



APPLICATION OF MICROSIMULATION MODELLING IN THE ASSESSMENT OF URBAN INTERSECTION RECONSTRUCTION

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Abstract

Intersections are critical points of the urban transport system according to various criteria such as capacity, safety, economic, ecological, etc. The reconstruction of the intersection affects various spatial and traffic aspects. Hence, the effects of the reconstruction need to be analyzed in the planning phase of design and analysis of alternative solutions. By applying microsimulation traffic modeling, it is possible to analyze the effects of the various solutions on existing and future traffic demand. In this paper, the traffic safety effects of the reconstruction of a selected urban intersection, where different horizontal discontinuities were applied, are analyzed. In addition to the functional indicators (vehicle delays, queue parameters), the effects of the reconstruction of conflict zones were analyzed through dynamic indicators (vehicle speeds of access routes). Vehicle speed has the greatest impact on the outcomes of traffic accidents in human-vehicle interaction. The analyses were done on the intersection located near an elementary school where potential child-vehicle collision can occur. In this paper, the existing intersection and three alternative reconstruction solutions were analyzed, using microsimulation traffic modeling for the measured traffic load and traffic increase of 100%, 150%, and 200%. Speeds on the major street were measured automatically for 24 hours. The morning peak hour, when children go to school, was chosen as relevant, when the traffic count was made for all traffic flows in the intersection by using a video camera. The optimal reconstruction solution was chosen by analyzing selected functional and dynamic indicators with the basic goal of increasing the traffic safety of pedestrian traffic flows.

Keywords: reconstruction; urban intersection; microsimulations; pedestrian safety

1 Introduction and research overview

According to the 2022 Report of the EU Council for Traffic Safety [1], data on child road safety in the EU show progress over the last decade. The data published by UNICEF [2] show that in other parts of the world the situation has not significantly improved, 600 children and young people still die in traffic accidents in the world every day. In the Republic of Croatia, in 2022, the number of traffic fatalities decreased by 5.8% compared to the previous year, but the number of injured persons increased, severely injured by 10.3%, and slightly injured by 10.6% [3]. Last year, a total of eight children (up to 13 years of age) were fatally injured in traffic, of which 3 were pedestrians (37.5%), which is a worse statistic than the previous year. In the same period, 121 children were seriously injured in traffic, of which 53 (43.8%) were pedestrians.

Statistical indicators for the pedestrian population over 65 years of age are even worse. 23 people (53.5%) were fatally injured as pedestrians, and 178 people (41%) were seriously injured, which makes this age group of pedestrians the most vulnerable road users [3]. The results of the research by Elvik et al. (2019) show a strong relationship between the mean speed of traffic and road safety, stated as the number of fatalities and the number of injury accidents [4]. Research shows that increasing speeds [5-7] and increasing speed variation [5,6,7] have an impact on increasing the number of accidents. A 1% increase in speed variation is associated with a 0.3% increase in the accident rate [6]. According to research Wang et al. (2023) the number of crashes was significantly correlated with average speed, speed variance, road segment length and number of lanes [7]. Speed limit is the most widespread traffic calming measure, but its effectiveness is doubtful [8], so the effectiveness of other solutions [9,10,11] to increase the safety of pedestrian flows is being investigated. It should be emphasized that pedestrian flows are not homogeneous and include particularly vulnerable groups. Children's behavior has its own specificities [12], both in reaction time [13] and in crosswalks speed through the conflict zone [14]. Elderly pedestrians are particularly vulnerable on the streets and are at great risk of injury or death, when involved in a collision. Conducted research [15] identifies the exclusive contributing factors to elderly pedestrian collisions rather than younger pedestrian collisions.

In this paper, the traffic safety effects of the reconstruction of a selected urban intersection, where different horizontal discontinuities were applied, are analyzed. In addition to the functional indicators (vehicle delays, queue parameters), the effects of the reconstruction of conflict zones were analyzed through vehicle speeds of access routes. The analyses were done on the intersection located near an elementary school, Care facility for the elderly and Primary health care institution where potential vulnerable pedestrian-vehicle collision can occur. Infrastructural solutions were analyzed and evaluated by application of microsimulation traffic modeling for the measured traffic load and three levels of traffic load increase due to a better analysis of the reconstruction solution. The goal is to detect optimal infrastructural solution in different traffic conditions that can assure pedestrian traffic safety. Chapter 2 describes the methodology, chapter 4 presents the results of the research, and chapter 5 provides a discussion of the results and conclusions.

2 Methodology

2.1 Location

The selected intersection is a non-traffic light four-leg intersection of city roads of higher (Drinska ulica) and lower (Krbavska ulica) functional levels, as shown in Figure 1. The intersection is located near the Elementary School, which has a main entrance oriented to the east approach of Drinska Street, as well as the Engineering and Architectural High School. On the west approach of Drinska Street, there is a Care facility for the elderly and a Primary health care institution. The Secondary school of Applied arts and design, the Ivan Štark education Center for children with special needs and the Hungarian cultural center, which includes kindergarten, elementary and high school, are oriented to the south approach in Krbavska street. The north approach of Krbavska Street has predominantly residential facilities. There is a large concentration of vulnerable road users at the observed intersection.

An automatic traffic counter was installed on Drinka Street, which measured the traffic load (Figure 2) and the speed of vehicle movement (Table 1) for a period of 24 hours. Table 1 shows the minimum speed (V_{min}), maximum speed (V_{max}), 85th percentile speed and percentage of vehicles that drove faster than the administrative speed limit (V_{exc}) for both directions and in total for the morning peak hour.

Table 2 Traffic load in morning peak hour - road approaches and pedestrian crosswalks

	Drinska street		Krbavska street	
	East	West	North	South
Vehicles [veh/h]	205	164	38	63
Pedestrians [ped/h]	107	-	17	72

Of the total number of vehicles, 89% are passenger cars, 9% are trucks, 1% are buses and 1% are motorcycles. Of the total number of pedestrians, 86% are children and adolescents, and 14% are adult pedestrians. On the recordings, 62 bicycles were observed on the footpaths on both sides of Drinska Street.

2.2 Microsimulation traffic models

Using microsimulation traffic modelling (VISSIM software), four models were created (Figure 3) – a model of the existing intersection and three variant reconstruction solutions. The aim of the reconstruction is to increase the safety of pedestrian traffic, so in addition to functional criteria (maximum length of queue [m] and average delays [s/veh]) a dynamic criterion (approaching speeds of vehicles [km/h]) was also selected for the evaluation of reconstruction solutions.

The first reconstruction solution includes pedestrian islands and the narrowing of traffic flows on three approaches (east, north and south) at pedestrian crosswalks. On Drinska Street, the construction of a pedestrian island narrows the conflict zone from 2x3.2m to 2x2.6m. The second solution is the central islands designed in Drinska Street, the narrowing of the road to 2x2.8m was designed before the conflict zone. The third solution envisages the reconstruction of Drinska Street and combines central islands with additional horizontal discontinuities and relocation of traffic lanes, without narrowing the road. In all reconstruction solutions, a bicycle path was designed next to the crosswalks on the southern side of Drinska Street. The detailed geometric characteristics of each solution are presented in [16].

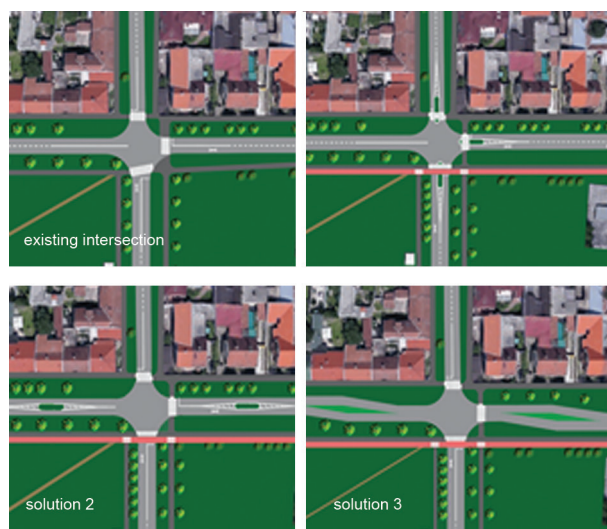


Figure 3 VISSIM models [16]

Analyses were made for existing traffic load and traffic load increase for all traffic flows of 100%, 150% and 200%, to see the potential of solutions for some extraordinary traffic demand. The same 10 traffic scenarios of vehicle arrivals were analyzed for each model, in order to simulate the stochastic nature of the traffic flow, and to make the results comparable.

3 Results

Table 3 shows the traffic flow indicators for all 4 models and for all analysed traffic loads. The maximum queues of vehicles (QLen_{max}) were compared shown in [m] that appear in the intersection in the observed peak hour and the average delays (VehDelay) in [s/veh] for the existing intersection and reconstruction solutions. A more detailed comparison by individual approaches and for a larger number of functional indicators is available in [16]. Table 4 shows the mean speeds for the existing intersection and reconstruction solutions and for all analysed traffic loads.

Table 3 Comparison of functional indicators

	Counted traffic		Increase 100%		Increase 150%		Increase 200%	
	QLen _{max}	VehDelay	QLen _{max}	VehDelay	QLen _{max}	VehDelay	QLen _{max}	VehDelay
Existing l.	10,38	1,59	28,28	3,85	35,95	4,56	38,5	11,97
solution 1	13,79	1,85	36,29	5,13	41,57	7,59	42,4	15,71
solution 2	22,63	2,06	38,44	4,31	39,84	11,17	43,62	20,41
solution 3	27,15	2,78	37,6	6,54	44,87	12,07	45,51	25,2

Table 4 Comparison of approaching speeds

		Counted traffic	Increase 100%	Increase 150%	Increase 200%
Existing Intersec.	East	51,12	50,47	48,98	47,81
	West	50,15	45,43	43,55	40,67
	North	50,46	38,55	37,51	37,34
	South	48,55	40,03	36,35	31,61
solution 1	East	28,9	33,04	22,37	24,11
	North	28,88	28,56	30,52	21,20
	South	29,26	24,96	27,26	27,44
solution 2	East	23,39	29,19	24,99	25,27
	West	26,95	29,03	26,94	28,85
solution 3	East	28,5	29,1	26,66	24,49
	West	28,87	29,8	28,08	28,93

4 Discussion and conclusions

It is clearly visible from Table 3 that for the existing intersection and the existing traffic load, traffic flow indicators are the best, which is expected. The problem of the existing intersection is not a problem of traffic flow, but of traffic safety. By increasing the traffic load for the existing intersection and all reconstruction solutions, the traffic flow indicators are worse, but only for an increase in traffic of more than 150%, they are significantly worse. Of the reconstruction solutions, the first solution has in most cases the best traffic flow indicators for all levels of traffic demand (Table 3). When we compare the dynamic indicators, speeds on the access roads (Table 4), of which the speeds in Drinska Street are critical, it is evident that in all reconstruction solutions, a reduction in speed at the pedestrian crosswalks was achieved. The approaching speeds of vehicles in front of the pedestrian crosswalks were analysed, so it can be seen that solutions 2 and 3 have values for Drinska Street, because the reconstruction included the pedestrian crosswalks with critical approaching speeds only. At the same time, it should be taken into consideration that on the southern approach of Krbavska street there are 72 pedestrians in the morning peak hour, which should certainly be taken into consideration in the reconstruction of the intersection. Basically, an increase in traffic load decreases speeds, but this decrease is not linear and there are exceptions. A higher traffic load affects the driver's reaction time, both in reality and in the model, so the deviations can be explained in this way. Higher traffic jams usually result in an increase in the attention of road users, smaller gaps in following vehicles, shorter reaction time, but also forcing the right-of-way of vehicles and a greater number of errors by road users.

The chosen optimal reconstruction solution is, according to the analysis results, the first solution with pedestrian islands and narrowing of the roadway in the place of the vehicle-pedestrian conflict zone. Pedestrian islands, first of all, enable a phased crosswalks of the conflict zone and require an assessment of the approaching speed of vehicles for only one oncoming traffic flow. This has significant advantages for pedestrians, especially for children who, until a certain level of cognitive development, do not have the ability to correctly estimate the speed of oncoming vehicles [12,14]. A narrowed roadway means a shorter stay in the conflict zone, which is a particular advantage for pedestrians, especially for the elderly pedestrian population. The first solution with pedestrian islands has the best functional indicators for all levels of traffic load, and the reconstruction also includes the pedestrian crosswalks in Krbavska Street, which is another significant advantage of this solution.

Field measurements presented in the paper have shown that people make mistakes, they do not respect the given speed limits, unaware of the risk to which they expose themselves and other road users. Human errors are an input parameter with which we need to enter into the infrastructure design. This paper shows an example of the analysis of a potentially critical traffic situation for sensitive categories of road users - children and the elderly. It has been shown that proposing a solution requires a comprehensive analysis of the behaviour of all traffic participants in order to find the optimal solution from the aspect of capacity and especially traffic safety.

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