The Simulation of Sanitary Objects Evacuation - an Example of Hotel "Radon" in Niška Banja

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Object evacuation is one of the most important, the most responsible and the most complex tasks for human safety in objects generally. This is especially important for objects with lot of humans, such as health facilities, high residential objects, hotels, schools, etc. This is still an open and ongoing problem which can be confirmed by many injured people who were not evacuated in the disasters. This paper has written to show the possible evacuation situation and calculate minimal time for evacuation in case of Hotel Radon in Niška Banja, as one specific health facility with hardly moving and immobile patients.

Key words: Evacuation, Simulation, Sanitary objects

1. INTRODUCTION

The prediction and projection of evacuations routes presents one of the most important tasks in object projecting and realization. The evacuation term, generally, presents the safest, shortest and fastest way of moving for people, animals and material properties from endanger object or location to the secure place. At the other side, this ways should provide possibilities for safe and fast approach for fire and medical services. There are many different causes for evacuation: fire, gas, bomb threat, earthquake, overflow, civil disorders etc. An example of fire in high building as an evacuation situation is presented on figure 1.

Figure 1 - An example of fire in high building (building The Torch in Dubai, 21.02.2015, source: <http://faktor.ba/pozar-zahvatio-neboder-u-dubaiju-izgorjelo-60-spratova-foto/>)

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According to the cause of evacuation, the proper strategy of projecting would be realized. The explorations on the field of evacuation in case of fire started in the late seventies of the XX century and that explorations were caused by several catastrophic disasters. Unfortunately, lot of situations showed that there was no absolute safe evacuation in sense of human lives preservation and confirmed the fact that this area has to be constantly improved.

Evacuation of objects with lot of humans inside in case of fire presents especially case in the evacuation problematic. These objects comprise high buildings, hotels, schools, hospitals and similar object, very often with huge dimensions. These are facts that significantly can complicate projecting and design of evacuation routes and, if they don't realize correctly, directly harm safety of humans inside them.

The object evacuation should be fast, rational, 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.

One particularly interested aspect according to object evacuation is panic and stress affects to the occupants. It is well known fact that calm occupants have bigger chances to leave the determinate object than occupants influenced by stress and panic. In panic and stress situations, occupants move faster but chaotic. That implies many unexpected situations in object. Evacuation routes in object have its own maximal occupant flow. That is especially important for stairs and elevators. Very often case is, that in the state of panic and stress, occupants shrilly try to get out from the object and cause tragedy. The influence of stress and panic could have terrible consequences on occupant's lives in case of object evacuation. These facts are very important in projecting of potential evacuation routes. The occupant's behavior, knowledge and education, physical and psychic condition (occupant speed, panic and stress influence, moral and human qualities) should be studied in details.

The successful object evacuation and saving of human lives and material properties can be significantly improved in early stage of disaster, for example in early stage of fire or in early stage of overflow. That implies the using of different modern monitoring types, sensors, information technologies, connection instruments and other necessary things that were defined by proper standards and laws. Very important fact for successful evacuation is that disaster should be discovered in its early stages. This is especially important for object evacuation in case of fire. All these exposed facts show that the object evacuation must be realized on proper, laws and standards regulated way no matter on its financial aspect [1, 5].

2. SIMULATION PROGRAM PATHFINDER

The accuracy and correctness of the evacuation route project could be checked by proper simulation software. 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). 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

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 [6].

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.

3. SIMULATION MODEL

Hotel Radon is one 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, kinezoterapija 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 a 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 electrotherapy, 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, Ro 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 contains 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 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. Hotel Radon in Niška Banja is presented on figures 3, 4 and 5 [7].

Figure 3 - Hotel Radon in Niška Banja, front side

Figure 4 - Hotel Radon in Niška Banja, back side

Figure 5 - Hotel Radon in Niška Banja, lateral side (pictured from hotel's terrace)

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 363 occupants was in fact that the maximum of hotel's capacity is 300 beds and the presumption was that each of them was occupied. The limits of this paper don't allow to present every of them, but, some of them are presented in table 1.

Table 1. Some specifications used in 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	3
Number of possible exits	6

The simulation model of Hotel Radon in Niška Banja, in Pathfinder 2012 program is presented on figure 6.

Figure 6 - Hotel Radon in Niška Banja, Pathfinder 2012 presentation

4. SIMULATION RESULTS

The simulation of hotel occupant's evacuation was realized for five scenarios. The reason for that was in fact that different types of patients don't have the same

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 0,75 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 0,6 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 0,5 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 0,3 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 the basement didn't have to use the elevators (swimming pool and wellness centre). Some scenes from the first scenario are presented on figures from 7 to 12, while the complete simulation results were presented on figure 13 [8, 10].

Figure 7 - An example of the simulation for the first case scenario at the start of the simulation

Figure 8 - An example of the simulation for the first case scenario in the 44,8 second of the simulation

Figure 9 - An example of the simulation for the first case scenario in the 96,6 second of the simulation

Figure 11 - An example of the simulation for the first case scenario in the 206,4 second of the simulation

Figure 10 - An example of the simulation for the first case scenario in the 161,3 second of the simulation

Figure 12 - An example of the simulation for the first case scenario in the 412,6 second of the simulation

Figure 13 - Complete simulation results for every of five scenarios

5. RESULTS DISCUSSION

Realized simulation results for presumed evacuation conditions showed that with foreclose proper

behavior, evacuation of all occupants were possible without jams. The foreclose proper behavior meant that, according to the evacuation plans that were

positioned in hotel, occupants from every floor, randomly overtaken persons and personal had their precise evacuation routes to noted exits. It could be seen that, in the fifth scenario, there was slightly jam which was quickly resolved. Because of its great healing potentials, it is very real situation that hotel Radon in Niška Banja will be filled almost completely in the most time of the year. It was also obvious that, in the case of evacuation procedures irrelevance, cases with jams and much longer time for occupant's evacuation from the hotel would be very often. It is very important to note that simulation of similar objects realized results that could be compare with realize results in this paper [11, 12].

6. CONCLUSION

Analyze of evacuation times and evacuation routes using proper software is very effective because it gives good presentation how available evacuation routes could be used for different accidents (fire, earthquake 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 [13, 14].

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REZIME

SIMULACIJA EVAKUACIJE ZDRAVSTVENIH OBJEKATA - PRIMER HOTELA "RADON" U NIŠKOJ BANJI

Evakuacija objekta je jedan od najvažnijih, najodgovornijih i najkompleksnijih zadataka vezanih za sigurnost ljudi u objektu generalno. Ovo je posebno važno za objekte u kojima ima dosta ljudi, kao što su zdravstveni objekti, veliki stambeni objekti, hoteli, škole itd. Ovo je uvek otvoren i aktuelan problem što može biti potvrđeno mnogim unesrećenim ljudim koji se nisu evakuisali u katastrofama. Ovaj rad je napisan da pokaže moguću evakuacionu situaciju i izračuna minimalno vreme za evakuaciju u slučaju hotela Radon u Niškoj Banji, kao specifičnom zdravstvenom objektu sa pacijentima koji se slabo kreću ili uopšte ne kreću.

Ključne reči: evakuacija, simulacija, zdravstveni objekt