Microsimulation of pedestrian conflict with other transport modes

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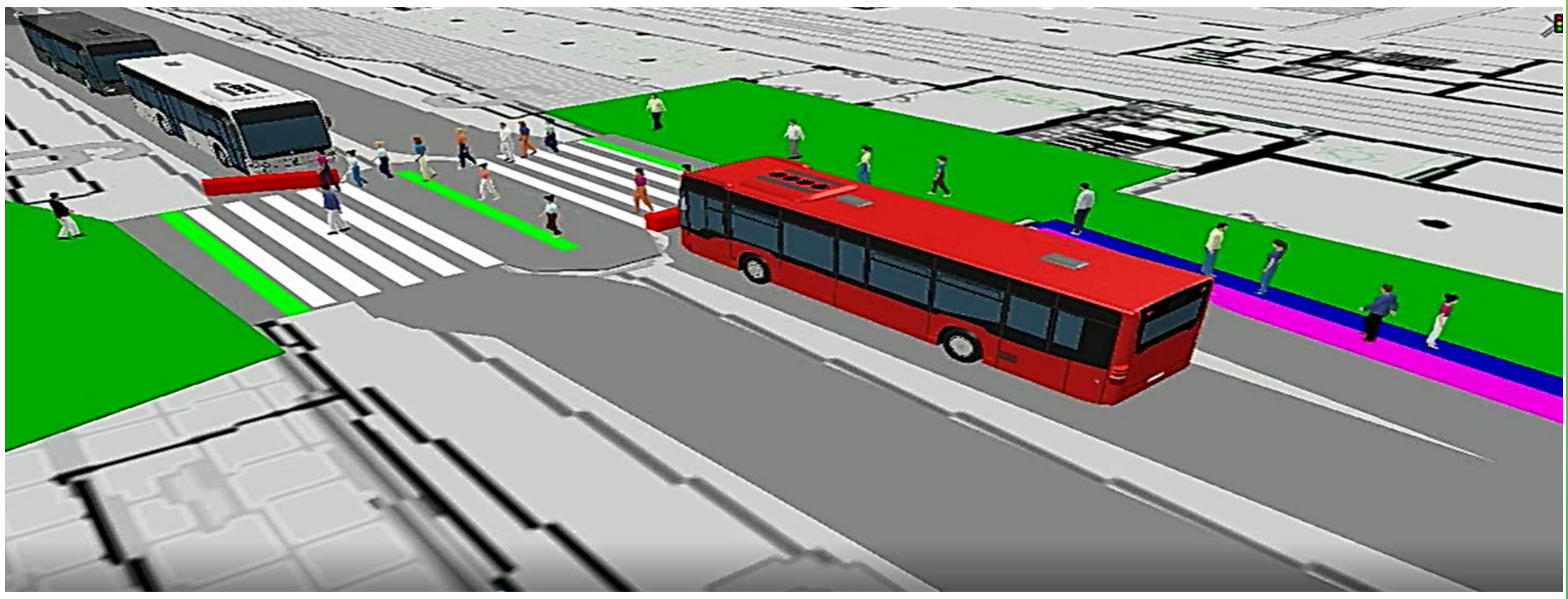
Abstract

An effective solution of the conflict points of different transport modes is a significant issue at the urban level today. With the permanent increase of traffic in cities, it is necessary to look for suitable and sustainable transport solutions to these situations, so that the traffic flow is smooth and the transport remains safe, ecological and economical. The paper deals with the design of a simple decision-making tool for selecting the solution of pedestrian conflict with other traffic modes (classical pedestrian crossing, controlled pedestrian crossing for defined pedestrian and vehicle flows, based on experimental microsimulation. High pedestrian flows their dependence on the delay time of road users are not properly implemented in Czech legislation. The results are verified in a case study of conflict solution within the reconstruction of a public transport terminal in Prague.



Methodology

The research aims to verify by a microsimulation experiment on a model the conflict between pedestrians and vehicles to verify the influence of input values of pedestrian flow exceeding 500 pedestrians per hour and vehicle flow not exceeding 500 vehicles per hour on the values of output variable delay time of pedestrians and vehicles in place before the conflict on classical pedestrian crossing without traffic control. The basic premise is that pedestrians experience minimal delays due to their advantage and vehicles gradually experience greater delays with higher pedestrian and vehicle flow rates. Assuming high pedestrian flows, even lower vehicle flow rates will be sufficient to create vehicle congestion in the model when the pedestrian crossing is handled classically. The purpose of the experiment is to generalize its results for determining the critical values of pedestrian flow and vehicle flow rate in conflict, where it is already appropriate to solve the situation in a different way than with a level crossing for pedestrians, i.e. mainly by traffic lights or extra-level solutions. The model situation has the following setting parameters: The simulation is performed in the PTV VISSIM. The pedestrian crossing intersects a two-lane two-way road with a total width of 8 meters, which is 4 meters wide as standard, the entry of vehicles into the model network is located 400 meters before the pedestrian crossing. The behaviour model is used by Wiedemann 95. The velocity models were taken from the VISSIM program. The entry of vehicles is random, with all vehicles coming from one direction, the entry of pedestrians into the network is also random, and pedestrians come evenly from both directions to the place of conflict. The distribution of pedestrians and vehicles in time is uniform. The combinations of pedestrian and vehicle input flow rates were changed during the simulation and the dependence of pedestrian and vehicle delay time on these combinations was investigated. Verification of these results occurred on a real example of microsimulation of the planned new solution of the "Černý Most" terminal in Prague. Input data were entered into the simulation on the basis of our own traffic survey, the course of which is described in more detail in the chapter with the case study.

Simple decision tool

The dependence of a suitable choice of conflict resolution can be summarized based on our experiments in the form of Table below. The table answers the question for which values of pedestrian and vehicle flow rates it can still be considered in terms of capacity, classical pedestrian crossing ("YES" values) and for which it is already necessary to look for other solutions, such as traffic control or pedestrian bridge ("NO" values).

		Vehicle flow rate					
		0-50	50-100	100-200	200-300	300-500	500 and more
Pedestrian flow rate	500	YES	YES	YES	YES	YES	NOT CHECKED
	1,000	YES	YES	YES	YES	NO	NO
	1,500	YES	YES	YES	NO	NO	NO
	2,000	YES	NO	NO	NO	NO	NO

Discussion and future work

As part of the research, a simple decision-making tool was created, which can serve high pedestrian flows with an easier decision to solve pedestrian conflicts with other road users. Given the assumption that similar conflicts will occur more frequently in larger cities, it might be appropriate to develop a similar tool at a much more detailed level of distinction and to implement it in Czech technical standards or technical requirements. This decision tool was verified in the model of the new terminal solution in the Černý Most case study and it can be assumed that it will be possible to use it for any further solution to the conflict between pedestrians and vehicles if the input flow rates are known. Of course, it is necessary to proceed individually in each case, because for these high numbers of pedestrians to cross two lanes road on crossing in a given time (one minute for controlled crossing) can reduce their safety. In the case of the considered case study, the advantage is the construction of other considered pedestrian crossings through the terminal near the main crossing controlled by traffic lights and the assumption of a slight distribution of pedestrian traffic between other crossings.

Results

The results of the experiment can be read from Table below. The simulation was repeated thirty times for each combination of inputs. For each simulation, a set of delay times of individual vehicles and individual pedestrians before the conflict crossing for two hours was generated and their average value was calculated (using the arithmetic mean). The resulting value, "Average Pedestrian Delay," is then the average of all replicates of the experiment. The value "Number of Unloaded Vehicles Due to Congestion" is then the average value of the number of vehicles that were not loaded into the simulation at all due to the resulting column, which reached the entry of vehicles into the network (greater than 400 meters).

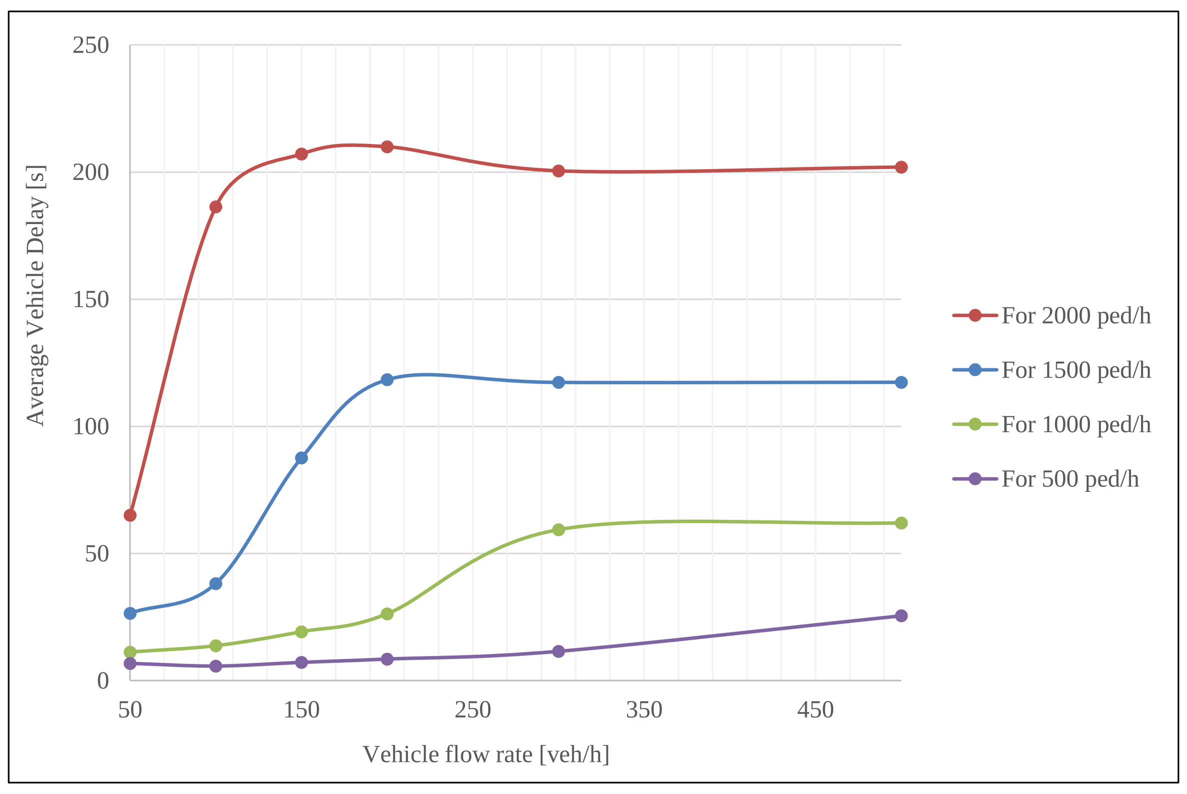
The following summary can be drawn from the experiment. At a given **pedestrian flow rate of 500 pedestrians/hour** and a changing vehicle flow rate in the range of 50-500 vehicles/hour, there is a very small increase in pedestrian delay in the tens of milliseconds and a relatively small increase in vehicle delay from seconds to tens of seconds. It can be stated that at these flow rates the level solution of the pedestrian crossing is stable, although at higher flow rates the level of service for vehicles decreases slightly.

At a given **flow rate of 1,000 pedestrians/hour** and a changing vehicle flow rate in the range of 50-500 vehicles/hour, there is a very small increase in pedestrian delay, but a higher increase in vehicle delay in the tens of seconds range. The increase then stops at values of around 60 seconds, which is because at a vehicle flow rate of 300-500 vehicles per hour, a critical point occurs and the formation of such a long traffic queue that some vehicles can no longer be loaded into the network.

At a given **flow rate of 1,500 pedestrians/hour** and a changing vehicle flow rate in the range of 50-500 vehicles/hour, there is still a very small increase in pedestrian delay, but a high increase in vehicle delay. When the vehicle flow rate exceeds 200 vehicles per hour, a critical point occurs and there is the formation of such a long traffic queue that some vehicles cannot be loaded into the network.

At a given **flow rate of 2,000 pedestrians/hour** and a changing vehicle flow rate in the range of 50-500 vehicles/hour, there is again a very small increase in pedestrian delay in tens of milliseconds as the vehicle flow rate increases, but a high increase in vehicle delay. The critical point when the vehicles could not be loaded into the simulation in this case is 100 vehicles per hour.

The described situation is graphically illustrated in Figure below. At higher pedestrian flows, there is a sharper increase in delay, higher delay values, earlier stagnation of the curve, and at that moment when the curve stagnates, a traffic queue forms in front of the place of conflict. It should be emphasized that the curves for high intensity values converge because some vehicles could not be loaded into the simulation. Otherwise, of course, the residence time would increase to even higher values.



Input: Pedestrian flow [ped/h]	*Input: Vehicle flow [veh/h]*	*Output: Average Pedestrian Delay [s]*	*Output: Average Vehicle Delay [s]*	*Number of Unloaded Vehicles Due to Congestion [-]*
500	50	0.88	6.78	0
500	100	0.95	5.73	0
500	150	1.03	7.17	0
500	200	1.13	8.48	0
500	300	1.30	11.53	0
500	500	1.65	25.54	0
1,000	50	1.04	11.26	0
1,000	100	1.16	13.74	0
1,000	150	1.25	19.24	0
1,000	200	1.39	26.28	0
1,000	300	1.63	59.34	0
1,000	500	1.60	62.01	420
1,500	50	1.25	26.52	0
1,500	100	1.41	38.21	0
1,500	150	1.53	87.60	0
1,500	200	1.60	118.39	0
1,500	300	1.60	117.33	268
1,500	500	1.60	117.38	683
2,000	50	1.50	65.03	0
2,000	100	1.64	186.34	0
2,000	150	1.67	207.08	72
2,000	200	1.67	209.95	180
2,000	300	1.67	200.48	388
2,000	500	1.68	201.94	803

Verification of these results occurred on a real example of microsimulation of the planned new solution of the "Černý Most" terminal in Prague. As part of the new solution, the bus terminal is moved to the metro level in Černý Most, which, however, results in new conflicts between buses and pedestrians at level crossings. Concerns about the resolution of these conflicts are justified. On average, about 34,000 pedestrians enter the metro at the Černý Most station on a normal non-holiday Wednesday. 30,000 then leave it on the same day. The bus terminal will serve an average of around 2,500 buses from 6:00 to 20:00. The most fundamental conflict in the new solution occurs at the central pedestrian crossing that connects the metro to the area of the Černý Most residential area. In addition, level crossings are created at two other locations within the terminal at a distance of about 50 meters from the central crossing. To give relevant input to the microsimulation, a traffic survey must first be carried out to detect the vehicle flow rate at the terminal (buses) and the pedestrian flow rate through individual pedestrian crossings. The future bus rate estimation was determined based on current transport data so that it should not exceed a flow rate of 200 veh/h during peak hours. To determine the pedestrian flow rate, the pedestrian traffic survey was conducted in April 2021, however, faced with older data, which were not affected by the situation around the COVID-19 pandemic. Thus, the established coefficients resulted in a more realistic situation for future years. As a result, at peak times, pedestrian flows at the central crossing will exceed 2,000 ped/h, while at secondary crossings they will generally not reach values greater than 500 ped/h. The simulation time was 2 hours.

Looking at Table above, it can be assumed that while for the central crossing the level solution for vehicles does not meet the capacity and traffic congestion will occur, for secondary pedestrian crossings the level solution will be sufficient due to the lower flow rate. After microsimulation, this assumption was confirmed. At the central pedestrian crossing, the network gradually becomes overcrowded, and a bus queue forms over time. In the case of associated pedestrian crossings, these will easily meet the input flow rate. Therefore, it is important to emphasize that in the case of pedestrian flows higher than 2,000 pedestrians, it does not make sense to think about the classic level crossing for pedestrians at all under the given conditions. Likewise, in this particular case, it does not make sense to consider an extra-level solution because the architectural purpose of the whole project is to have a metro and bus stop at one level for a more comfortable change compared to the existing solution.

Therefore, a traffic control is considered, where previous research has also shown that this solution will work. The case study also examines the differences between conflict management using fixed signalling plans and dynamic control of pedestrian or bus preference. The preference of selected road users is a very topical issue and research is still underway on which categories of road users should be preferred. For the case study of the terminal in Černý Most, traffic control was finally recommended with the following more detailed comment: At the time between morning and evening rush hour, from the point of view of traffic control, dynamic control can be recommended in the form of a permanent green for pedestrians and a challenge for registered buses. During rush hour, the solution is not as clear, because there are quite a lot of registered buses, in contrast to the high pedestrian flow rate at crossings. A fixed signal plan then causes less delay for pedestrians than dynamic control because it creates regular clusters of buses and pedestrians are more likely to arrive at the green signal and conversely causes more delays for buses. However, thanks to the extension of the phase for buses, dynamic control can significantly reduce their delay and passage through the terminal, but at the expense of pedestrians who stay longer at the central crossing. The respective advantages and disadvantages for the individual parties must be well balanced in the final proposal. Side crossings are recommended to be solved by uncontrolled pedestrian crossings or crossing points. When implementing crossing points, bus delays are saved, pedestrian delays are minimal, but at the same time, this solution may be less safe for pedestrians.

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