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The application of microscopic models in the study of pedestrian traffic

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Abstract. Cities (especially in Central and Eastern Europe) focus on improving the road network, which aims to improve the efficiency of motor traffic and minimize congestion. Most of existing tools for analysing the effectiveness of urban transport networks do not assume to analyse the impact of walking and cycling on efficiency of transport systems. It is therefore necessary to develop solutions that on the one hand will reduce congestion, and on the other hand, improve the safety and quality of travel of vulnerable road users. One of the tasks to be developed in order to improve pedestrian conditions is to determine the relationship between pedestrian and vehicle traffic. An attempt has been made to establish the relationship between pedestrians and vehicle traffic in order to describe traffic conditions and pedestrian safety at pedestrian crossings. The analyses were based on simulations carried out using the PTV Vissim/Viswalk software and with the use of surrogate safety measures.

1 Objectives

Pedestrian crossings are designed to help pedestrians cross a road. There are at-grade pedestrian crossings with or without traffic signals and grade separated crossings such as subways and footbridges. Pedestrian crossings may be located next to a junction or on road sections between junctions. Where at-grade crossings are involved, pedestrians and motorists interact, which may lead to dangerous situations and road traffic conflicts [1,2]. These mutual interactions between infrastructure users determine how pedestrian crossings operate. They also affect the operation of junctions, if they are next to them.

Car ownership in many cities (including Poland) currently exceeds 500 - 600 vehicles per 1000 inhabitants. Walking and cycling can play an important role in facing urban challenges such as local air pollution, health and energy consumption. Pedestrians make up from 11 to 25% of trips in Western European countries [3]. Poland is one of the most dangerous and the least pedestrian-friendly countries for the road users [4]. Increasing pedestrian protection should therefore become a priority. However, there is no systematic study of the pedestrian risks in urban and non-urban areas in Poland. One of the tasks that need to be done to for better safety of road users is determining the place of occurrence and causes of conflict situations between pedestrians and vehicles at the pedestrian crossing to improve the level of

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safety an efficiency of traffic participants. It is therefore necessary to introduce solutions that will, on the one hand, reduce congestion and, on the other, improve the safety and travel quality of vulnerable road users. Microsimulation tools like PTV Vissim / Viswalk can be used in pedestrian and vehicle interaction studies and provide data for safety analysis using surrogate safety measures.

The research took into account different types of pedestrian crossings in Poland:
- typical pedestrian zebra crossing
- with central refuge island and humps before crossing to protect pedestrians
- pedestrian zebra crossing on double carriageway road.

Field studies were carried out at pedestrian crossings with traffic signals and without them, however, the final analyzes focused on crossings without traffic signals.

2 Methodology of research

Field studies allowed to obtain the most reliable observation data. The study included:
- inventory of pedestrian crossings to determine the average length of pedestrian crossings;
- video recording of pedestrian behaviour;
- measurement of walking speed;

One of the tasks that need to be done to improve pedestrian conditions is to determine the relationship between pedestrian and vehicle traffic through analysis gap accepted, capacity of pedestrian crossing, pedestrian and vehicle speed, safety of road users, time delay, conflict situations on the crosswalk. The obtained data were used to calibrate the microsimulation model (PTV Vissim and Viswalk) and the control sample to verify it. After the calibration, micromodel was used to analyze wider range of traffic parameters and used in Surrogate Safety Assessment Model to analyze conflicts situation between pedestrians and vehicles. The parameters that were analyzed and are presented in the article, are pedestrian delays and traffic conflicts.

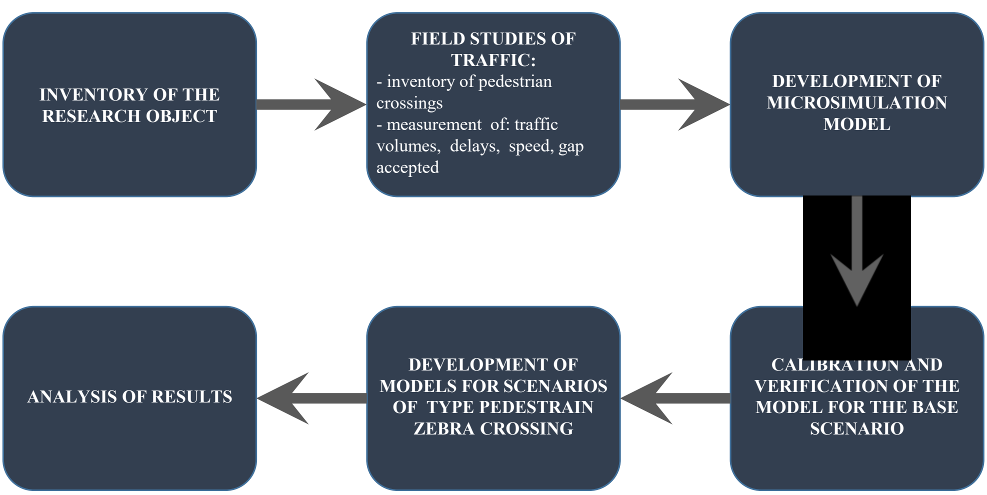

Fig. 1. Methodology of the study.

Parameters of road traffic and the behavior of road users, which allow identification and assessment of changes affecting road safety and efficiency are referred to as surrogate safety measures. Surrogate safety measures have their origin in traffic conflicts. The traffic conflicts technique is a methodology for field observers to identify conflict events at intersections by watching for strong braking and evasive maneuvers. Surrogate safety measures can be also estimated with help of microsimulation techniques [5]. The model developed in PTV Vissim enabled to obtain information on the trajectory of each vehicle in traffic flow. Data are stored in the form of x, y coordinates and a time marker. Trajectories analyses were carried out using the Surrogate Safety Assessment Model [6]. The model allows to automate the analysis of conflicts by processing the trajectory of the vehicle obtained from the microsimulation model made in PTV Vissim and Viswalk. Surrogate safety measures values observed during the conflict are determined. Estimates are based on the current location, speed and trajectory of two vehicles at a given moment [7].

The following surrogate safety measures were estimated (Fig.2):

- Time to collision (TTC)
- Post-encroachment time (PET)
- Deceleration rate (DR)
- Maximum of the speeds of the two vehicles involved in the conflict event (MaxS)
- Maximum relative speed of the two vehicles involved in the conflict event (DeltaS)
- Conflict point or conflict line line location
- Vehicle speed difference - DeltaV (MaxDeltaV).

It has two main thresholds to define vehicle-to-vehicle conflicts. One is time-to-collision (TTC), with a default value of 1.5 seconds, and the other one is post-encroachment time (PET). The results would be displayed in a table representing number of conflicts.

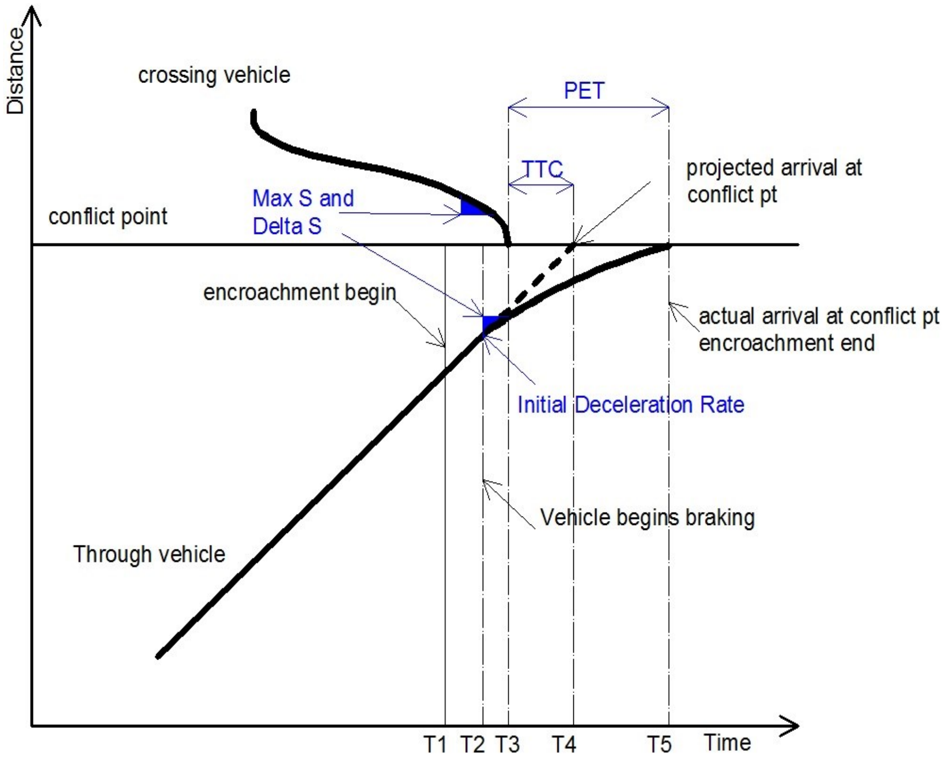

Fig. 2. Surrogate safety measures for vehicles with conflict manoeuvres [4].

3 Results

The difference in time between the situation while a pedestrian walks freely to the intended destination and the situation while getting the destination requires additional expenditure of time, resulting from the impact of other vehicles or pedestrians can be considered as delays. Vehicle (DTv) and pedestrian (DTp) delays were analyzed with use of microsimulation model. Vehicle volumes (Qv) up to 2000 [veh/h] every 100 [veh/h] and number of pedestrians (Qp) to 2000 [ped/h] were taken into consideration. Drivers are reluctant to give the way to pedestrians waiting for the passage through the crossing in Poland. It may be the result of legal provisions in which the driver is not obliged to give way to the pedestrian until the pedestrian does enter the zebra. It was reflected in the model by defining behavior within the pedestrian crossing. Results from the simulation analysis are shown in Fig. 3 and Fig.4. At high pedestrian number, groups are more likely to cross the roadway, and their delays are lower. At the level of 800 vehicles in two directions the delays of pedestrians are comparable regardless of the number of pedestrians at the crossing. At higher values of vehicle traffic intensity, the more pedestrians the less their individual delays which do not increase with higher traffic volumes. In the case of motor vehicles we can observe the opposite trend [8].

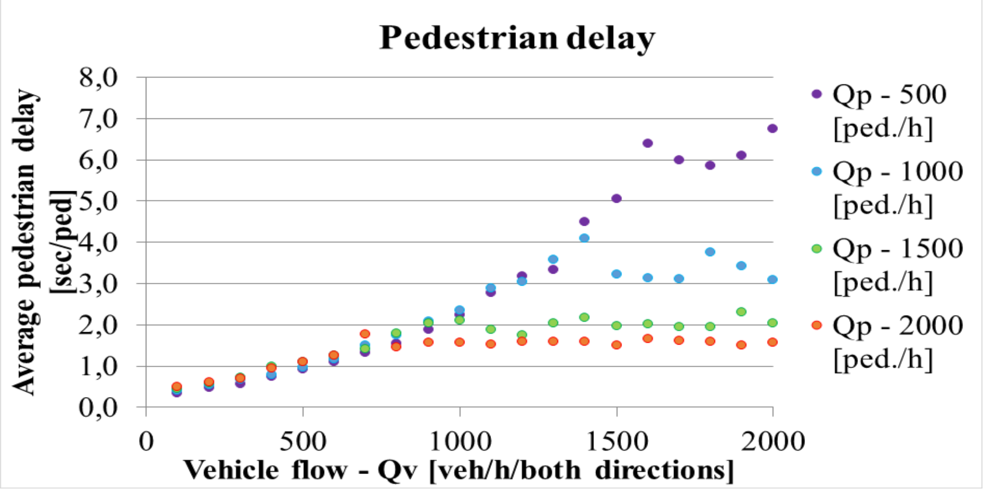

Fig. 3. Pedestrian delays [6].

Model (Fig 4) shows the impact of pedestrian numbers and vehicle traffic volume on vehicle delays:

$$TD_v = Q_p * (-6{,}1 * Q_v^2 + 20{,}9 * Q_v) - 1{,}8 \tag{1}$$

where:
TD_v – Delay Time of vehicle [sec/veh]
Q_v – Vehicle traffic volume [thousand veh/h]
Q_p – Pedestrians volume [thousand ped/h]
a,b,c – parameters, for P<0,05 and R2= 0,872 estimated values of parameters:
a= -9,427; *b = 26,279*; *c = -3,021*

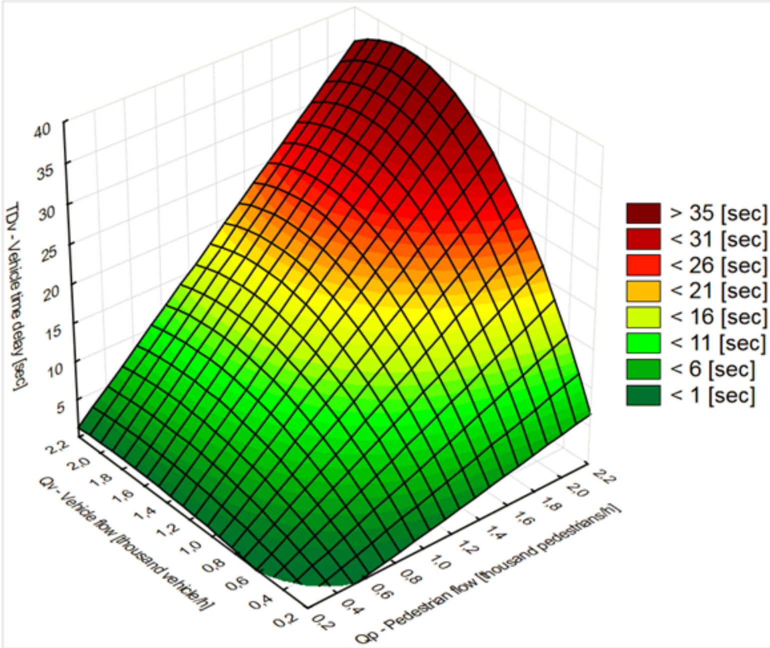

Fig. 4. Vehicle time delay [6].

To complement the analysis, the Conflict Technique is used which, to a large extent, shows the risk of a pedestrian being involved in a road accident. As part of the conducted research, the number of conflicts was compared depending on the type of street cross-section (Fig. 5) and different volumes of vehicles.

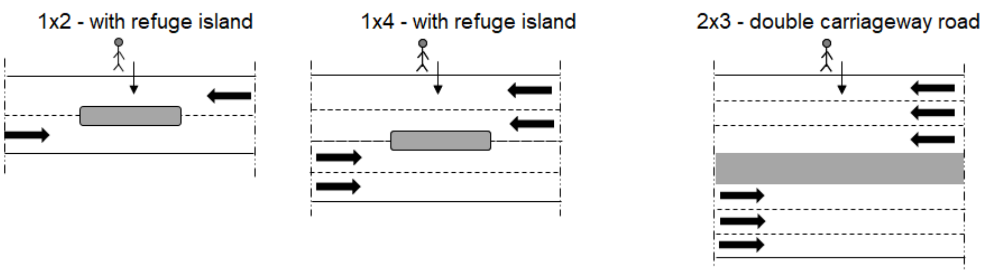

Fig. 5. Analyzed types of road cross-sections.

On the basis of tests carried out with the use of the Surrogate Safety Assessment Model, it was observed that the type of street cross-section and the volume of vehicles has an impact on the number of traffic conflicts between pedestrians and vehicles. Among the analysed cross-sections, the greatest number of conflicts occurred on long pedestrian crossings (cross-section 2x3). This is the result of a large area of pedestrian crossing determining the greater number of possible points where crossing trajectories of pedestrians and vehicles may occur. Number of conflicts at cross-section 2x3 was about three times higher than on the section 1x4 at the maximum tested vehicle volume with value Q_v = 1000 [veh/h/traffic lane] and pedestrian intensity Q_p = 1000 [Ped/h]. The lowest number of conflicts (around 10) was recorded at the 1x2 crossing with the refuge island. The research also concerned rear-end conflicts between vehicles. Most of the conflicts were recorded in the case of pedestrian crossing on a road with a section of 2x3, followed by crossing 1x4. The lowest number of conflicts was recorded in the case of a cross-section of 1x2 in the range of the vehicles volume to about Q_v = 800 [veh/h/traffic lane]. For 1x2 cross-section, the number of conflicts turned out to be higher than for the 1x4 cross-section with a higher then Q_v = 800 [veh/h/traffic lane] vehicles volume. This is due to the inability to change the traffic lane to the less congested at given time.

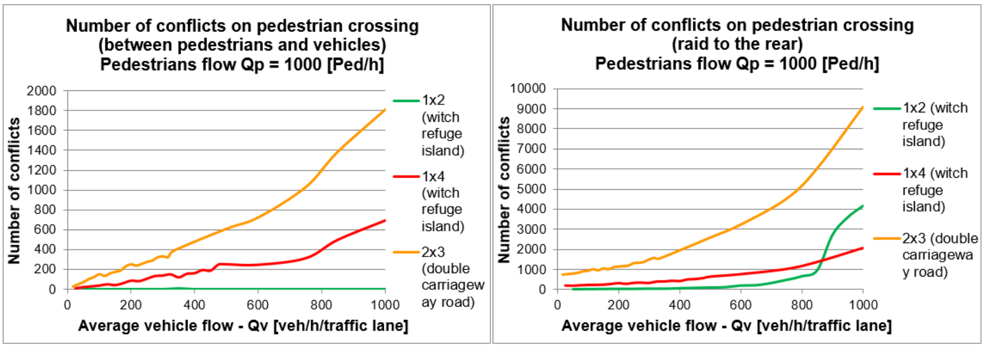

Fig. 6. Left: Number of conflicts (between pedestrians and vehicles), Right: Number of conflicts (rear-end).

4 Conclusion

An example of the application of microscopic models PTV Vissim/Viswalk in the study of pedestrians and vehicles interaction at the pedestrian crossing is presented in this paper. Simulation models included e.g. geometric parameters of pedestrian crossing as well as pedestrian and vehicle flows intensity. Microsimulation tools have been used in the study to determine the impact of pedestrian and motor vehicle traffic intensity on delays of traffic participants and conflicts situation. The analysis can be used to plan the location, size and function of facilities generating high pedestrian traffic in relation to the level of traffic on the roads adjacent to the object / area. Such analysis can also be helpful in determining the places of pedestrian crossings with regard to the location of public transport stops. It should be remembered that high delays of pedestrians' time may affect their impatience and be the reason for entering pedestrians in front of oncoming vehicles (this is violation in Polish legal conditions), which decreases the level of traffic safety. Without a doubt, the law in this area should be changed. Research will be continued to develop recommendations for the type of crossing depending on the forecasted or existing numbers of pedestrians and vehicles.

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