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Modelling of traffic on a selected roundabout in Žilina

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Abstract A high-quality network is currently a prerequisite for sustainable transport systems. The sharp increase in automobile traffic has resulted in increased transport problems. The most serious transport problems include traffic infrastructure congestion, increased accident risk and of course environmental impact. Daily mobility and securing the transport of goods is one of the key transport objectives. The most critical point of the road network is the intersection. Therefore, great emphasis is placed on the vehicle to pass smoothly and safely when passing through this place. In this paper an analysis of the current status of the selected roundabout is created. Based on the survey it is proposed three solutions to improve the traffic conditions of the intersection. Aimsun micro-simulation was also used to create solutions.

Keywords intersection, simulation, traffic

JEL L90, L92

1. Introduction

The rising standard of living of the population has an impact on increasing the level of automobile production. This fact also affects the increase in individual car traffic. Communication capacity is often exceeded, leading to congestion. Drivers are often nervous and begin to threaten their behavior with other drivers. Despite major investments in infrastructure development, the traffic situation is deteriorating. Communication, crossroads are achieved daily. Therefore, the term "communication capacity" refers to the maximum number of vehicles that release these per time unit. The intersection is a point in the communications network where the currents of vehicles meet, connect, disconnect or intertwine. In other words, there is a place where the roads intersect or merge in the plan and at least two are interconnected. [1] The intersection must have sufficient capacity and capacity. Otherwise, the vehicles could remain at or at the intersection. It is necessary to ensure continuous, smooth and safe passage of vehicles through the intersection. Intersections can be divided into three basic groups:

Uncontrolled junction
- Roundabout
- Light-controlled junction

Using the appropriate software, it is possible to simulate different kinds of intersections. The simulation outputs can be further processed and reviewed. Traffic modeling is an interesting tool. The advantages of microscopic modeling include the assessment of the outlook, the analysis of several aspects of transport infrastructure, etc. Before selecting a suitable type of intersection, it is also necessary to analyze its position, transport significant in the area, its dimensions. The output of the simulation should be the optimal variant taking into account all the specifics of the intersection. [2]

2. Analysis of the traffic situation of the intersection

Žilina is located in the north of the Slovak Republic. The intersection is located on the road connecting the city center with the largest housing estate. Vysokoškolákov Street is one of the most important roads within the Žilina transport infrastructure. [3] At present, the street is characterized by three single-lane small roundabouts.

The selected junction is the second in the middle (Figure 3.). Entry number 1 leads from the city center. Entry number 2 connects the intersection with the shopping center. The other two entrances lead to the settlement of the wolfhound and surrounding villages. The roundabout has an outside diameter of 37 m. Due to frequent constipation it is necessary to look for another type of intersection, e. g. turbo roundabout or light-controlled junction. Changing the type of

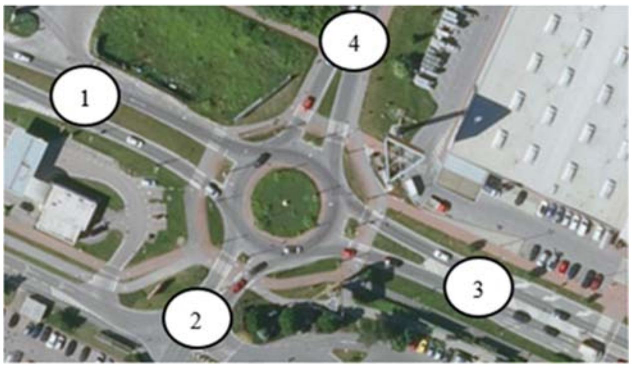

Figure 1. Vysokoškolákov street with a solved intersection [4]

intersection can improve the road traffic situation. In addition, it is also possible to reduce emissions because the time spent in the city center is also reduced.

3. Number of vehicles at the intersection and traffic survey

To find out the necessary data, a survey was carried out on 11.10.2018 in the afternoon. Data were recorded at regular intervals of 15 minutes. Subsequently, a peak hour was found that started at 3:00 pm and ended at 4:00 pm. During this time it passed a crossroads in total 2666 vehicles. The number of vehicles is shown in Table 1.

Table 1. Matrix of vehicle directions during peak hour [own study]

O/D	1	2	3	4	Sum
1	*	150	737	275	1162
2	252	*	97	98	447
3	592	40	*	43	675
4	244	88	50	*	382
Sum	1088	278	884	416	2666

For better illustration of vehicle flows from individual entrances, see Figure 2.

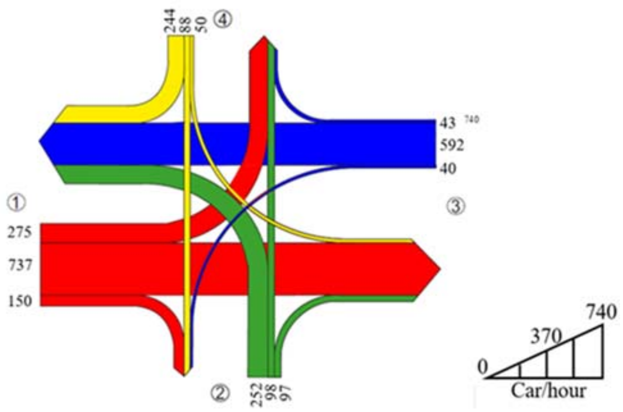

Figure 2. Load scheme during peak hour [own study]

4. Number of vehicles at the intersection and traffic survey

In order to verify and evaluate the current and prospective state, the given section of Vysokoškolákov Street was modeled in Aimsun software. Aimsun is a traffic modeling software from TSS, a Spanish company based in Barcelona. The Aimsun program enables macroscopic, mesoscopic as well as microscopic simulation. The simulation outputs are intensity, density, average speed, different speeds, travel time, delay time, stop time, number of stops, total distance traveled, total travel time, fuel consumption and emissions produced. [2,5,7]

4.1. Creating a transport model and using microsimulation

In total, three transport models (3 types of intersections) were drawn in the Aimsun simulation program:

- Current roundabout
- Designed light-controlled junction
- Designed turbo-roundabout

All transport models worked with the same input parameters that were obtained during peak hour traffic surveys.

The first step in creating a map layer was importing a communications network. The communications network has been imported from the Open Street Map database, which has retained the correct scale.

In total, 10 simulations were made for each model. The simulation created an average of values such as delay time, stop time, travel time, stop count, density, speed, and intensity. Delay time and travel time are also shown graphically by the types of vehicles.

4.2. Current status

The transport model reflects the current traffic situation (Figure 3). The resulting values of this microsimulation were compared with the resulting values of the other two proposals. An assessment of the current situation and proposals is given in the last chapter of this document (5).

4.3. First proposal - light-controlled junction

The first is to change the current intersection to a light-controlled intersection. The number of lanes for individual entrances and exits was created according to TP 102. We have limited one lane capacity to a maximum of 500 cars /

Figure 3. Current status in Aimsun [own study]

hour. [2]. Based on this condition for entry 1, 4 lanes were

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created and 2 lanes were used for exit. Branch number 3 consisted of 3 entry lanes and 2 exit lanes. Branch number 2, 4 have a staggered number of lanes, entry 2, and 1 lane on the exit. (Figure 4)

Another important step is to create a light signaling plan. The greens and total number of signal groups were generated

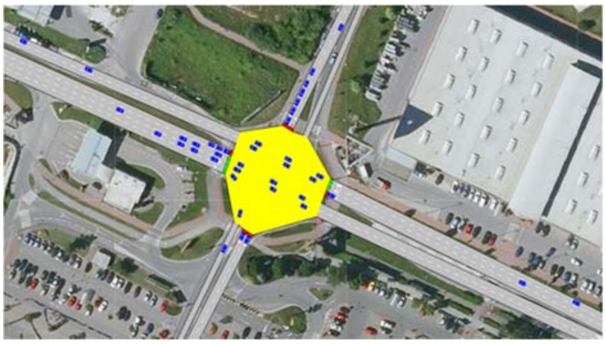

Figure 4. First design - light-controlled junction [own study]

according to the procedure also described in TP 102. A fixed light signaling plan was calculated with a cycle duration of 60 seconds, an offset of 2 seconds and a 3 second yellow light. The signaling plan is shown in Figure 5.

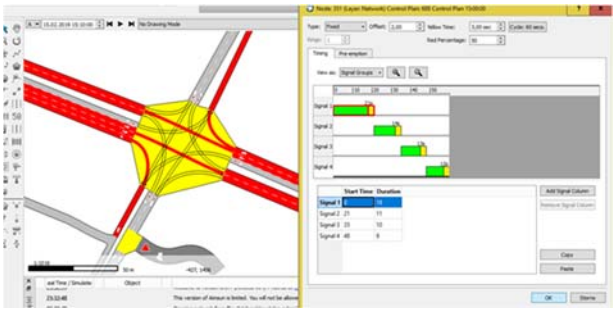

Figure 5. Designed light signaling plan [own study]

4.4. Second proposal - turbo-roundabout

The second proposal was the creation of a turbo-intersection. This type of intersection is expected to increase safety and capacity compared to classic roundabouts.

The advantage of the turbo-roundabout way the direction of lanes on the track. [6]

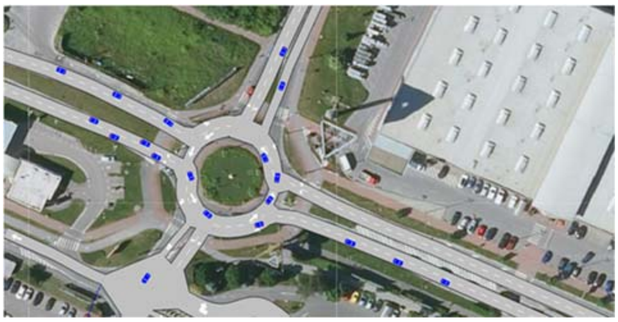

Figure 6. Second design - turbo-roundabout [own study]

5. Microsimulation of traffic models

For each traffic model, we have performed 10 simulations. From these simulations we have created average. In the previous figures (Figure 3, 4, 6) it is possible to see the running of the simulation for all three types of intersections. Output indicators that have been tracked and compared between each intersection type are stopl time, delay time, travel time, number of stops. Of course, the three main traffic flow characteristics of density, intensity and speed were also observed. All the above indicators were analyzed and then compared between the current roundabout and the two new proposals. Each simulation lasted one hour.

The following tables (Table 2, 3) compare the resulting values between the current status and the new proposals.

Table 2. Comparison of Simulation Result Values Current State and First Proposal [own study]

Parameter	Current status	Traffic light	Unit	Change (%)
Number of Stops	3,60	1,24	#/veh/km	-65,56
Delay Time	262,37	142,91	sec/km	-45,53
Stop Time	234,22	126,31	sec/km	-46,07
Travel Time	332,51	209,60	sec/km	-36,96
Density	47,77	15,68	veh/km	-67,18
Speed	18,91	26,56	km/h	+40,45
Flow	2500,60	2705,20	veh/h	+8,18

Table 3. Comparison of Simulation Result Values Current State and First Proposal [own study]

Parameter	Current status	Turbo-roundabout	Unit	Change (%)
Number of Stops	3,60	1,81	#/veh/km	-49,72
Delay Time	262,37	132,31	sec/km	-49,57
Stop Time	234,22	103,29	sec/km	-55,90
Travel Time	332,51	203,09	sec/km	-38,92
Density	47,77	24,09	veh/km	-49,57
Speed	18,91	26,75	km/h	+41,46
Flow	2500,60	2589,80	veh/h	+3,57

From the table 2 is clear, that individual parameters have significantly decreased or declined. The most noticeable decline was recorded at the density - the decrease was up 67% for first proposal. Another significant decline was recorded at the delay time and the number of stops, which fell by over 65%. Stop time and delay time decreased by over 46%, and travel time decreased by over 37%. If the first proposal is used, it can be assumed to increase performance of the junction about 8%.

Three indicators achieved lower values for the second proposal. The biggest drop reached the stop time by almost 56%. Also, travel time and delay time have been reduced compared to the first proposal. If the first proposal is used, it can be assumed to increase performance of the junction about 3,5%.

As a result of decreasing some indicators, vehicles lose less time in traffic congestion. This fact also affects the reduction of emissions because the passage of the vehicle through the intersection is smoother.

The following figures show two important indicators travel time and delay time for the current roundabout, first proposal and second proposal. The indicators are given for three categories of vehicles (car, truck, bus) and for all vehicles.

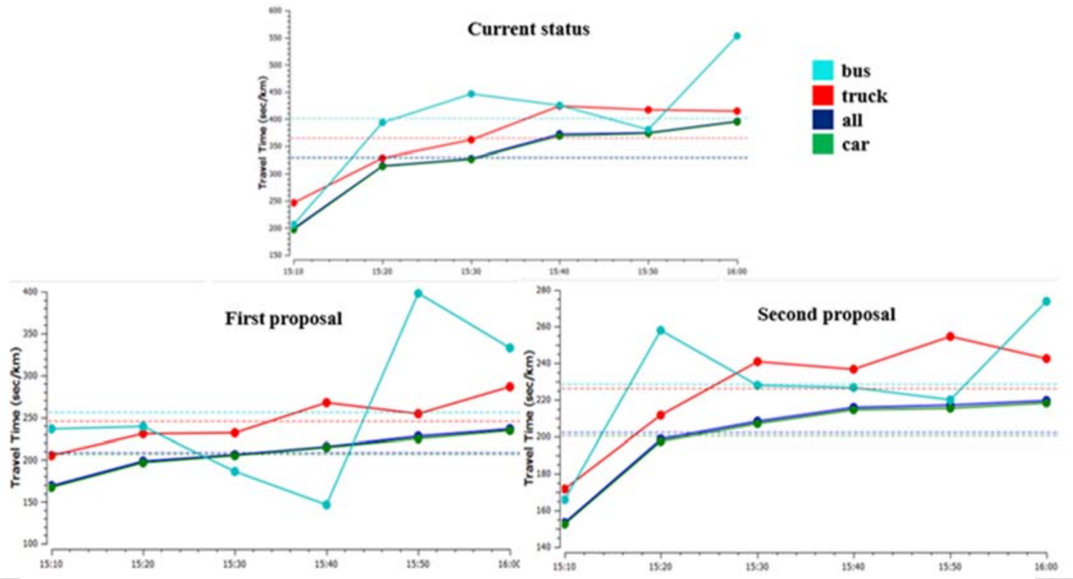

Figure 7. Travel time progress according to vehicle categories [own study]

Travel time is one of the most important indicators. The total average for each vehicle is much lower than the current situation on small circular junction. This indicator has increased during the last stages of time. See figure 7.

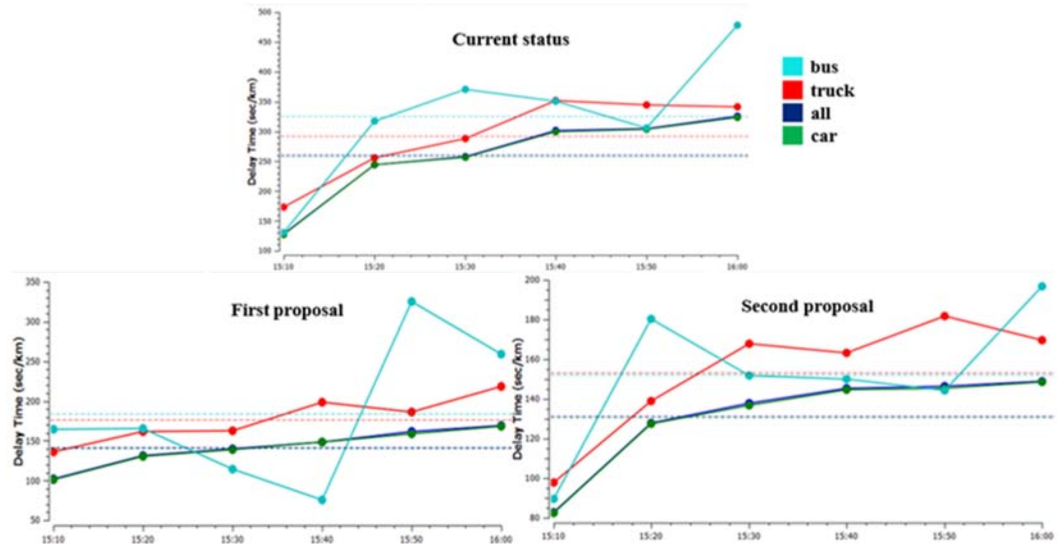

Figure 8. Delay time progress according to vehicle categories [own study]

Figure 8 shows the progress of the delay time. During the last stages of the simulation, the time delay has increased for buses, but the overall average is much lower

The average of the various categories of vehicles in both new designs is significantly lower than for the current roundabout, especially at the second proposal turbo-roundabout.

5. Conclusions

The aim of this paper was to evaluate the traffic situation at a selected roundabout in Žilina. The current traffic situation is difficult. Especially during the rush hour, columns are formed in front of the intersection that slow down the entire traffic flow of the vehicles. In view of this problem, two other repair solutions have been proposed - a light-controlled junction and a turbo-roundabout. Three transport models were created using microsimulation. As the simulation showed, the number of stops, density, and intensity increased significantly at the light-contolled junction. However, the turbo-roundabout has significantly reduced up to three variables, namely stop time, delay time and travel time. The simulation results showed proposal 2 as better. The results confirmed that the Transport Engineering Program can bring some benefits, especially in identifying possible transport infrastructure problems. Ultimately, it can be assumed that both proposals can improve the current traffic situation of the roundabout.

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