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ANALYSIS OF MOVEMENT OF PERSONS WITH DISABILITIES DURING EVACUATION BY LIFT

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Abstract: Lifts are indispensable for the evacuation of mobility-impaired people from buildings in case of emergency. It is necessary to quantify the movement parameters of these people and describe the entire process using a suitable algorithm. The aim of the research was to quantify the times and speeds of movement for a person using a wheelchair and for an injured person. An experiment in situ was used. During the experiment, arrivals at the lift, cabin entries, and exits were monitored. The results include the times and speeds of a mobility-impaired person's movement. The experiments showed that a person using a wheelchair was slower than an injured person. The results can be used to expand computational models to account for the possibility of using lifts for evacuation.

Keywords: Evacuation by lift, Mobility-impaired person, Time of movement, Lift, Evacuation

1. Introduction

Passenger lifts are not used to their full potential. They are not allowed for the evacuation of people in the Slovak Republic or abroad, with the exception of lifts directly intended for evacuation. Lifts designed specifically for evacuation, i.e. fire and evacuation lifts, also operate during a fire or power failure. However, the legislation of the Slovak Republic [1], requires the inclusion of evacuation lifts in the design of buildings only in rare cases. That is why people are bound to use staircases for evacuation in most types of buildings. For example, a building more than two stories

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high, containing up to ten people with limited movability can be designed without any evacuation lifts [2]. As a result, many buildings (not only in the Slovak Republic) pose a series of challenges for a safe evacuation, mainly due to two reasons - mobility limitations caused by physical impairments of people [3], [4], or fatigue caused by descending stairs [5]. The legislation of the Slovak Republic [6] distinguishes three types of personal mobility. The first group includes people able to move without any assistance. Each person whose mobility is not limited from the health point of view can be categorized into this group. People with limited movability belong to the second group. It includes persons whose evacuation is more demanding than others'. Old people, children, disabled persons with limited movability are some examples of this group. The last, third category comprises immobile people. Persons whose evacuation is only possible with the assistance from other people are categorized into this group. For example, people with mental disorders, in-patients with serious health conditions, infants, and toddlers belong to this group. According to the Statistical Office in Slovakia [7], in 2017, almost 20% of inhabitants were people in the old pension age (62 years and above), and 12% of inhabitants were school-age children (4 to 15 years). In the design of escape routes, at least one-third of the inhabitants of the Slovak Republic can be considered persons with limited movability. Moreover, since 2002 the legislation has required that all public buildings in the Slovak Republic be accessible for people with limited movability and orientation. Therefore, it is essential to design escape routes with due regard to the presence of mobility-impaired people in the building. The number of people with limited movability is determined by the fire safety engineer. As mentioned above, the need to install an evacuation lift increases with the number of people with limited movability. Often, the number of people with limited movability does not exceed the limit of ten. It is thus possible to avoid installing evacuation lifts in the building, which is a more economical solution, as the construction costs are lower. Only passenger lifts will then be used in the design. However, the staircase is the only vertical connection of the floors in the event of a fire or other emergency situation. Evacuation via stairs is difficult for mobility-impaired people, e.g. those using a wheelchair, and practically impossible without the assistance of another person. This is true even if there is only one person with limited movability in the building. During an evacuation, it is not possible to guarantee that people without a mobility limitation will be willing or able to help the person with limited movability. There may occur a situation when a person with limited movability remains alone on a particular floor, unable to exit safely. Therefore, lifts are indispensable for the evacuation of people with limited movability. If people with limited movability use evacuation lifts, people with no mobility limitations do not need to focus on helping others. This will allow the simultaneous and even use of evacuation means, which shortens of the overall evacuation time.

In 2010, Averil [8] defined several steps that need to be taken to cope with serious challenges presented by building emergency evacuation solutions. One of these steps is the quantification of the missing data related to the evacuation of people using lifts. Up to the present day, several papers and studies on the evacuation of people using lifts have been conducted, based on simulated calculations or in-situ experiments. In their paper, Ding N. et al. [9] aimed to ascertain how people behave while being evacuated and factors affecting their behavior during fire and evacuation. They decided to carry out an experiment using simulated conditions of fire, where the lift was used for evacuation of people. In this way, the study was able to obtain data about the time of getting in and out of the lift, time of opening and closing the lift door and the behavior of people during the formation of a queue. According to the results of the study, the time of getting into the lift was shorter than the time of opening and closing the door. They also have ascertained that the number of people being evacuated affects their behavior; however, the presence of smoke does not. The shape of the queue has an influence on the time of the passage of people through the lift door - a curved queue being faster than a straight one.

A study by Ding Y. et al [10] can serve as another example in this field, where simulation software was used to ascertain the ratio between people using the lift and the staircase with the most favorable effect on the course of evacuation. Therefore, in their study, they modeled a 28-storey building with a staircase and two lifts. Their study also included people of different age groups. They claimed that the simulation results show that the optimal percentages of the occupants evacuated by the lifts, when achieving the shortest evacuation time, is almost not related to the number of evacuated persons and floors. Furthermore, when focusing on age groups, it was ascertained that if older people use the lift, the staircase does not get significantly overloaded. Also, if the lift is used by children, its utilization rate is higher. Therefore, the selection of people to be evacuated by lift according to their age groups can reduce congestions on the staircase, and effectively speed up the evacuation process.

Software and computing are an integral part of modern building design. An example of this is the study by Etlinger et al. [11], devoted to elements of active fire protection. Papers by Heyes et al. [12], Kinsey et al. [13] and Jönsson et al. [14] focused on problems related to waiting and they demonstrated that people prefer the use of lifts to staircases for evacuation; however, they are not willing to wait too long for the lift. It is assumed that 90 to 97% of people will not wait longer than 5 minutes. The decision to wait for the lift increases with the increased height of the building - people are more willing to wait for a longer period of time on the higher floors than on the lower ones. In another study that used a simulation tool, Andrée et al. [15] focused on a high-rise building, evacuees' choice of exits and waiting time for evacuation lifts. Their objectives were, inter alia, to examine the effect of the lighting system on the selection of exits, and to quantify the waiting time for the lifts. The study found that good design and simplicity of the escape route marking system has an influence on the selection of an exit. This system can also be used for increasing the portion of people who will decide for the evacuation lift as their first choice of an escape route. Furthermore, their results have demonstrated that people were willing to wait for the lift up to 5 minutes; however, when they decided to wait, their waiting time was usually extended to 20 minutes and more. Safe evacuation does not only concern new buildings but also existing and historic buildings. For example, Horváth [16] dealt with the requirements of reconstructed buildings, in which he also included fire protection requirements.

In general, the process of lift evacuation consists of several phases (*Fig. 1*). As it can be seen in *Fig. 1*, the total evacuation time consists of the movement of the evacuee towards the lift, the movement of the evacuee directly related to getting in/out of the lift, movement of the lift cabin and the movement of the evacuee away from the lift and towards the exit. The movement of lift mechanisms cannot be influenced by a human. Nevertheless, human behavior can affect the time of getting in or getting out, which, during an evacuation, can differ considerably from normal conditions. As a result, in an emergency situation, the entire process of evacuation can be decelerated; for example, people being evacuated do not want to leave the lift cabin, when the signal indicates overloading [9]. Results of previous research have indicated the potential of lifts for the evacuation of people. However, in all aforementioned papers, the authors call attention to the need of the quantification of other movement parameters and description of the entire process using a suitable algorithm that could be used for simple, but also complex calculation models.

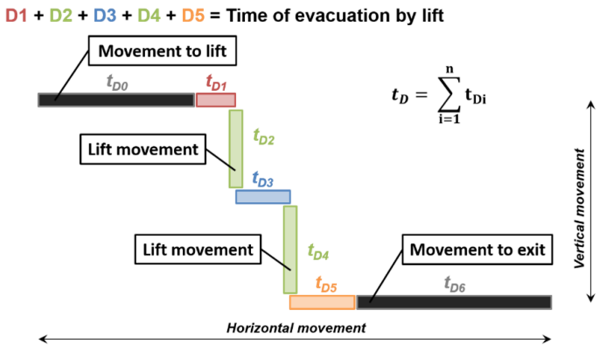

Fig. 1. Evacuation phases

As stated above, approximately 30% of inhabitants of the Slovak Republic can be considered people with limited movability. According to legislation, they should have available accessible evacuation routes that do not prevent their evacuation. Therefore, lifts are indispensable for the solution of evacuation. However, no relevant information on the movement parameters of people with limited movability exists for the assessment of calculations. Therefore, the research focused on the collection of this information, particularly on the quantification of selected phases of evacuation using lifts - the time of movement for people with limited movability. The in-situ experimental method was used for the collection of data, where movements of people were monitored - their arrival to the lift, getting into the cabin, and getting out of the cabin, including leaving the defined area

2. The method used

2.1. Description of the experiment and the scenarios

Ten people participated in the experiment (7 men and 3 women) and imitated the movement of people with limited movability - the movement in a wheelchair and the movement of an injured person (broken leg). None of the participants involved in the experiment had experienced using a wheelchair prior to the experiment. In contrast, three participants confirmed that they had to use a crutch or a support stick at least once in their lives.

Two different evacuation alternatives were examined. In the first alternative, the person with limited movability moved alone, without any assistance from another person. The second alternative included an accompanying person assisting the person with limited movability. In this case, the accompanying person had no movability limitation. This person's task was to push the wheelchair with the mobility-impaired person or to support the person with a broken leg. In all measurements, people displayed evacuation-related behavior; i.e. they moved like in emergency situations. Two passenger lifts were selected for the experiment in the university building - identified as L1 and L2, respectively. The dimensions of the lift cabin L1 are 1.00×1.26 m and the clear width of the door is 0.78 m (*Fig. 2*). The prescribed maximum capacity of lift L1 is 6 persons. The dimensions of the lift cabin L2 are 1.10×1.40 m and the clear width of the door is 0.78 m (*Fig. 2*). The prescribed maximum capacity of lift L2 is 8 persons. A measurable area was marked in front of both lifts, representing the nearest surroundings of the lift where a change in the nature of the movement occurs (slowing down, changing direction and the like). The dimensions of the lift-surrounding areas were determined as 2.35×3 m for the L1 lift and 3×3 m for the L2 lift (*Fig. 2*).

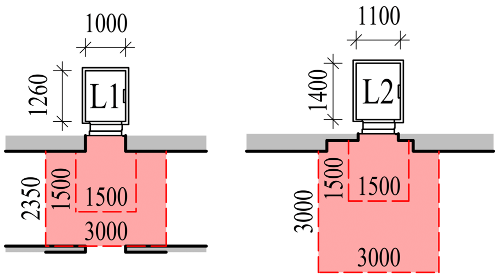

Fig. 2. Scheme of measurable areas and dimensions of lifts L1 and L2

The entire experiment included 8 scenarios that are a combination of all input variables labeled as follows:

- Lift designation: L1 - Lift No. 1; L2 - Lift No. 2;
- Type of mobility impairment: W - Person using a wheelchair; IP - Injured person;
- Number of persons: 1p - one person with a limited movability; 2p - one person with a limited movability assisted by an accompanying person.

All participants performed each measurement 3 times. In total, 720 measurements were taken for 8 scenarios and three monitored phases. A manual wheelchair was used to imitate the movement of a person in a wheelchair. The wheelchair is categorized as a standard wheelchair with a folding frame and a seat width of 0.4 m. Crutches of two different sizes and medical orthoses were used to imitate the mobility impairment of an injured person. These aids were to ensure that the person's leg was fixed to prevent movement and could not be bent in the knee. The fixation represented a broken leg in a plaster cast.

2.2. Description of the experiment

The objective of the measurement was to quantify the time values of the selected phases:

- Arrival at the lift;
- Getting into the lift cabin;
- Getting out of the lift cabin and leaving the lift-surrounding area.

The research only focused on the determination of movement time values. The experiment was conducted under standard conditions. The areas were sufficiently lighted by natural and artificial lighting. No fire products (flame, smoke, etc.) were used in the experiment. The times of the lifts travelling from one floor to another one were not monitored. Therefore, the experiment was carried out only on one floor of the building, where the movements were monitored in particular phases.

Arrival at the lift - time No. 1 'D1' (*Fig. 3*): The time is related to the motion in the marked lift-surrounding area. The procedure was as follows: the person with limited movability was outside the marked area, where he/she started moving towards the lift. Crossing the boundary of the lift-surrounding area represented the beginning of measured time D1. Subsequently, the person moved autonomously across the area in order to get to the lift door with the control panel for opening the door as soon as possible. When near the lift door, the person had to slow down and stop. Finally, he/she had to press the button on the lift panel to call the lift or to open the lift door. The moment of pressing the button represents the end of the measured time D1.

Fig. 3. Selected phases

Getting into the lift cabin - time No. 3 'D3' (*Fig. 3*): This phase included the time of door opening and the time of a person's entrance into the lift cabin. The procedure was as follows: The person with limited movability waited in the marked area in front of the closed lift, ready to open the door. Subsequently, this person opened the lift door by pressing the button on the lift control panel, which represented the beginning of the measured time D3. The person had to wait until the door fully opened, and then he/she could start getting into the cabin. When the person passed through the door and entered the cabin, he/she had to stop near the lift cabin control panel. Finally, the person had to press the buttons located on the control panel to select the exit station and to close the lift door. The moment of pressing the button intended for closing the door represents the end of measured time D3.

Getting out of the lift cabin - time No. 5 ‘D5’ (*Fig. 3*): This period included the door opening time and the time of the person’s exit from the lift cabin and out of the marked area. The person with limited movability was inside the closed lift cabin, ready to open the door. Subsequently, the person opened the lift door by pressing the button on the cabin control panel, which represents the beginning of the measured time D5. The person had to wait for the door to fully open and he/she could start his/her movement outside of the cabin. The person using the wheelchair had to reverse because the cabin size does not provide any wheelchair turning space. When this person got out of the cabin, he/she had to stop his/her movement and to turn by approximately 90° in the direction, in which he/she wanted to leave the marked area. Subsequently, the person started his/her movement and passed through the marked area boundary. In contrast, the person with an injured leg could stand facing the door, because the dimensions of the cabin were sufficient for turning around. Subsequently, the person started his/her movement out of the cabin and passed towards the marked area boundary without a need for stopping and turning. The moment of passing the marked area boundary represents the end of measured time D5.

When the person using a wheelchair was assisted by another person, the movement was provided just by the accompanying person. In the case of the person with an injured leg, the accompanying person provided support during movement. The choice who presses the button was based on the free will of the participants. As mentioned above, times ‘D3’ and ‘D5’ also included the door opening time. The door opening time is 3.45 s for lift ‘L1’ and 3.58 s for lift ‘L2’.

3. Results and discussion

During measurements, the following time values of individual phases were obtained for the person using a wheelchair with/without an accompanying person (*Fig. 4a*), and for the injured person with/without an accompanying person (*Fig. 4b*). The graphs show the mean, maximum and minimum measured time values of the phases.

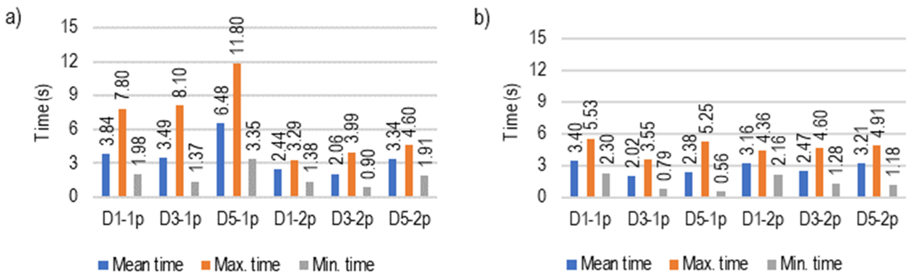

Fig. 4. Mean, maximum and minimum measured times for:
a) person using a wheelchair; b) injured person;
(1p - without an accompanying person; 2p - with an accompanying person)

When measuring the arrival at the lift, the mean time of movement for the person using a wheelchair was longer than for the injured person (*Fig. 5a*; the difference was 0.44 s, 11%). This might have been caused by the fact that the person had to maneuver the wheelchair during movement. For example, in front of the lift door, it was necessary to slightly turn the wheelchair so the person would face the lift. This slowed down the movement. In contrast, the injured person moved straight to the lift, practically without any noticed interruption. The injured person only slowed down when reaching the lift door. The mean time of getting into the lift cabin was longer for the person using a wheelchair than for the person with a leg injury (*Fig. 5a*; the difference was 1.47 s, 42%). This was caused by the fact that the person using a wheelchair had tighter conditions for the passage through the lift door in comparison to the injured person. During maneuvering, some participants on the wheelchair bumped into the frame and the lift door, which slowed them down and sometimes they even came to a halt. The maximum time of 8.1 s for getting in was recorded, when the person stopped at the door for almost 4 s and could not move. In contrast, the injured person could adapt his/her width during passage through the door, facilitating the process of getting in; the maximum measured time value was 3.55 s. The time of getting out of the cabin was 1.5 times longer than the time of getting in (*Fig. 5a*; 4.11 s, 63%). This was caused by the fact that the person had to reverse out of the cabin, stop in the lift-surrounding area, turn, and only then he/she could continue moving towards the marked area boundary. The problems with bumping the frame and the lift door occurred both when getting into and getting out of the lift cabin. Therefore, the maximum time value reached 11.8 s, when the person was nipped by the lift door during the passage through the door. In contrast, the injured person could move practically without any interruption of movement directly to the area boundary – maximum measured time value of movement was 5.25 s. In the case when the mobility-impaired person was assisted by the accompanying person (*Fig. 5a*), the time differences related to the nature of impairment were smaller than in the previous cases. The differences were as follows: in the phase of arrival at the lift the difference was 23% (0.71 s); in the case of getting into the lift it was 17% (0.41 s); in the case of getting out of the lift it was 4% (0.13 s). It is possible to conclude that the mean time values for getting in with an accompanying person are almost the same both for the person using a wheelchair and the injured person. In contrast, there is a significant difference between the mean time values of arrival and getting in with an accompanying person in comparison to a situation when a mobility-impaired person is alone.

The presence of the accompanying person had an influence on shortening the time of movement for the person using a wheelchair (*Fig. 5b*). The difference was 1.40 s (36%) for the arrival at the lift, 1.43 s (41%) for getting into the lift cabin, and 3.14 s (48%) for getting out of the cabin. It was due to the fact that an unassisted person using a wheelchair moves slower. However, an accompanying person can push the wheelchair without any apparent movement problems - that result in higher acceleration, higher speed, and faster deceleration. When getting into the lift cabin, the accompanying person almost always maneuvered the wheelchair without bumping into the frame of the lift door. When getting out of the lift cabin, the accompanying person could reverse more quickly, turn and start walking, pushing the wheelchair.

As it can be seen from the right half the graph (*Fig. 5b*), the presence of the accompanying person has a negative influence on the time of getting in and out of the lift for the injured person. The difference was 0.45 s (18%) for getting into the lift and 0.83 s (26%) for getting out of the lift (*Fig. 5b*). In the phase of the arrival at the lift, the influence of the accompanying person on the movement time of the injured person can be considered negligible, since the difference between an assisted and unassisted movement is only 0.25 s (7%) in favor of the assisted movement (*Fig. 5b*). The main reason is the fact that two persons had to pass through the lift door with a width of 0.78 m, normally, the injured person and the accompanying person walked next to each other. When passing through the lift door, however, both persons had to turn a little, to be able to enter the lift cabin. The crutch hampered movement, for example, it got caught by the door near the floor, and the person had to maneuver it more. It resulted in slowing the movement down. The unassisted persons nearly always passed without slowing down because the width of the door was sufficient for them.

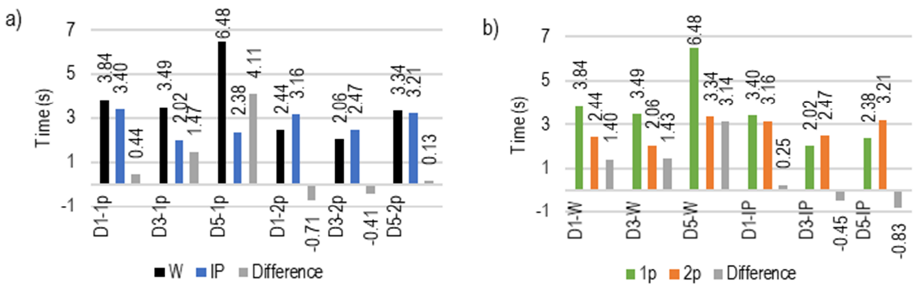

Fig. 5. Comparison of mean times, a) wheelchair (W) and injury (IP); b) one person (1p) and two persons (2p)

When comparing the genders of persons with limited movability, it was ascertained that the mean time of movement of women was longer than the mean time of movement of men, if unassisted (*Fig. 6a*). The maximum difference was 29% (1.43 s) and the minimum difference was 9% (0.20 s). On the other hand, the time of movement of women was shorter than the time of movement of men, if the persons with mobility impairment were assisted by an accompanying person (*Fig. 6b*). The maximum difference was 20% (0.44 s) and the minimum difference was 0% (0 s). The accompanying person declared that pushing and stopping the wheelchair with a woman sitting in it was significantly easier than with a man. Similarly, in case of accompanying an injured person, an accompanying person declared that it was physically more demanding to support a man weighing between 70 and 90 kg than a woman weighing between 50 and 70 kg, due to the transfer of weight from the injured person to the accompanying person.

During measurements, the following values of the movement speed of phase 'D1' were obtained for the person using a wheelchair without an accompanying person and with an accompanying person (*Fig. 7a*), and for the injured person without an accompanying person and with an accompanying person (*Fig. 7b*). The mean speed values were based on movement time values and distances.

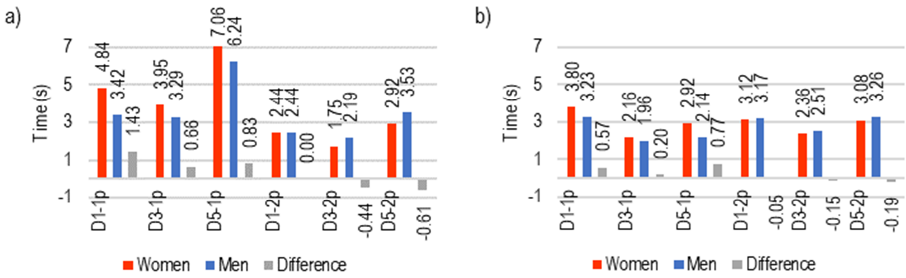

Fig. 6. Mean times for, a) person using a wheelchair; b) injured person;
(1p - persons without the accompanying person;
2p - with the accompanying person)

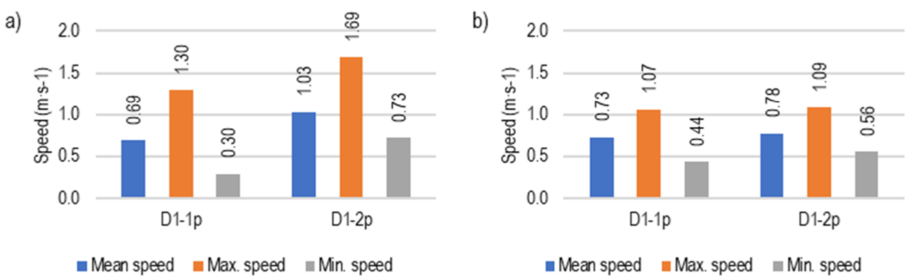

Fig. 7. Mean, maximum and minimum measured movement speed for:
a) person on wheelchair; b) injured person;
(1p - persons without the accompanying person;
2p - with the accompanying person)

Different techniques of movement of persons on wheelchair were observed during measurements. Some persons encountered problems with movement during passage through the door. Therefore, they decided, in their following trials, to grasp the lift door with hands, and to pull themselves into the cabin (*Fig. 8a*). In this way, the person could avoid bumping the wheelchair into the lift door. Another interesting phenomenon was related to the accompanying of a person using a wheelchair during arrival at the lift and deciding which person would press the button on the lift panel. If the button was pressed by the person in a wheelchair, no delay of movement occurred (*Fig. 8b*). In contrast, when the button was pressed by the accompanying person, slowing down by approx. 0.5 to 1 s was observed. This happened because the accompanying person had to stop the wheelchair, pass by it or to lean over it. Only then the accompanying person was able to press the button on the lift panel (*Fig. 8c*).

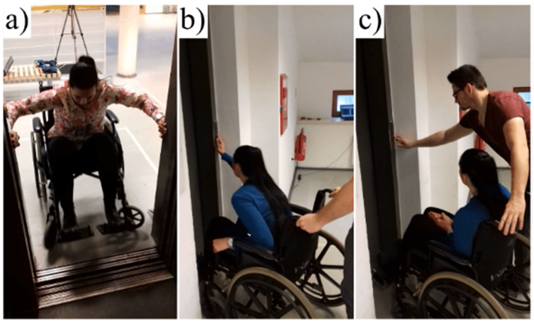

Fig. 8. a) Getting into the cabin using hands; b) the mobility-impaired person is pressing the button; c) the accompanying person is pressing the button

4. Conclusion

The research focused on obtaining the time values of individual phases of movement of mobility-impaired persons. The selected phases were analyzed, particularly the arrival at the lift, getting into the lift cabin and getting out of the lift cabin, the phases of getting in/out of the lift cabin included the times of opening the lift door.

The mean time of getting into the lift in the case of a person using a wheelchair was longer by 42% (1.47 s) than the mean time in the case of an injured person. When getting out of the lift cabin, this difference was up to 63% (4.11 s). If any hesitations occurred during the passage through the lift door, the resulting time was longer in comparison to the mean time by 132% (4.61 s) for the person using a wheelchair and by 121% (4.61 s) for an injured person. It has also been ascertained that the presence of the accompanying person shortened the time of movement for the person using a wheelchair by 48% (3.14 s). However, in the case of an accompanied injured person, the time value increased by 26% (0.83 s).

The time and speed values related to the movement of mobility-impaired persons can be used in designing the escape routes but also as a basis for numerical computational models or for simulation software.

Needless to say, that the research did not completely fulfill the need to quantify data. Many questions related to the evacuation of mobility-impaired people by lift remain unanswered. Future research should include the use of larger lifts (for example for two mobility-impaired persons). It is also necessary to focus on other types of movability limitations. An experiment with the participation of the elderly, children and people dependent on the assistance of others can be an example.

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References

[1] *94/2004 Decree of the Ministry of Interior of the Slovak Republic* laying down technical requirements for fire safety in the construction and use of buildings, Ministry of Interior of the Slovak Republic, 2004.

[2] *STN 92 0201-3, Fire protection of buildings*, General regulations, Part 3, Escape routes an evacuation of occupants, Slovak Office of Standards, Metrology and Testing, 2000.

[3] Dunlop K. E., Shields T. J. Real fire emergency evacuation of disabled people, *Proceedings of CIB W14 International Symposium and Workshops on Engineering Fire Safety in the Process of Design Equivalency*, Newtownabbey, Northern Ireland, 13-16 September 1993, pp. 157–164.

[4] Shields T. J., Boyce K. E., McConnell N. The behavior and evacuation experience of WTC 9/11 evacuees with self-designated mobility impairments, *Fire Safety Journal*, Vol. 44, No. 9, 2009, pp. 881–893.

[5] Averill J. D., Mileti D., Peacock R. D., Kuligowski E., Groner N., Proulx G., Reneke P., Nelson H. E. Final report of the federal building and fire safety investigation of the World Trade Center disaster, NIST NCSTAR 1-7 Occupant behavior, egress, and emergency communication, http://wtc.nist.gov/oct05NCSTAR1-7index.htm, (last visited 28 December 2018).

[6] *STN 92 0101, Structural fire protection*, Vocabulary, Slovak Office of Standards, Metrology and Testing, 1997.

[7] Statistical Office of the Slovak Republic, https://slovak.statistics.sk, (last visited 28 December 2018).

[8] Averill J. D. Five grand challenges in pedestrian and evacuation dynamics, *5th International Pedestrian and Evacuation Dynamics Conference*, Gaithersburg, MD, 8-10 March 2010, pages 1–11.

[9] Ding N., Chen T., Zhang H. Experimental study of elevator loading and unloading time during evacuation in high-rise buildings, *Fire Technology*, Vol. 53, No. 1, 2017, pp. 29–42.

[10] Ding Y., Yang L., Weng F., Fu Z., Rao P. Investigation of combined stairs elevators evacuation strategies for high rise buildings based on simulation, *Simulation Modeling Practice and Theory*, Vol. 53, 2015, pp. 60–73.

[11] Etlinger J., Rák O. Zagorácz M., Máder P. M. Revit add-on modification with simple graphical parameters, *Pollack Periodica*, Vol. 13, No. 3, 2018, pp. 73–81.

[12] Heyes E., Spearpoint M. J. Lifts for evacuation - Human behavior considerations in the use of lifts for evacuation from high rise commercial buildings, *Proc. 4th Intl. Conference on Human Behaviour in Fire*, Cambridge, UK, 13-15 July 2009, pp. 73–84.

[13] Kinsey M. J., Galea E. R., Lawrence P. J. Stairs or lifts? A study of human factors associated with lift/elevator usage during evacuations using an online survey, in: Peacock R., Kuligowski E., Averill J. (Eds) *Pedestrian and Evacuation Dynamics*, Springer, 2010.

[14] Jönsson A., Andersson J. Nilsson D. A risk perception analysis of elevator evacuation in high-rise buildings, *Proceedings of the 5th International Symposium on Human Behaviour in Fire*, Cambridge, UK, 19-21 September 2012, pp. 398–409.

[15] Andrée K., Nilsson D., Eriksson J. Evacuation experiments in a virtual reality high-rise building: Exit choice and waiting time for evacuation elevators, *Fire and Materials*, Vol. 40, No. 4, 2015, pp. 554–567.

[16] Horváth, T. Modernization of modern buildings - Case study on the main building of Széchenyi István University in Gyor, *Pollack Periodica*, Vol. 4, No. 3, 2009, pp. 67–78.