SIMULATING PEDESTRIAN BEHAVIOUR IN SCHOOL ZONES – POSSIBILITIES AND CHALLENGES

Ljupko Šimunović

Associate professor, Faculty of Transport and Traffic Sciences, Zagreb – Vukelićeva 4, ljsimunovic@fpz.hr

Mario Ćosić

Senior assistant, Faculty of Transport and Traffic Sciences, Zagreb – Vukelićeva 4, mcosic@fpz.hr

Dino Šojat[1]

Assistant, Faculty of Transport and Traffic Sciences, Zagreb – Vukelićeva 4, dsojat@fpz.hr

Božo Radulović

Research associate, Faculty of Transport and Traffic Sciences, Zagreb – Vukelićeva 4, bradulovic@fpz.hr

Domagoj Dijanić

Undergraduate student, Faculty of Transport and Traffic Sciences, Zagreb – Vukelićeva 4, 0135238736@fpz.hr

ABSTRACT

As a transport mode, walking often plays an important part in daily trips, especially in terms of multimodality. Pedestrians have a large amount of autonomy, with numerous interactions, individually or in groups. Their behaviour is therefore hard to describe by models. Contrary to motor traffic, where everything is defined by regulations, this field of research also lacks proper legislation. Therefore, regular vehicle traffic models are not desirable to implement when demonstrating passenger behaviour. If the fact that pedestrians have different behaviour in normal and extreme conditions is added, researching pedestrian behaviour becomes even more complex. In traffic engineering, passenger behaviour modelling can be roughly distinguished into two groups – analytical models and simulation models. The analytical models describe walking by mathematical formulas, and simulation models describe it by a series of predefined passenger behaviour norms. This paper will firstly analyse literature to show the current state and possibilities to implement modern tools in modelling individual and collective passenger behaviour. The focus of research is in showing pedestrian behaviour in school zones, for which the PTV Vissim program will be used. The stated tool is ideal for traffic engineers, architects, consultants, managers, and every other person who considers passenger needs in their studies.

Keywords:modelling, pedestrian behaviour, PTV Vissim, school zone, simulation

Introduction

Modelling and simulating pedestrian behaviour by using computer software technology is becoming more demanding challenge for traffic experts. Although walking could be considered as a simple process, it is in reality very complex due to the flexible route choices among pedestrians, or their random behaviour. Within pedestrian flows, there are interactions among pedestrians, and interactions with the environment (surroundings), which results in crowding, reduced pedestrian speeds, and poor road safety. Therefore, to apply the standard models describing vehicle flows would not be acceptable.

1 Corresponding author

Contrary to drivers, pedestrians choose the shortest path to their destinations to save the energy contained in their bodies. Sometimes, they tend to shorten their routes even more by crossing the road instead of using underpasses or overpasses, thus reducing their own safety. The research on this paper focuses on pedestrian behaviour while crossing the road.

Literature overview

There is a high interest for researching walking by using data models, generalized models and structured models in the world literature. However, the models supporting systematic approach to problems related to pedestrian traffic have not been worked out in detail.

A significant contribution to researching pedestrian flows on the macroscopic level was made 50 years ago by Germans Oeding (1963), Sholz (1963) and Reimer (1947), American Fruin (1971), BritainsHankin and Wright (1958) ,and Russian researchers Buga (1980), Roytman (1969), Predtečenski and Milinski (1969). They all used the continuity equation, i.e. using average values of the elementary traffic flow parameters – density and flow, with showing their relations graphically. These models have mostly been used for calculating and designing pedestrian infrastructure, assessing level of service, and as input parameters to simulate pedestrian flows at the beginning.

Microscopic pedestrian flow modelling is significantly younger. This modelling was firstly used by Blue and Adler (1998), Hoogendor (2002), Helbing and Molnar (1995). In microscopic modelling, each pedestrian in the flow is treated individually, with its own traffic parameters such as individual speed, and interactions with other pedestrians and the environment. Pedestrian behaviour also depends on traffc flow composition, cultural background, time of day (Weidmann, 1994), and demographics (Hoogendoorn at al, 2002). As mentioned earlier, microscopic pedestrian flow models are divided into two groups: simulation models and analytic models.

Analytic models were firstly applied by Henderson (1971), who used gas kinetic model (analogous to gas molecule flow) to demonstrate people movement when in crowds. Based on the gas kinetic models, Helbing (1992) used fluid dynamics to describe collective pedestrian movement.

To describe events in pedestrian flows, the simulation models use:

- Cellular automation (CA) models,
- Force models,
- Queuing theory.

Celular automation models were firstly developed and used by Gipps and Marksjo (1985), and later by Nagel and Schrecenberg (1992) and Blue and Adler (2000). The CA models got their name from automatons representing traffic flow entities, i.e. pedestrians crossing between stops in space represented by a square-shaped network. The automatons are artificially intelligent entities capable of calculating opportunities for moving to the next stop.

The magnetic force models was developed by Okazaki, Matsushita (1993) and Okazaki, Yamamoto (1981) to analyse and simulate pedestrian movements in urban areas. In this model, movement for each pedestrian is shown as particle movement in a magnetic field. These kinds of models are suitable to simulate evacuations (to calculate the time necessary for evacuation), standings, movements in queues, etc.

The social force model was introduced by Helbing, Molnar and Schweitzer (1994), and developed and used later by Farkas, Vicsek (2000), Kirlkland and Maciejewski (2003). The flow in this model consists of self-moving particles (granules) representing pedestrians with social forces among them, transmitted by complex mental, psychological and physiological processes. The social force model, upgraded with the route choice model, is a useful tool for urban and suburban planning, describing pedestrian route management, and other social phenomena.

The literature stated above was given to get the insight of the problems, voids and opportunities to develop even more efficient methods for simulating pedestrian behaviour.

Pedestrian flow parameters

To simulate walking dynamics, i.e. pedestrian behaviour in real traffic environment, it is necessary to determine pedestrian flow parameters. Since the simulation was developed in PTV Vissim (which has some pre-determined walking parameters), specific microscopic attributed for each pedestrian will not be considered. Walking in groups were developed from aggregating individual movements. Although each pedestrian decides on goals and the routs, the paper considers a compromise between moving individually and in groups. For example, the goals were mutual for the entire pedestrian group, and speeds were assigned according to age and gender. While moving towards the destinations, pedestrians tend to change directions and speed to avoid collisions with other pedestrians. Due to the complex interactions between pedestrians, the paper used the holistic approach to monitor pedestrian behaviour individually and in groups and the same time.

The speed is the basic parameter to evaluate quality of walking. The pedestrians are moving with different speeds. It was noticed that the speeds on underpass stairs were less than the ones when crossing the road illegally at ground level. When crossing the road illegally, pedestrians adjust their speeds according to traffic (space and time gaps between vehicles and vehicle speed). When vehicles approach, the pedestrians tend to increase their speed. It was noticed that the speeds measured this way were under 1.8 m/s, when the time gap from the approaching vehicle was between two and three seconds. It can be concluded that psychology has a significant role – if the coefficient of psychological influence over the speed in normal conditions is equal to one, then that coefficient is greater than one in illegal crossings (increased pedestrian speed), and the same coefficient is less than one on stairs (decreased pedestrian speed). Figure 1 shows pedestrian speed distribution and cumulative pedestrian speed function when crossing the road illegally atground level.

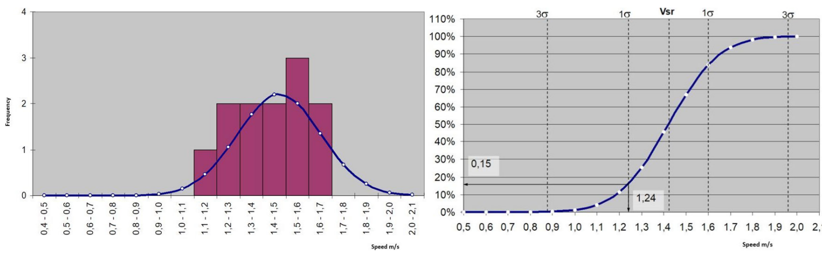

Figure 1: Pedestrian speed distribution when crossing illegally at ground level – normal (left) and cumulative (right)

Figure 1 shows that the 15-th speed percentile is 1.24 m/s, implying that 85 % of pedestrians moves at speeds higher than the mentioned one. The average movement speed (reflecting the general traffic flow characteristics) while crossing the road, obtained by the statistical analysis is 1.42 m/s with 0.18 m/s standard deviation. Since the road has a great width, with a pedestrian island in the middle, pedestrians crossed the road as they were crossing a one-way street – first, they crossed a part of the road, then they stood in the middle island, and crossed the remaining road section if they estimated that the gap in the opposite direction was sufficient. Due to the stated reason and the pedestrian flow structure, travel times were moving between 1.1 m/s and 1.8 m/s.

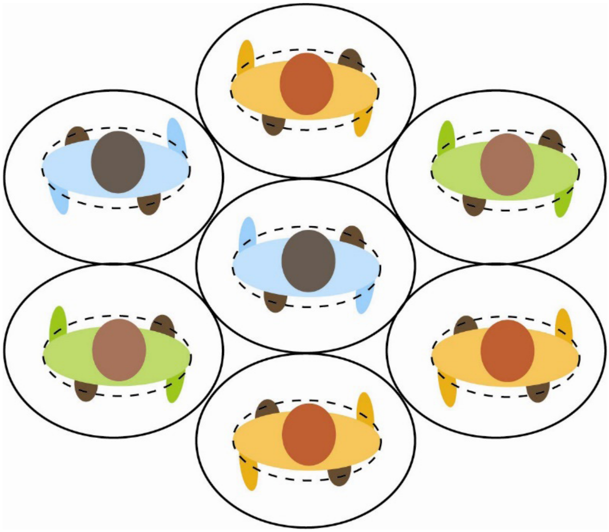

Figure 2: Zones without contacts (Fruin, 1971)]

The space occupied by a moving pedestrian is greater than the space occupied by a standing pedestrian. There are several reasons for that effect. To move, pedestrians must have more space to react on sudden stops, accelerations or decelerations of passengers in their surroundings, and because of leg movements, body movements and hand movements. Minimum required space for a pedestrian is 0.15 m2. This results in maximum pedestrian density of 6.6 pedestrians/m2 (Fruin, 1971). The observed passenger densities in this research were not above 1 pedestrian/m2, making the density negligible. By Fruin (1971), it is estimated that physical contacts with other pedestrians can be avoided if the space occupied by one pedestrian is greater than 0.7 m2 (density below 1.4 pedestrians/m2), which is equivalent to a surface covered by a typical open umbrella (Figure 2).

Simulation experiment

Simulation pedestrian behaviour while crossing the road was made in the simulation tool PTV VISSIM. The PTV VISSIM, and its module, VISWALK adjusted for simulation pedestrian traffic, is one of the most prominent piece of software for this type of problem, next to AIMSUN and its module LEGION.

Pedestrian behaviour observing was made at several locations in the City of Zagreb. Figure 3 shows the intersection of Ivan Lučić Street and Čazmanska Street, which was used for research within the National Road Safety Programme 2011-2020 of the Republic of Croatia, which will be used as an example for demonstrating the simulation experiment.

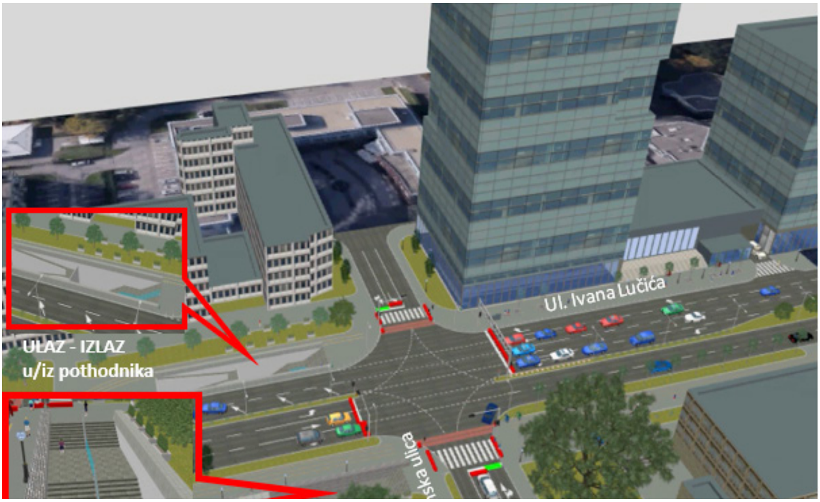

Figure 3: The location of passenger flow observation – PTV VISSIM

Ivan Lučić Street has four lanes, two for each direction and additional left-turn lanes, with total width of 23 meters in the intersection. Both sides have pedestrian sidewalk 2 meters wide, making the roadway 27 meters wide. Čazmanska Street is two-way, with three lanes, and its width is 9 meters. To cross the intersection, it is possible to use the underpass 51 meters long. The vehicles passing the intersection were counted, and vehicle intervals and the proportion of pedestrians crossing the intersection illegally (pedestrians cross the intersection when there is an acceptable vehicle gap) and the proportion of pedestrians using the underpass were analysed. The key output data for evaluating pedestrian behaviour while crossing the street are walking time and time lost for waiting.

To analyse pedestrian movements while crossing the road and their interactions with the vehicles, it was necessary to establish the map of the environment in GIS with barrier markings. After the analysis, origin-destination points (where the pedestrians come from and go to) were determined, with waiting areas to draw a path diagram. Walking speeds were used to calculate movement times, and the time necessary to spot the favourable conditions to cross the intersection illegally based on traffic flow (Figure 4).

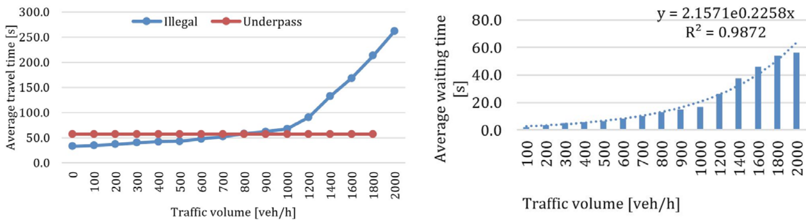

Figure 4: Average pedestrian times –travel time (left) and waiting time (right)

The times in this manner were obtained for the entire pedestrian group (30 pedestrians). Minimal travel time over the illegal crossing was 33.2 seconds per pedestrian. The favourable situations for illegal crossing depended on gaps occurring in motor vehicle flows. It was determined that the gaps in vehicle flow occur following the exponential distribution.

Discussion

Evaluating pedestrian behaviour when crossing the street was based on walking time and time lost for waiting. Based on these two parameters, it was estimated which vehicle flow conditions will make the pedestrians cross the intersection by using the underpass (a safe solution) or to cross the intersections illegally (an unsafe solution). When motor vehicle volume is low (below 800 veh/h in one direction), a lot of favourable gaps for road crossing are usually created in the flow, and using these gaps, almost every passenger cross the intersection illegally, exposing himself or herself to danger. Below traffic volume of 800 veh/h, total time to illegally cross the road for the group of 30 pedestrians is 57.4 seconds per pedestrian, equal to time for crossing it by using the underpass. It was concluded that a large proportion of passengers (10 – 15 %) cross the intersection illegally, independent of motor vehicle volume – most of them were the young people. According to the facts determined on the site, the pedestrians will cross the intersection illegally when the estimated time loss for their waiting is less than 15 %. By observing the illegal crossings on the narrow Čazmanska Street, it was determined that the number of illegal crossings rises to somewhere between 20 % and 30 % related to underpasses. However, if the illegal crossing takes significant amount of time (depending on motor vehicle density), the number of pedestrians crossing the intersection illegally is gradually reduced.

The stated above could result in the statement that pedestrian safety is less important when making decisions on crossing type. However, pedestrian safety while crossing the road also depends not just on road width and traffic volume, but also on time of day, route directness, energy consumption, and the reasons for travelling. For the people rushing to their work, travel time is most significant, so they will take the risk of crossing the road illegally, cutting themselves some time. People who travel for shopping are willing to take longer paths, or to wait for longer gaps when crossing illegally. The answer to the problem with pedestrians and underpasses lies also in energy consumption (pedestrians lose more energy on stairs and in the passage). All stated variations cannot be simulated in VISSIM, because the basic parameters used by VISSIM are density, speed, walking time, and waiting time.

Conclusion

There is a significant number of simulation software intended for specific transport problems such as PC CRASH, which analyses road accidents or PTV VISUM for traffic planning; however, there is currently no universal computer software for each area, and thus, a program for a complete pedestrian behaviour simulation. This paper presented an idea to use PTV VISSIM software to simulate pedestrian behaviour while crossing the road. There are numerous open problems of the software to be used for pedestrian simulations such as joint optimization of time losses for pedestrians and vehicles, problems related to the possibilities for improving road safety, etc. The stated problems are open for further research, and due to the shortage of efficient tools, this is a major challenge for traffic experts.

Acknowledgement

The paper is a part of the project Child pedestrian safety in school zones, financed by the National Road Safety Programme 2011-2020 of the Republic of Croatia.

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