UDC: 725.381:355.58
DOI: 10.7562/SE2019.9.02.04
Original article

RADOJE JEVTIĆ

Elektrotehnička škola „ Nikola Tesla“,
Aleksandra Medvedeva 18,
18000 Niš, Serbia

milan.jvtc@gmail.com

EVACUATION FROM A PARKING GARAGE

Abstract: *Traffic jam in large cities is a frequent problem. A lot of vehicles, the lack of parking space, and old narrow streets are just some of the reasons. Parking garages can partly solve this problem. They can be stationary and modular, with a capacity of several thousand parking lots. Although these facilities are not completely closed, there is still a possibility of fire. Parking garages are designed to be used by a large number of people at the same time; however, in case of fire, those people must leave the facility. This paper has been written to demonstrate the potential evacuation from the parking garage using simulation software.*

Keywords: garage, simulation, fire, evacuation.

INTRODUCTION

A huge number of vehicles in large cities causes traffic congestion and other problems in traffic. Also, due to lack of parking space, the citizens are forced to somehow find or improvise new spaces that can be used for parking. Public parking garages are an effective way of increasing parking space. These garages are often built as half-enclosed or opened multistory structures. They are usually built near the main street, they must have good accessibility and, as much as possible, must be located near the leisure activities and urban amenities. The capacity of the public car garage rarely satisfies the real demands. Parking garages differ in terms of their purpose (public garages and garages of special purpose), building level (in the level, underground and landline) and types of outer walls (opened and closed). The design and building of parking garages is a very complex task conditioned by many different factors, rules, standards and regulations [1].

The history of car garages dated very early in the XX century. One of the earliest multistory car parking was built in the 1902-1903 period, for the London Motor Garage Co. at 33-37 Wardour Street with a capacity of 200 cars. Also, Botanic Gardens Garage in Vinicombe Street, Glasgow, was built between 1906 and 1911 with a typical art deco facade, provided with ramped access to the second floor and a category A listing with Historic Scotland. These garages were built to provide space for parking cars that belonged to residents, see figure 1. [2].

Modern parking garages, in many cities in the world, are masterpieces of architecture, and their capacity, construction, design solutions are, very often, more than impressive. Some of the most famous parking garages in the world are Marina City, Eureka Car Park, Herma Parking Building, BMW Welt, Cordova Parkade, Santa Monica Civic Center, Parkhaus Engelenschanze, Michigan Theater Parking Garage, Umihotaru the Floating Car Park and Autostadt CarTowers.

Figure 1. *Botanic Gardens Garage in Glasgow built between 1906 and 1911(figure source: http://www.parkmark.co.uk/brief-history-of-car-parks).*

As interesting and impressive examples of modern car garages are the Marina City and the Parkhaus Engelenschanze. The Marina City, shown in figure 2, is a mixed-use residential-commercial building complex in Chicago. The building was completed in 1964 and contains two identical towers with a parking capacity of 896 vehicles each.

The Parkhaus Engelenschanze car garage in Stuttgart, Germany, also presents one interesting architecture solution for car parking. It has a structural glass façade, and there is a courtyard with a waterfall and used-glass curtains. This parking garage has six levels for 485 vehicles and a lot of other amusements [3, 4].

Figure 2. *Marina City in Chicago, a modern car garage (figure source: https:// www. popularmechanics.com /cars/g324/worlds- strangest-parking-garages/).*

In Serbia, there are several public park garages in Belgrade and Novi Sad. According to available information, Belgrade has nine parking garages with a complete capacity of 3150 parking places. The parking garage with the biggest capacity is a garage in Obilićev venac street which provides 804 parking places [5]. This parking garage is shown in figure 3.

Figure 3. *Parking garage in Obilićev venac street in Belgrade (figure source: http://www.apartmani-u-beogradu.com / parking-beograd/parking-garaza-obilicev-venac).*

In parking garages, there are lots of vehicles very close to each other; therefore, they increase the possibility of rapid spread of fire which can cause a lot of damage, despite the fact that garages are built of non-combustible materials. The main reasons for that are several characteristics, such as high fuel load caused by the presence of fuel in parked vehicles and a parking structure with one big vertical opening with floors connected by ramp systems. This kind of construction enables fire and smoke to spread more easily.

Fires in parking garages are generally low-frequency events; however, dealing with a fire in a parking garage is not an easy and simple job. The biggest number of these fires was caused by burning vehicles, and fires in storage areas or mechanical rooms. The proportion of human victims and material damage directly depend on the number of occupants in the garage at the moment of fire, the number of vehicles, installed fire protection systems, distance to the fire brigade station, potential garage access points and other important factors [6, 8].

The experience shows that fires in these buildings can produce great material damage, despite adequate and modern systems for fire detection and protection.

In 2018, a parking garage in Liverpool - Echo parking garage suffered a great damage with approximately 1400 vehicles completely destroyed. The fire started inside the vehicle and caused the ignition of other nearby vehicles. Luckily, there were no victims in this accident. There were several dogs in some vehicles, but, according to Merseyside Fire and Rescue Service, they were rescued by fire crew. [9, 10].

On the other hand, the proper response and preparedness to fire can eliminate fire consequences in a very short time. For example, in the fire in the garage at the Green Town Centre, in Beavercreek, in 2013, only five vehicles were destroyed. Also, a good example of proper fire protection is a fire that happened in a parking garage in Fort Lauderdale. According to Fire Officials, the emergency services reacted fast and evacuated the building promptly and the building sustained minimal damages [11, 12].

One of the most important tasks in these buildings is to evacuate humans on time. This means that parking garages must have the appropriate fire detection systems, fire extinguishing systems and strictly defined evacuation procedures.

SYSTEMS FOR FIRE DETECTION AND EVACUATION PROCEDURES

Fire detection systems in parking garages are different in case of an underground parking garage and the parking garage at open space.

In underground parking garages, the presence of exhaust gasses limits the appliance of fire detectors on line heat detectors and carbon monoxide detectors. Those detectors can be installed on the garage walls or at the garage ceiling. The distance between detector lines are in accordance with the rules for point heat fire detectors arrangement and it is 10.6 m (5.3 m covering from each cable side). In cases of open-space parking garages, line heat detectors can be combined with flame detectors, but only with the adequate structural construction - eaves or fence that separates the parking places. The arrangement of line heat detectors in underground parking garage is shown in figure 4 [13].

Structural construction can be made of steel or concrete with the exterior of brick walls. Roofs are usually made using coverlets or glass. As it was shown in the examples, the height of these buildings is several tens of meters. The occurrence of fire in these objects can trigger fire in vehicles, burning fuels or both.

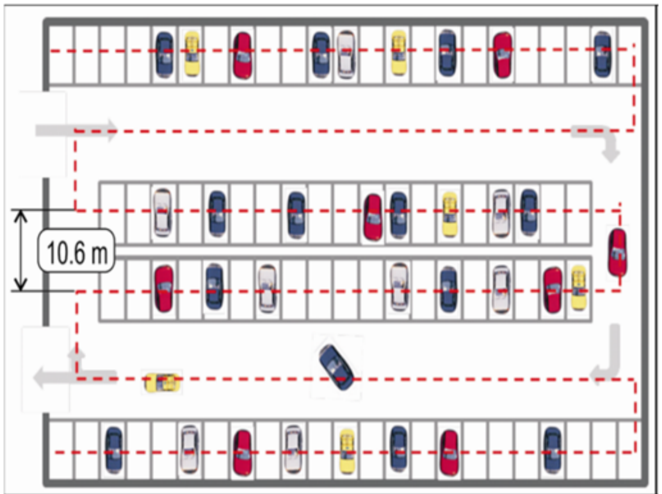

Figure 4. *The arrangement of line heat detectors in the underground garages (source: Fire protection systems designing, Milan Blagojević, AGM Book, Belgrade, ISBN 978-86-86363-89-3, 2018, pp.157).*

The basic task of firefighters is to save vehicles and move them out. For this action, all available firefighters should be engaged and fire engines and all other equipment must be located in a way that they do not block or hinder the evacuation routes. In fire extinguishing process, all the vehicles near the inflamed ones as well as structural constructions and flammable materials around must be protected. Water sprays should be located at the positions where they can reach maximum effect, and at the positions with safe range for firefighters. In such cases, it is advisable to change crews from time to time. For extinguishing of fire, foam, dust, or combination should be used. First, the powder should be used to stop the flame and then foam in order to prevent contact with air and to cool flammable material. When it comes to water, the usage of water sprays and water fog is possible, but it is important to note that the usage of water on car motor parts can cause damage. Because of this, water is usually used for the protection of nearby vehicles in fire brigades' actions.
Sprinkler or drencher systems are often used in parking garages as fire protection systems. These systems can be used for fire extinguishment and at the same time as fire detectors. Depending on the type, these systems can extinguish only part of the garage where the fire occurred (sprinkler) or completely extinguish the fire (drencher). However, one of the most important tasks in case of fire in these buildings is human evacuation. For this purpose, it is recommended to use simulation software as a very effective, economic and safe option for fire prediction [14].

SIMULATION MODEL

The simulation model was designed in Pathfinder simulation software. This software enables calculation of evacuation times from buildings with the option to visualize the occupants. The particular benefit of this software is the possibility to import buildings created in another software (Auto Cad or PyroSim for example) and use them for calculation. For this paper, the Pathfinder 2018 version was used [15].
The simulated building was a garage with a ground floor and additional six floors, with dimensions: 91 m x 21.8 m x 2.8 m. The maximal height of the object was 16.8 m. On every floor, there were 60 vehicles in two columns, which a total of 420 vehicles - the full capacity of the garage. The distance between the two vehicles was 1 m. The dimensions of the vehicles were 4.8 m x 1.8 m x 1.4 m. Floors were connected with stairs for occupants and roadways for vehicles. The length of stairs for occupants was 125 cm, while the length of the roadway was 4 m. The outdoor widths were 2 m. The example of the Pathfinder simulation model of the mentioned car garage is presented in figure 5.

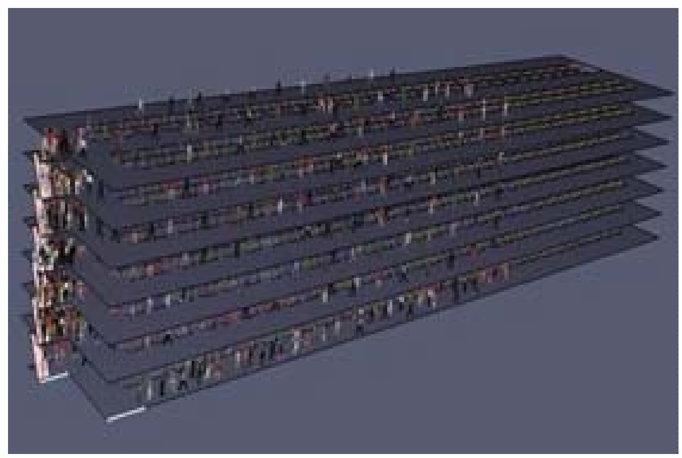

Figure 5. *The Pathfinder simulation model of the car garage*

SIMULATION

The simulation of the evacuation from the car garage involves three potential scenarios. In the first scenario, all the occupants were in their vehicles, which means 1680 occupants total (maximal four in one vehicle). The second scenario involved 840 occupants (50 % of complete occupant`s number) in a car garage and the third scenario involved 240 occupants (14.28 % of complete occupants' number). In each scenario, the arrangement of occupants was uniform all over the garage. The speeds of occupants for every scenario were 1.19 m/s, 1.3 m/s, 1.5 m/s and 1.85 m/s, respectively. These speeds were chosen because they assumed a calm walk of occupants and walk in the state of fear or panic. In addition, there were areas, like stairs, where occupants were not able to walk at a faster pace. Routes, where occupants could go, were stairs and roads that connected platforms for vehicles.

In this paper, the computer used for simulation was Laptop Dell Vostro 3578, processor: Intel Core i5-8250U, 1.6 GHz, 6 MB cash, TDP 15 W; memory 8GB DDR4, 2400 MHz; graphic: Intel HD Graphics 620 + AMD Radeon 520; screen: 15.6 inches; HDD Toshiba 1 TB, 5400 rpm. The complete simulation time was set to 3500 seconds.

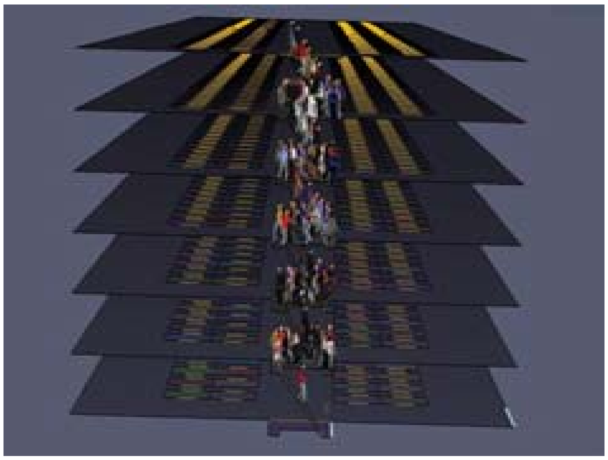

Figure 6. *Simulation after 79.6 seconds for the third scenario at occupants' speed of 1.85 m/s*

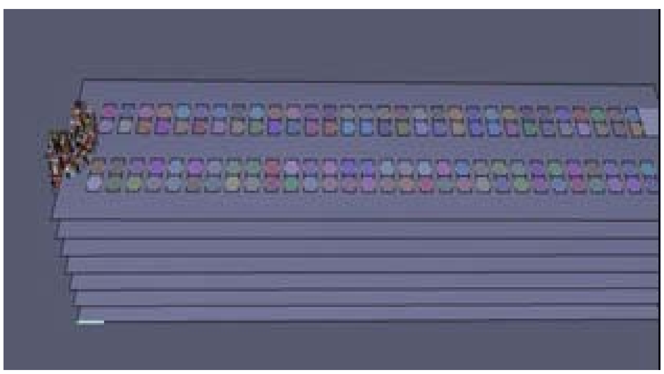

Figure 7. *Simulation after 243.1 seconds for the first scenario at occupants' speed of 1.85 m/s*

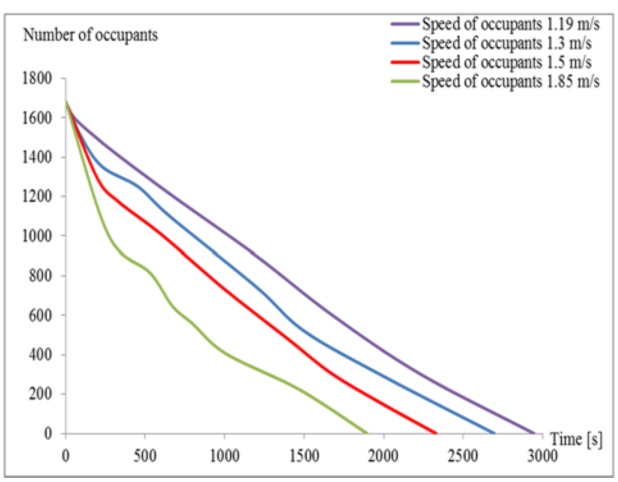

Figure 8. *The complete simulation for the first scenario at different speeds of occupants*

Figures 6 and 7 display a part of the simulations, while the whole scenario with complete simulation results is presented in figures 8, 9 and 10.

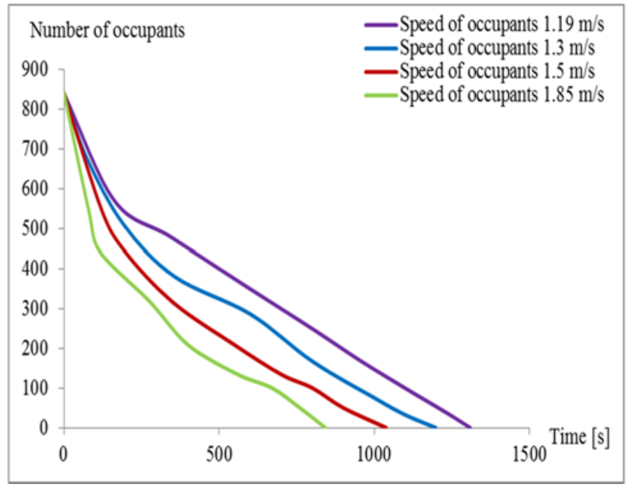

Figure 9. *The complete simulation for the second scenario at different speeds of occupants*

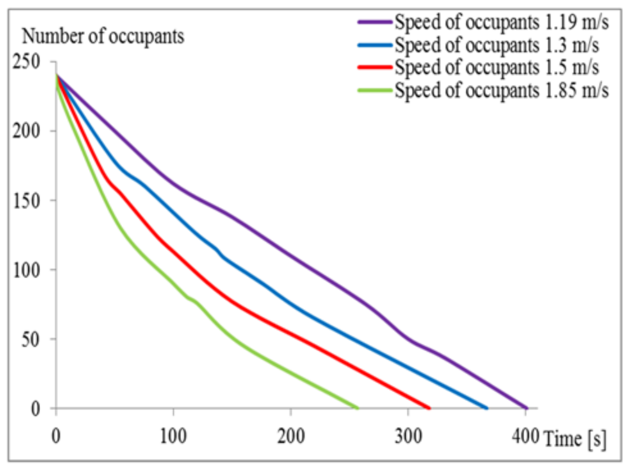

Figure 10. *The complete simulation for the third scenario at different speeds of occupants*

SIMULATION ANALYSIS

The first simulation scenario is a scenario with a very small probability and here it has been used mostly as a theoretical case. Even in cases when a car garage is built as an additional part of another building (a supermarket, an airport, etc.), there is a low probability that all people would be in their vehicles at one particular moment. According to the measurements carried out in July and August in 2018, in daily hours, at the parking garages Zeleni venac and Delta City in Belgrade, the percents of occupants present in the garages at the same moment were from 8.5 % to 19.2 %. Of course, these numbers can vary and depend on many different factors.

The simulation results show that the shortest evacuation time was in the case when the occupants' speed was 1.85 m/s (1895 seconds), while the longest evacuation time was at the occupants' speed of 1.19 m/s (2945 seconds). For every evacuation scenario, the simulations showed final evacuation times. The potential jamming could occur at the occupants' speed higher than 2.75 m/s, which is shown in figure 11.

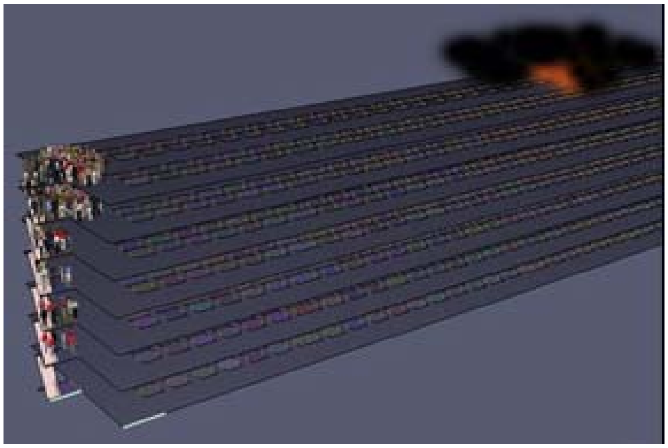

Figure 11. *Potential jamming at occupants' speed of 2.75 m/s in the case of the first scenario of evacuation*

The second scenario showed that maximum evacuation time was in the case when occupants' speed reached 1.19 m/s (1309 seconds) and the shortest evacuation time was at occupants' speed of 1.85 m/s (842 seconds).
The third scenario is the most probable real-case scenario. The maximal evacuation time was again for occupant's speed of 1.19 m/s (401 seconds) and the shortest evacuation time was for occupant's speed of 1.85 m/s (257 seconds).
It is very important to note that all simulations were done when all occupants moved at the same speed, which is almost impossible in reality. Also, each occupant has a unique personality, and it is rather questionable how they would behave under stress, panic or some other mental disorder. Also, in the case when there are one or more occupants with disabilities, the evacuation time and dynamics would be different - for example, the people that need help would move at the speed of about 0.8 m/s; the people who use crutches would move at 0.57 m/s; the mechanical movable chair for invalids would move at 0.69 m/s, whereas the electrical movable chair would move at 0.89 m/s. [16, 17].

CONCLUSION

This simulation software is a very important tool for engineers and designers. Calculation check, the input of new ideas, fast and easy tests and other benefits imply that this type of software should be considered in the design. The special benefit is, of course, its safety. An engineer or a designer does not need to use humans to perform tests of, for example, the evacuation route or behavior of several occupants who move at the same or different speeds. Of course, the knowledge from other disciplines and sciences is needed for proper and successful use of this type of software. This is very important for the development of new algorithms and approaches to the issue of evacuation [18-21].

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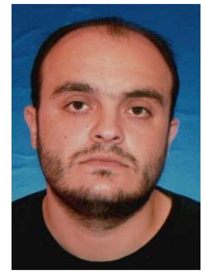
BIOGRAPHY



Radoje Jevtić was born in Aleksinac, Serbia, in 1973. He received a diploma in electrical engineering for automatics and electronics from the Faculty of Electronic Engineering at the University of Niš, a diploma of Magister of Technical Sciences from Faculty of Occupational Safety, and a PhD diploma in technical sciences from Faculty of Occupational Safety, University of Niš. His main areas of research include fire and burglary protection systems, simulations, fire and burglary sensors, etc. He is currently working as a teacher of vocational subjects at Electrotechnical School “Nikola Tesla” in Niš.

EVAKUACIJA IZ AUTO PARKING GARAŽE

Radoje Jevtić
Elektrotehnička škola „ Nikola Tesla“, Aleksandra Medvedeva 18, 18000 Niš,

Sažetak: *Problem zagušenja saobraćaja u velikim gradovima je veoma čest. Veći broj vozila, nedostatak prostora za parkiranje, stare uske ulice su samo neki od razloga ovog problema.Parking garaže mogu delimično rešiti ovaj problem. One mogu biti stacionarne i montažne. Kapacitet garaža može biti veći od nekoliko stotina vozila. Iako se ovi objekti realizuju kao poluotvoreni, mogućnosti za požar postoje. Broj ljudi u garaži u jednom trenutku može biti različit, ali u slučaju požara, ti ljudi moraju napustiti objekt. Ovaj rad je napisan da pokaže mogućnosti evakuacije iz auto parking garaže realizovane simulacionim softverom.*

Ključne reči: garaža, simulacija, požar, evakuacija.