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5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

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Road and Rail Infrastructure V

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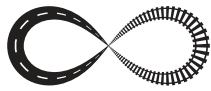
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TRAFFIC SIMULATION TOOL IN SERVICE OF DECISION MAKERS

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Abstract

In recent decades one can observe a huge increase in traffic volume on Slovenian highways, and consequently on the Ljubljana ring, where 4 main highways intersect. High traffic volumes result in traffic congestion and delays on highways, on the Ljubljana ring, and on the main roads towards and in Ljubljana. On the east side of Ljubljana is located BTC – a shopping mall, sports, entertainment and business area, with more than 500 shops. Although being one of the largest shopping and entertainment complexes in Europe, the future development of this area is foreseen. New business and shopping facilities will have a significant impact on the traffic situation. Additional traffic will decrease the level of service on the nearby roads and on the already often congested Ljubljana ring, and therefore measures for the road infrastructure will be needed. To set the optimal solution several possible infrastructure measures should be tested and evaluated, usually with the macroscopic and microscopic simulations. For the problem presented in this paper the macroscopic model was used for the traffic forecast, while the microscopic model was used for the optimization of proposed solutions.

Keywords: tram, track, vibrations, urban areas, analysis

1 Introduction

Continuous growth in motorization and constant changes in travel behaviour result in increased traffic volumes on existing road networks, so road conditions can change drastically. At the study area, on the east side of Ljubljana, new business and shopping facilities are planned that, based on experiences, will highly influence the traffic situation in the area. BTC is located next to the north-east part of the Ljubljana ring. On existing ramps to the Ljubljana ring traffic volumes in peak hours are already very high, and queues of vehicles are often longer than the length of the ramps, so unsuitable traffic conditions are also reflected on the highway.

The aim of this study is to propose the optimal infrastructure layout, whereby traffic volumes would be evenly distributed on Šmartinska cesta and Leskovškova cesta, with the highest utilization capacity for all roads in the study area and with the highest possible safety. The study area is shown in Figure 1.

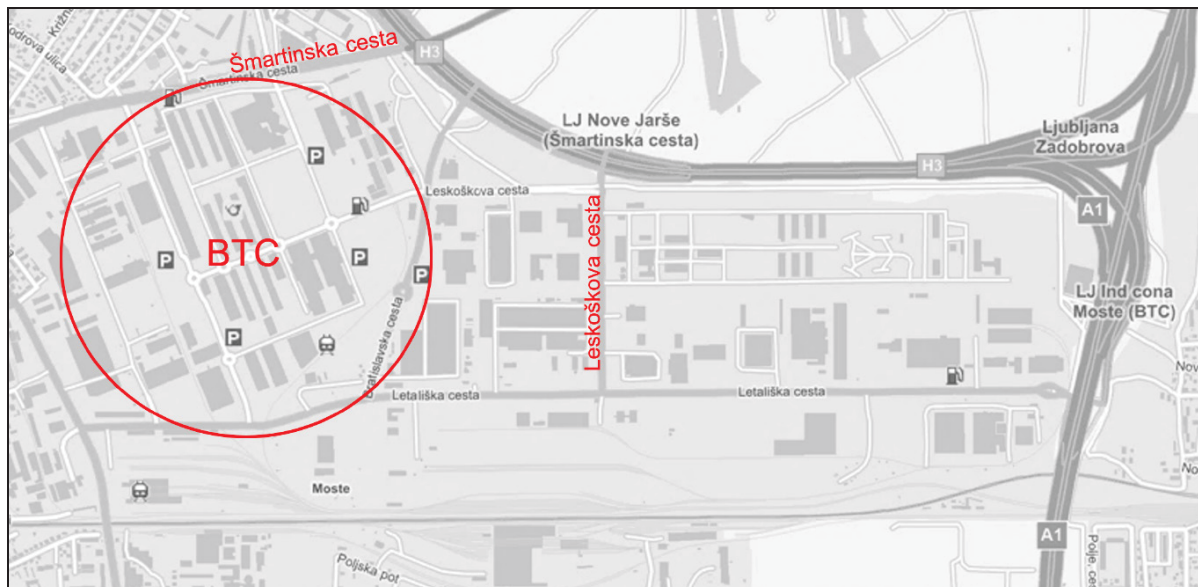


Figure 1 Study area

2 Simulation tools

Computer-based traffic flow simulations are one of the most useful tools for the optimization of road design solutions before the design is realized in the real world and before negative impact starts to show in real-life situations. State-of-the-art simulation tools are applicable to contemporary concepts of lane permission and designs and give insight into the efficiency and the effectiveness of different solutions. Based on the results the optimal solution can be determined. The efficiency of any empiric and/or analytic calculation methods for traffic flow characteristics, or estimations based on the observations of the traffic in different circumstances cannot exceed the efficiency of simulation tools, due to:

- lower costs;
- results available within reasonable time;
- results having several measures of effectiveness, e.g. delays, average speed, number of trips, traffic volumes, fuel consumption, greenhouse gases emission;
- gradual improvement and optimization of the solution;
- the possibility of highly accurate modelling of the effect of changes in land use and future increase in traffic volumes on traffic flow.

Macroscopic traffic flow simulations are used to simulate wide area road networks, where individual vehicles are presented, but due to the calculation efficiency the entity is a group of vehicles. Macroscopic simulation can be carried out in three to four phases, namely trip generation, distribution, mode choice, and assignment. In three-phase simulation models all but the mode choice phase are conducted. In the trip generation phase the present and future traffic volume for all user-defined zones are estimated. In this phase only the number of started and completed trips is the focus, meanwhile other characteristics of trips, e.g. destination, mode choice, the path on the road network, are calculated in later phases. Future traffic volumes are estimated based on the following most common assumptions:

- land use (and possible changes in land use);
- socio-economic characteristics of passengers and
- traffic transport systems.

In the distribution phase a variety of trips between pairs of locations reflecting the choices of drivers are calculated. Each trip begins in a particular zone i and ends in a particular zone

j, and the result is the origin-destination trip table, where all the trips in the study area and in the selected time frame are included. In the assignment phase for each trip the route in the road network for each vehicle is calculated. The calculation is based on several different approaches regarding longer travel times due to the traffic volumes and road capacity utilization. The result is traffic volumes on all roads in the study area.

In contrast to macroscopic simulation, the average value of traffic parameters such as speed and density are not entirely the point of interest. The aim of the microscopic simulation is to understand the traffic down to the level of “microscopic” accuracy or in other words to the individual vehicle. The input data should be for the individual vehicle, e.g. different behaviour data of trucks and cars, and in addition, the results of the microscopic simulation are for the individual vehicle, e.g. maximum speed of the vehicle, and delay of each driver’s vehicle. The input and output data of macroscopic simulation should be as dynamic as possible.

2.1 Case study

In the study the wider surrounding area of BTC was taken into consideration, and was divided into zones with comparable land use within one cone. Conning of the study area is presented in the figure below (Figure 2). Information on existing traffic volumes was gained with the counting of the traffic, expected traffic volumes in the future were estimated based on the perceived annual growth data (based on the historical traffic data) and based on estimated additional traffic due to new traffic generators (new business and shopping facilities) determined according to Trip Generation [1].

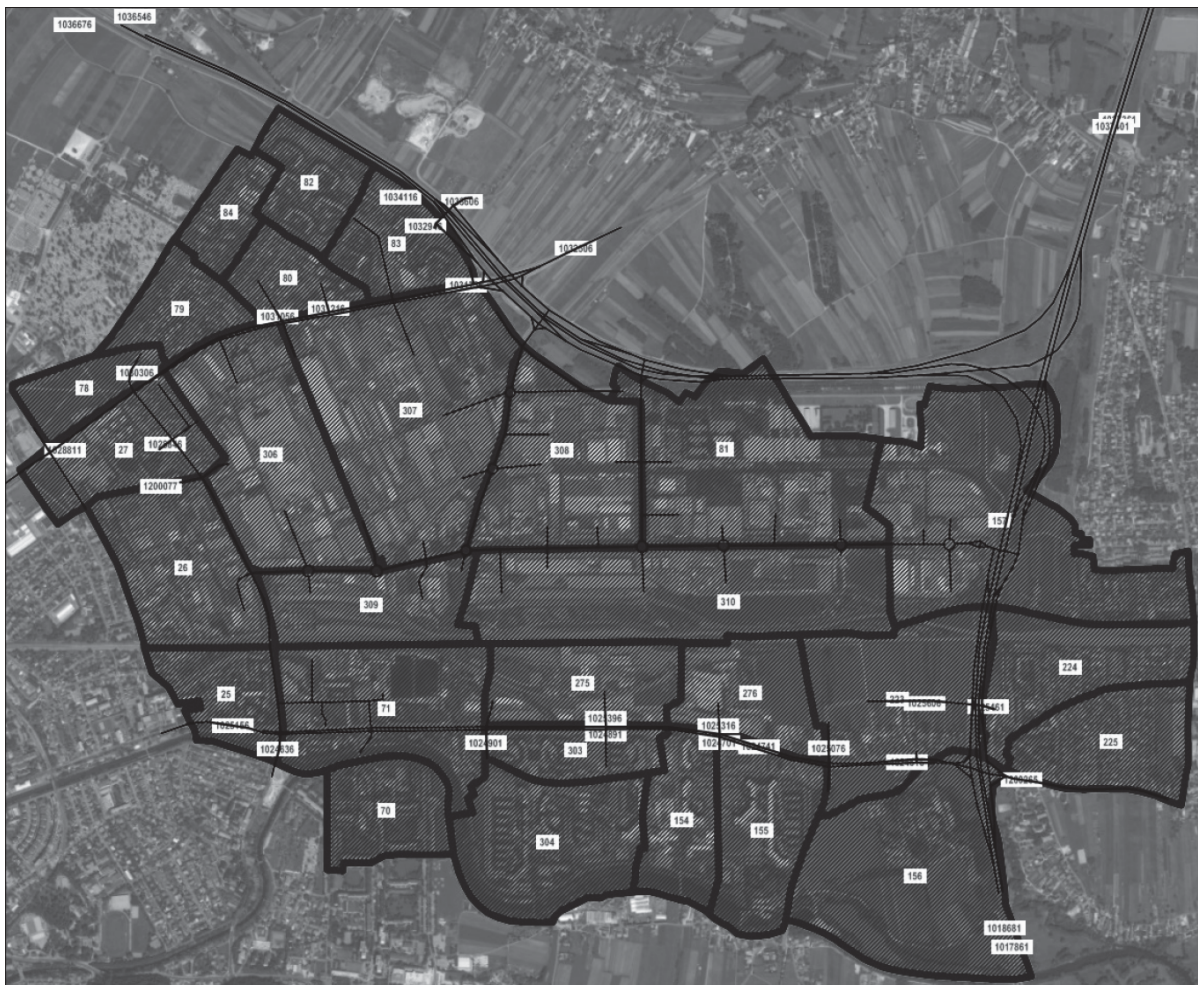


Figure 2 Conning of the study area

2.2 Macroscopic model

To begin with, the macroscopic simulation was used, where existing roads and present signal plans were implemented. Only calibrated models can be used in the research where changes in the traffic volumes or/and road network are examined. The model was carefully calibrated; that is, the parameters of the model were in the incremental process set to the values where maximal accordance between existing data (e.g. number of counted vehicles in real-life situations) and data obtained with the simulation (e.g. number of calculated vehicles in the same road section) were assessed. In the study presented in this paper, the appropriateness of the model was estimated in accordance with the Design Manual for Roads and Bridges [2]. The model for the peak hour is appropriate if the following two criteria are met:

1) 85 % of individual traffic flows have $GEH < 5$, where:

$$GEH = \sqrt{\frac{(TF_m - TF_c)^2}{0,5(TF_m + TF_c)}}, \quad \begin{array}{l} TF_m \dots \text{traffic flow obtained with the model} \\ TF_c \dots \text{traffic flow obtained with counting} \end{array} \quad (1)$$

2) on a maximum of 15 % of road sections the difference between traffic volumes obtained with the model and traffic volumes obtained with on-site counting can exceed the following criteria:

- for traffic flow < 700 veh/h, maximal difference is 100 veh/h;
- for traffic flow between 700 and 2,000 veh/h, maximal difference is 15 %;
- for traffic flow $> 2,000$ veh/h, maximal difference is 400 veh/h.

The results of the calibrated macroscopic model are traffic volumes for all roads in the study area, for different times of the day (peak hours), for different years, and for different categories of vehicles (cars, buses and heavy vehicles).

2.3 Microscopic model

With the microscopic simulation, calculated traffic volumes were used as the input data for the microscopic model where capacity analyses were conducted. To mimic the road situations as realistically as possible, the stochastic nature of the traffic was embraced with several re-runs of the simulation. Each run was conducted with a different random seed; that means that in each run of the simulation vehicles enter the road network at different times.

Within the project several possible solutions were tested and evaluated with the microscopic simulations; in this paper only existing situations and proposed solutions are presented (please see Figure 3 and Figure 4 below).

Variant 0 – existing situation

On Leskovškova cesta both intersections of the traffic flow from/towards the Ljubljana ring are controlled with traffic lights. At these intersections present peak hour traffic volumes lead to traffic jams, longer delays and queues. Taking into consideration additional traffic due to new land use in BTC the traffic situation would be unsustainable, and not only in the peak hours.

Variant 7 – proposed solution

With respect to the existing situation eight main changes to the road infrastructure are proposed, namely (numbering matches with Figure 4):

- 1) new overpass over Ljubljana ring for the direction east-west with the deviations of the north-east exit ramp;
- 2) south-west exit ramp merged with new overpass in the area on the south service road;
- 3) new turbo roundabout (diameter 40 m);

- 4) deviation of secondary road in the south;
- 5) new underpass (under Leskovškova cesta);
- 6) new connection between Leskovškova cesta and Bratislavská cesta;
- 7) east leg of turbo roundabout only towards Zadobrova;
- 8) existing north and south intersections with traffic lights are abolished since no level of crossing traffic flow will be present.



Figure 3 Existing situation at Leskovškova cesta



Figure 4 Proposed Variant 7 at Leskovškova cesta

3 Results

To propose the optimal variant of comprehensive capacity analysis including several different parameters, e.g. average delay per vehicle, number of vehicles that left the road network, average and maximal length of queues for separate network locations were conducted. In this paper the results for all tested variants and for traffic volumes characteristic for the afternoon peak hour in year 2028 are presented in the figures below. The comparison of the parameters, delay per vehicle (grey columns) and number of vehicles that left the network (black markings) is presented in Figure 5. One can see that Variant 7 outperforms other variants, since it enables the highest number of vehicles to leave the road network with the lowest average delay of the vehicles. Additionally, the average and maximal queues for all variants, for both peak hours and all year perspectives were analysed for all major intersections in the study area. In this paper only the results of the key intersection for the year 2028 are presented in Figure 7. The results of the analyses confirm Variant 7 to be the most appropriate.

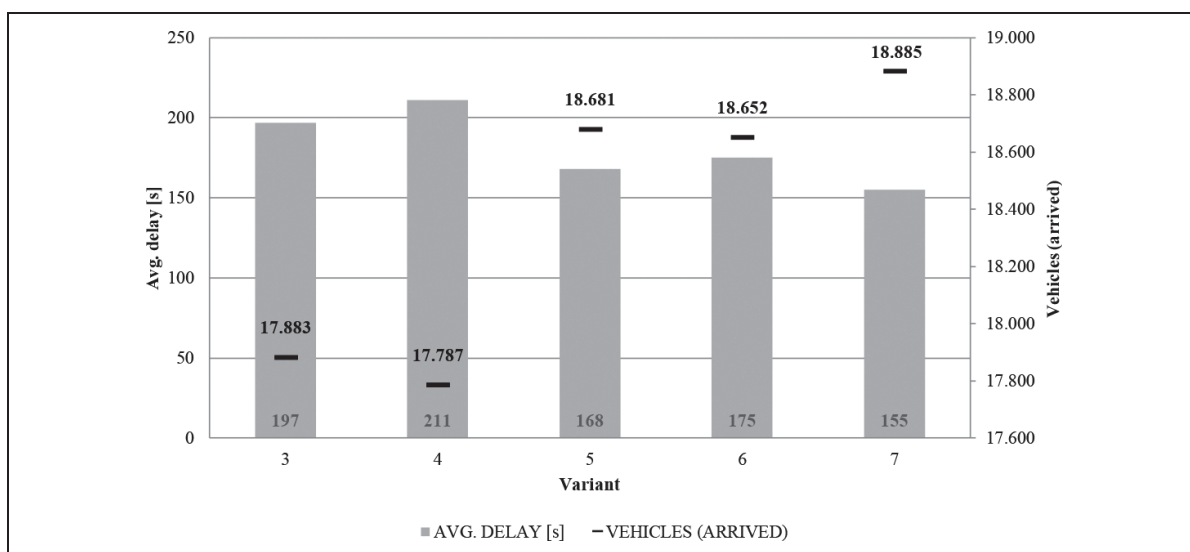


Figure 5 Average delay per vehicle and number of vehicles that left the network for all tested variants, for traffic volumes estimated in the afternoon peak hour in the year 2028

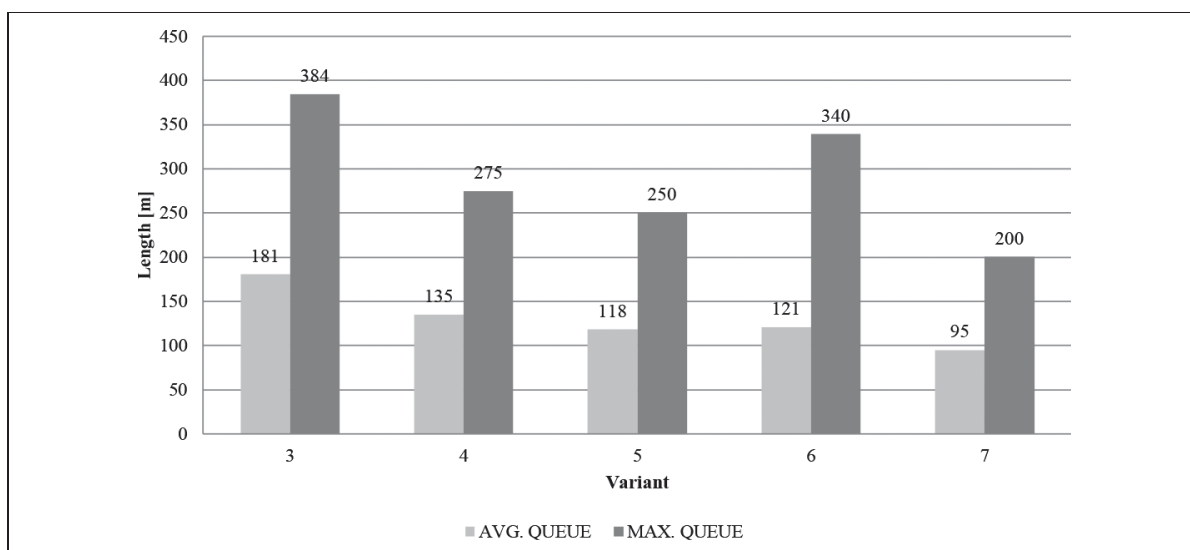


Figure 6 Average and maximal queues for all tested variants, for traffic volumes estimated for the afternoon peak hour in the year 2028

4 Conclusion

The study presented in this paper was conducted with the aim of finding the best possible solution for connecting Leskovškova cesta on the Ljubljana ring where personal and heavy vehicle traffic is evenly distributed on the roads influenced by trip generators in BTC. Today's traffic volumes lead to long queues stretching on the shoulder lane, which presents potential danger on the highway. Changes in the land use in the study area, and consequently evident changes in the traffic volumes require well considered changes in road infrastructure.

To select effective solutions for today and for the future, especially for critical ramps on Leskovškova cesta, both macroscopic and microscopic simulations were used. Trip distribution where all input data regarding road infrastructure and traffic parameters were implemented was calculated with the macroscopic simulation. The optimal solution was selected based on the results of microscopic simulations. The result is the variant where 2 existing intersections controlled with traffic lights are replaced with several infrastructure measures, which enable high capacity and high road safety. As in many other projects the computer aided simulations, expert knowledge, incremental variant optimization ... enabled development of the long-term best solution, where the impact of the investment is assessed well before the construction starts.

Case study presented in this paper presents usefulness of the computer-based traffic flow simulation tool on one test instance. Nevertheless, simulation tools can be used for different size problems (from intersection to large road network), for different road types (from rural road to highway), and can mimic different characteristics of drivers. So, state-of-the-art simulators enable building any user-defined road network, simulation of specific characteristics of the traffic including different driving culture in different countries and calculate several parameters (e.g. average delay, queues) important for the decision on optimal variant. Therefore, the use of the traffic simulation tools can be (and should be) main support for decision makers in the process of organization and traffic management in modern urban conditions. Experiences presented in this paper are valid for almost all capitals and other major cities in Europe.

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