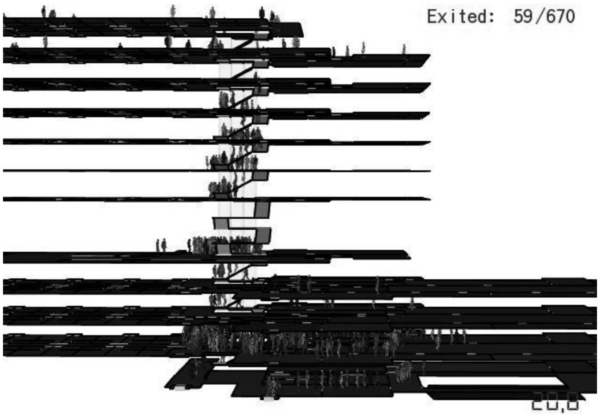


Figure 8. *Simulation example for the second scenario after 72 seconds from the start of the simulation.*

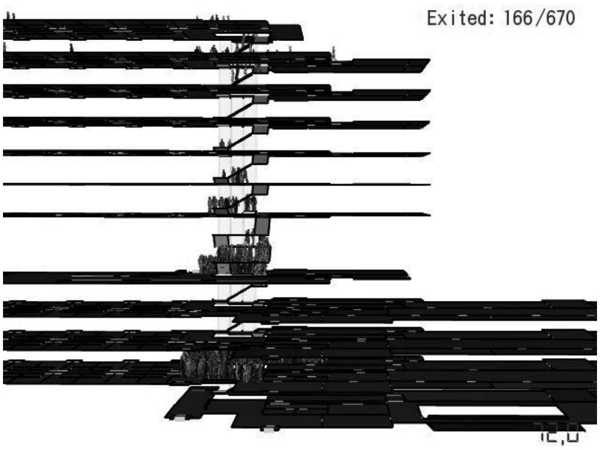


Figure 9. *Simulation example for the second scenario after 140.8 seconds from the start of the simulation.*

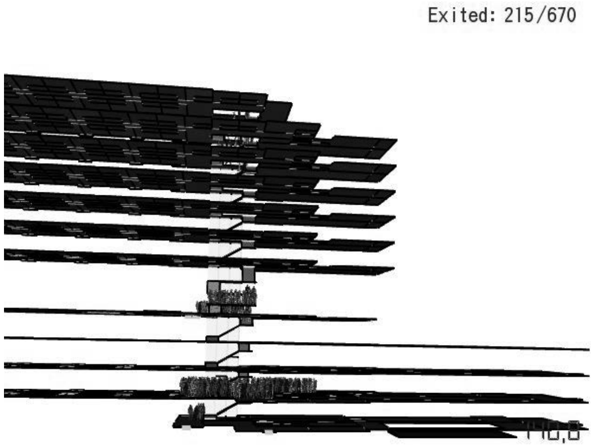


Figure 10. *Simulation example for the second scenario after 318.9 seconds from the start of the simulation.*

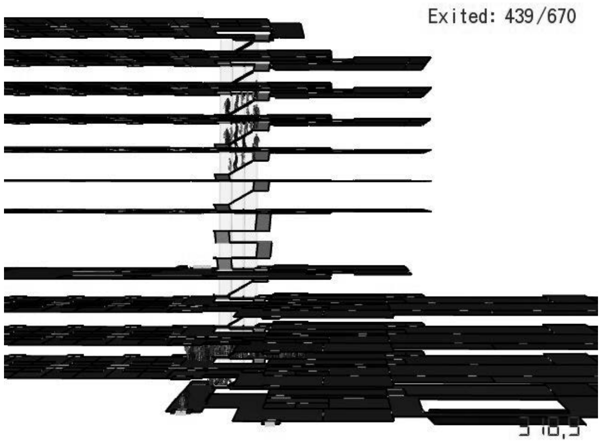


Figure 11. *Simulation example for the second scenario after 443.3 seconds from the start of the simulation.*

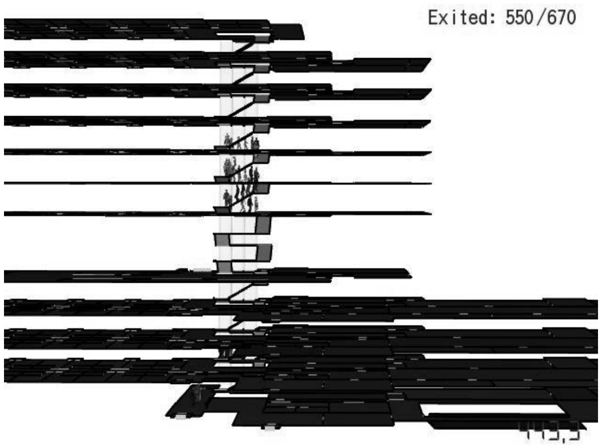


Figure 12. *Simulation example for the second scenario after 604.3 seconds from the start of the simulation.*

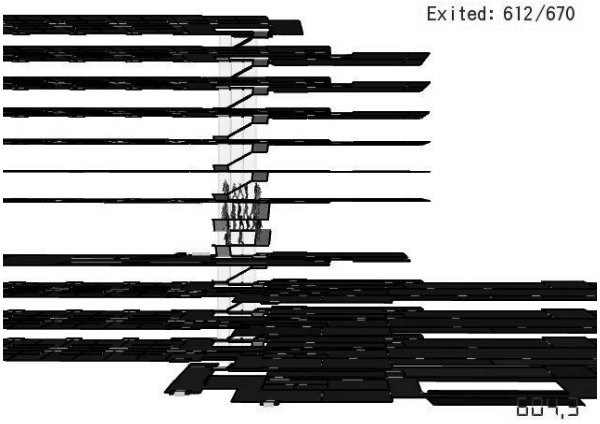
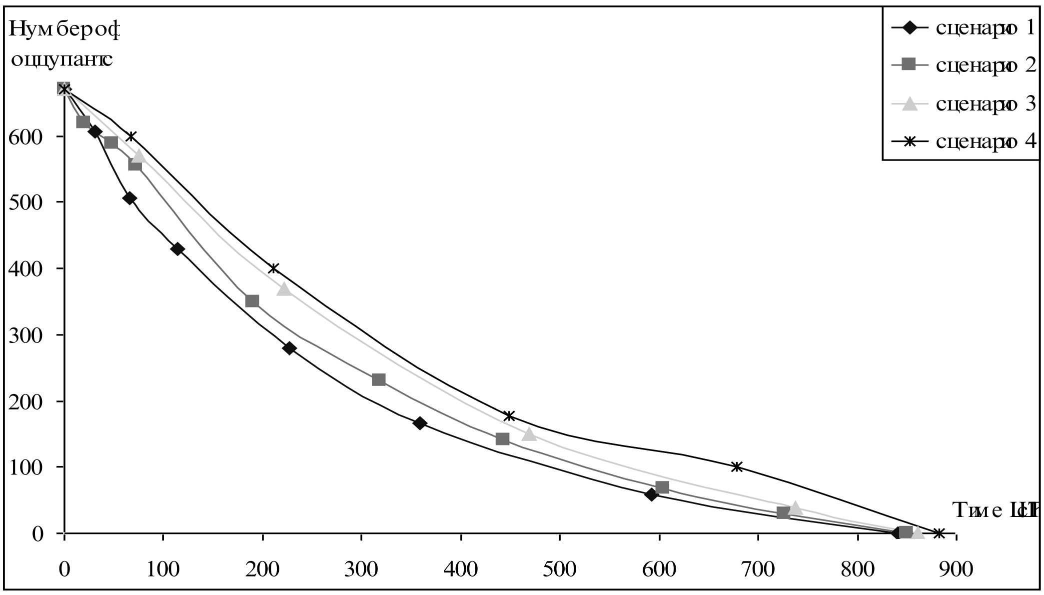


Figure 13. *Complete simulation results for every of four scenarios.*



DISCUSSION

Realized simulation results for presumed four evacuation scenarios showed that with foreclose proper behavior, evacuation of all occupants were possible without jams, for determinate time. The foreclose proper behavior implied that, according to the evacuation plans that were positioned in hotel, occupants from every floor, occupants in amphitheatre, randomly overtaken persons in and personal had their precise evacuation routes to noted exits.[8, 9] But, according to the realized results, the shortest time for complete evacuation was for the first scenario, where the occupants speed was the least – 1 m/s. The longest time for evacuation was for the fourth scenario, where the occupants speed was 3,2 m/s and had the highest value. The realized results showed that in some particular cases, for example in the cases of panic and stress, the highest speed very often implied very long time for evacuation with high opportunities for jam.[10] Very important is the fact that medical personal cant help to immobile patients if they react fast (for example, it is very hard possible and medically incorrect to push and run immobile patients). The results realized in this paper could be compared with realized results in similar papers.[11, 13]

CONCLUSION

Analyze of evacuation times and evacuation routes using proper software is very effective way for safety and secure projection of evacuation routes because it gives good presentation how available evacuation routes could be used for different accidents (fire, earthquake, terrorist etc) that could happen. It is also possible to locate new evacuation routes that could be used in accident (lower floors exits, lower windows etc), but in this case, where the occupants were patients in the biggest number, this was poorly applicable. Testing these factors for different occupant's speeds and behaviors gives good real presentation of potential evacuation scenario in object and great advantages in projecting and installing of complete protection systems, such as, fire protection system, additional elevator system or something similar. The appliance of this program for different objects puts it to the queue of inevitable engineer's tools for calculating and projecting safety evacuation systems for any type of evacuation causes [14, 15].

REFERENCES

1. Jevtić RB. *The importance of fire simulation in fire prediction*. Tehnika elektrotehnika, Beograd, Serbia, 2014; Vol 1: pp. 153-158. ISSN 0040-2176

2. http://www.politika.rs/rubrike/Drustvo/Pozar-u-bolnici-Dr-Dragisha-Mishovic.lt.html

3. http://www.telegraf.rs/vesti/1735520-pozar-u-bolnici-ubio-tri-pacijenta

4. Jevtić BR, Ničković TJ. *Object evacuation for different speeds of occupants*, 58thETRAN CONFERENCE, Vrnjačka Banja, Serbia, 2014.

5. Thunderhead, *Pathfinder Exmple Guide*, USA, 2012.

6. Jevtić BR. *The simulation of sanitary objects evacuation-an example of hotel radon in Niška Banja*. Tehnika Elektrotehnika, Beograd, Serbia, 2015; Vol 3: pp. 545-550. ISSN 0040-2176

7. http://www.radonnb.co.rs/ci/

8. Fitzgerald WF. *Building Fire Performance Analysis*. John Willey and Sons, 2004.

9. Izdavački zavod Forum, *Plan evakuacije i uputstva za postupanje u slucaju pozara*. Novi Sad, 2012.

10. Helbing D., Farkas I., Viscsek T. *Simulating dinammical features of escape panic*. Nature, 2000; Vol. 40: pp. 487–490.

11. Jevtić BR, Ničković TJ. *Object evacuation for different speeds of occupants*. 58thETRAN CONFERENCE, Vrnjačka Banja, 2014.

12. Jevtić BR. *Simulation of the shopping centre Zona I evacuation*. Tehnika Elektrotehnika, Beograd, 2014; Vol 3: pp. 537-541. ISSN 0040-2176

13. Jevtić BR. *The simulation of sanitary objects evacuation-an example of hotel radon in Niška Banja*. Tehnika Elektrotehnika, Beograd, Serbia, 2015; Vol 3: pp. 545-550. ISSN 0040-2176,

14. Hasofere AM, Beck VR, Bennetts ID. *Risk Analysis in Building Fire Safety Engineering*. Elsevier, 2007.

15. Furness A., Mucket M. *Introduction to Fire Safety Management*. Elsevier, 2007.

Contact: Dr Radoje Jevtić, ETŠ „Nikola Tesla“ (School for electrical engineering “Nikola Tesla“), Aleksandra Medvedeva 18, 18000 Niš, Srbija, Phone: +381 63 759 019 3; +381 80 28 162, E-mail: milan.jvtc@gmail.com