ASSESSMENT OF THE EFFECTS OF TRAFFIC INFRASTRUCTURE RECONSTRUCTION AND INTRODUCTION OF A PEDESTRIAN ISLAND AS A TRAFFIC CALMING MEASURE USING TRAFFIC MICROSIMULATIONS

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Abstract

The reduction in the traffic death rate in the EU has stagnated in recent years, and the goal of halving the number of fatalities in traffic from 2010 to 2020 has not been met yet. The long-term goal of achieving "Vision 0" requires a multidisciplinary approach and shared responsibility between transport infrastructure that "forgives mistakes", traffic regulation, vehicle automation and traffic participants. At pedestrian crossings of the local roads, which do not have traffic lights, reducing the speed of vehicles by applying a traffic sign has not proved to be an effective solution. Vehicle speed is proved to be a key parameter that determines the outcome of a vehicle-pedestrian conflict. The pedestrian island spatially separates the opposite directions of vehicle flows, thus enabling a better perception of the conflict zone, which is important for vulnerable traffic users. In this paper, an analysis of the effectiveness of horizontal discontinuities and pedestrian island, as infrastructural measures for traffic calming, was made. The evaluation was made using microsimulation traffic modeling, and the calibration of the model was made using a neural network based on measured field data. Travel time is a traffic indicator used in the model calibration process. The calibrated model was then used for the analysis of the effects of the planned reconstruction of the road network segment near the children's playground in a residential area in the city of Osijek, Croatia. Statistical analysis was done to determine whether vehicle speeds on the observed road network segment before and after reconstruction differ significantly. Applied methodology showed that the application of microsimulation traffic modeling provides a possibility to assess the effectiveness of the reconstruction of transport infrastructure in the planning phase

Keywords: reconstruction assessment, pedestrian safety, vehicle speeds, traffic modeling, VISSIM

1 Introduction and research overview

In the period from 2010 to 2020, the goal set by the EU to have the number of deaths in road accidents was not fully met, on average that number decreased by 37 %. The largest drop in the number of deaths and injuries occurred from 2019 to 2020, certainly as a result of the Covid-19 pandemic, and it is to be expected that the numbers will rise again after the end of the pandemic [1].

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Although speed has some positive impacts, the most obvious being that it allows a reduction in journey time and therefore enhances mobility, excessive and inappropriate speed is the number one road safety problem in many countries, contributing to as much as one third of fatal accidents and an aggravating factor in all accidents [2].
In crashes between two different types of road user, pedestrians and other vulnerable road users, are the most unequal crash opponent. Crossing the road is the riskiest manoeuvre for pedestrians, even 64 % of pedestrian fatalities are a result of a crash while crossing the road [3].
According to research results [4], the European Transport Safety Council (ETSC) has calculated that if mean speeds were to drop by only 1 km/h on all roads across the EU, more than 2.200 road deaths could be prevented every year.
The severity of accidents that occur can be reduced by well-designed and maintained roads and roads that "forgive" mistakes, roads set on Safe System principles.
Measurements were done in Rijeka City, Croatia, on the road network where mixed traffic is expected on spots mostly located before different types of pedestrian crossings [5]. The results show that at all spots more than 58 % of vehicles were going at speeds beyond posted speed limits (that was 40 – 50 km/h) and on most of the spots that percentile was around 90 %. Also, average speeds on all cross-sections (longitudinal profile) were higher than posted speed limits.
Different are solutions applied in urban areas as traffic calming measures in order to control vehicle speed and assure safety of pedestrians both on streets and intersections. The research effectiveness of applied measures goes in different directions – establishment of influence of traffic calming measures on drivers' and pedestrian behaviour [5, 6] by on-spot measurements or traffic modelling of traffic calming measures in order to establish their impact on speed and capacity [7, 8].
The spread of traffic safety and sustainable mobility is linked to a structural approach and also preventive from the earliest stages of design. Several studies have shown the validity of some signage or systems integrated into the lanes to be able to increase pedestrian safety including pedestrian islands [9] or use of vertical signage [10]. Some studies have also demonstrated the influence of certain psychological characteristics on the effectiveness of different types of traffic calming measures at crosswalks, designed according to Human Factors principles [11].
Mostly used models are traffic microsimulations based on stochastic nature of traffic flow at a multi-modal level, through a detailed movement modelling of each entity and its interactions. They enable to test safety and capacity performance of infrastructural solutions before their implementation.
In this paper traffic microsimulation is used in order to test infrastructural traffic calming measures implemented in order to enhance pedestrian traffic safety at crosswalk. The aim is to establish effectiveness of introduced measure by statistically based analyses of traffic microsimulation outputs.

2 Model calibration

2.1 Model calibration methodology

The functioning of a traffic system is under the influence of various aspects of human behaviour [12]. Studies show that the behaviour of traffic participants is, among other things, territorially and culturally conditioned [13, 14]. The aim of the calibration is to adapt the model to the specifics of the local road network and to reduce the difference between measured and modelled traffic indicators by less than 5 %. The goal of calibration in this study is to obtain a sufficiently accurate model to be able to analyse the effects of reconstruction on the dynamic

parameters of vehicle traffic flow in the observed network segment. Microsimulation models include variable behaviour of drivers, at a level of each particular entity, and the reality of modelling results depends on the initial choice of the model [15] and the efficiency of the calibration process [16].
The selected microsimulation model for this analysis is PTV VISSIM. The method of calibration of microsimulation traffic models applied in this paper is the one using neural network approach. The methodology of calibration using neural networks is described in detail in the articles [16, 17], and the validation of the calibration methodology is described in papers [14, 18]. The travel time indicator between the measuring points was chosen for calibration, because it is easily measurable in the field. The distance between the measuring points in the field was 157.1 m. The model calibration results changed the default values of the car following parameters: average standstill distance - from 2 to 2.4 m, Multiplicative part of the desired safety distance - from 3 to 3.5 m. The change in these parameters indicates a greater distance between vehicles in the queue, which is expected because the observed segment is part of the local road network, and the driving style in local conditions indicates a less dynamic approach than the default model.

2.2 Comparison of modelling results with measured data in the field

Calibration efficiency can best be assessed by comparing modelled and measured field data. With the calibration procedure, the difference between the measured and modelled travel time is 1.33 %, which satisfies the first condition (< 5 %) for the model to be considered calibrated. Table 1 shows the basic travel time statistics obtained by field measurements and modelling using a calibrated and uncalibrated model. The Anderson – Darling test was used to assess data distribution and none of the three data groups met the conditions of normal data distribution. Therefore, the nonparametric Mann – Whitney U test was used to assess the statistical significance of the difference between the three data sets, and the test results are shown in Table 1.

Table 1 Comparison of measured data and data obtained by modelling

	N	Mean	StDev	Median	Min	Max	U test	p
Measured	88	12, 8	2, 62	12, 0	10, 0	20, 0	-	-
Calibrated	88	12, 6	2, 72	12, 0	9, 5	24, 8	7655, 5	0, 694
Uncalibrated	88	11, 1	2, 15	10, 7	9, 2	23, 6	5822, 5	0, 000

The results show that the difference between the measured data and those obtained by modelling with an uncalibrated model is statistically significant ($p < 0.000$) and between the measured data and those obtained by modelling with the calibrated model it is not statistically significant ($p = 0, 694$). From the presented results we can conclude that the model was successfully calibrated.

3 Evaluation of reconstruction efficiency

The road network in residential areas is part of the road network used by vulnerable traffic users in their daily walking. The observed pedestrian crossing is located near the children’s playground, and is part of the daily house-school route and back (Figure 1). The behaviour of children in traffic has its own specifics [19] and cannot be treated in the same way as adult traffic users, because they differ in the reaction time [20] and the speed of crossing the conflict zone [21].

Vehicle speed is proved to be a key parameter that determines the outcome of a vehicle-pedestrian conflict, the aim of the reconstruction is to slow down the speed of vehicles at the selected pedestrian crossing by applying the horizontal discontinuity of the traffic lane. The pedestrian island spatially separates the opposite directions of vehicle flows, thus enabling a better perception of the conflict zone, which is important for vulnerable traffic users.
The calibrated VISSIM was used to compare the effects of the planned reconstruction on the dynamic characteristics of the vehicle traffic flow. For pedestrian speeds in the conflict zone, two pedestrian speeds were simulated - adult traffic users (1.5 m/s) and children (1.0 m/s), which represents the 15th percentile of measured speeds of children at pedestrian crossings in Osijek, Croatia [21]. Due to the stochastic nature of the traffic flow, ten different scenarios of arrival of vehicles for the same traffic load were analysed. Using the same random number generator (random seed) of the default initial value and the same random number generator step (increment = 10), the same ten traffic scenarios before and after the reconstruction were analysed. In each model, speed detectors are placed in front of the pedestrian crossing on each lane (section 1 and section 2) for incoming vehicle traffic flow (Figures 1b and 1c). In the first road cross section (section 1), in both models the individual vehicle speed in the south-north traffic flow, called traffic flow 1, was detected. Analogously, for the opposite traffic lane (section 2). The speed was detected during a one-hour traffic simulation.

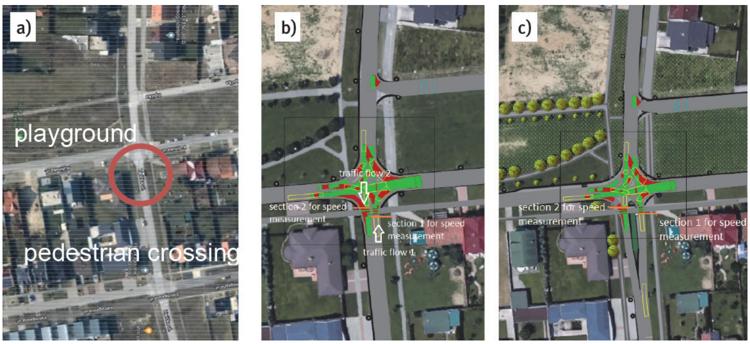

Figure 1 a) Observed pedestrian crossing [22]; b) models of existing roads; c) and reconstruction

Dynamic macro indicators for each scenario such as arithmetic mean velocity (mean time velocity) and harmonic mean velocity values (mean spatial velocities) are shown for the existing (before reconstruction – BR) and for the reconstructed pedestrian crossing (after reconstruction – AR) for Section 1 and for Section 2 (Table 2).
Given that the microsimulation model was used, it was possible to obtain the speed of each individual vehicle passage through the observed Sections 1 and 2. Statistically compared databases of mean speed values for all ten observed scenarios for each individual vehicle crossing before and after reconstruction, descriptive statistics are shown in Table 3. The Anderson – Darling test was used to assess data distribution and none of the two data groups met the conditions of normal data distribution (Figure 2). The nonparametric Mann – Whitney U test was used to assess the statistical significance of the difference between the two data sets (Table 3). The probability plot before and after reconstruction is shown in Figure 2a for Section 1 and 2b for Section 2.

Table 2 Dynamic macro indicators, Section 1 and Section 2

	Section 1				Section 2			
	Speed BR		Speed AR		Speed BR		Speed AR	
SimRun	Speed Avg Arith	Speed Avg Harm	Speed Avg Arith	Speed Avg Harm	Speed Avg Arith	Speed Avg Harm	Speed Avg Arith	Speed Avg Harm
1	51, 8	49, 3	44, 5	39, 1	53, 5	52, 5	48, 2	47, 1
2	50, 3	48, 4	43, 5	38, 1	52, 9	51, 8	47, 0	45, 2
3	50, 8	48, 5	40, 1	36, 2	53, 7	52, 6	48, 1	46, 4
4	49, 9	47, 9	39, 1	34, 2	51, 9	50, 8	46, 1	44, 2
5	50, 9	48, 0	40, 1	35, 3	52, 8	51, 9	47, 2	45, 2
6	51, 8	49, 1	40, 1	36, 4	52, 5	51, 7	46, 6	45, 4
7	50, 9	47, 8	39, 4	34, 1	54, 6	53, 8	49, 0	47, 1
8	52, 6	49, 3	40, 4	36, 2	53, 0	51, 8	46, 9	44, 5
9	50, 8	47, 6	45, 3	40, 1	53, 9	52, 9	48, 1	46, 2
10	52, 9	48, 8	43, 3	36, 0	52, 2	51, 6	47, 1	45, 3
Avg	51, 3	48, 5	41, 6	36, 6	53, 1	52, 1	47, 4	45, 7

Table 3 Descriptive statistics and Mann – Whitney U test

		N	Mean	StDev	Median	Min	Max	U test	p
Sec.1	Speed $_{BR}$	212	51, 3	7, 91	52, 9	10, 6	60, 0	61413	0, 00
	Speed $_{AR}$	212	41, 6	10, 6	45, 1	10, 4	53, 2		
Sec.2	Speed $_{BR}$	84	53, 1	5, 78	54, 7	24, 8	59, 1	9453, 5	0, 00
	Speed $_{AR}$	84	47, 4	7, 03	50, 3	18, 5	53, 3		

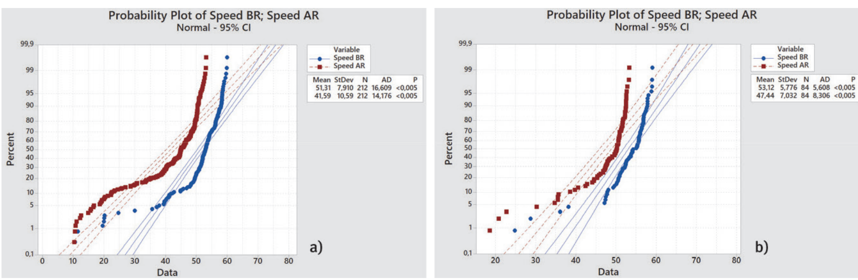

Figure 2 The probability plot before and after reconstruction: a) section 1; b) section 2

Additionally, a test for two variances was made for two sets of individual speeds - before and after the reconstruction. Null hypothesis was σ(speed BR) / σ(speed AR) = 1 and variance (speed BR) / variance (speed AR) = 1, with set significance level α = 0, 05. The results are shown in Table 4.

Table 4 Test for two variances – Bonett and Levene

	Ratio of standard deviations	Ratio of variances	Bonett	Levene	p_{Bonett}	p_{Levene}
Section 1	0, 747	0, 557	5, 78	14, 85	0, 016	0, 000
Section 2	0, 821	0, 675	0, 57	0, 40	0, 449	0, 526

4 Discussion and conclusion

The results presented in Table 3 show that vehicle speeds differ statistically significantly according to the nonparametric Mann – Whitney U test at both cross-sections after the reconstruction and introduction of the central pedestrian island for the overall database. When comparing individual scenarios in each scenario there is a reduction in speed, but the reduction is not statistically significant in each scenario. Interesting results are given by the Bonett and Levene test for two variances shown in Table 4 for the overall database. For section 1 the null hypothesis that the ratio of standard deviations and variances is equal to 1 is rejected. For section 2 the null hypothesis cannot be rejected. This is explained by the fact that section 2 is located immediately after the conflict zone of the intersection, which homogenizes velocities, so the difference is not statistically significant.

Within this paper, only one reconstruction solution is analysed, in order to preliminarily assess the impact of this type of traffic infrastructure reconstruction on the dynamic characteristics of vehicle traffic flow. According to the results, the analysed traffic calming measure has potential and the impact of different geometric design of the central island at different locations of the road network should be investigated. Bearing in mind that we are interested in a potentially critical scenario of a vehicle-pedestrian conflict, the impact of the temporary lack of attention parameter and its frequency should be modelled, as well as lower speeds of children at the pedestrian crossing (the 15th percentile of the speed of children under 7 years is 0.8 m/s, and from 8-11 years 0.9 m/s in Osijek [21]).

The advantage of using microsimulation tools is that it is possible to analyse the effects of reconstruction in the planning phase and provide the ability to analyse different critical scenarios without affecting the observed system. Future research should include the assessment of impact of traffic calming measures on speed and traffic flows distribution in wider area.

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