CETRA2024 15-17 May 2024, Cavtat, Croatia
8th International Conferenceon Road and Rail Infrastructure

OPTIMISING SIGNALISED INTERSECTION-ROUNDABOUT DISTANCE: INSIGHTS FROM MICROSIMULATION ANALYSIS

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Abstract

While roundabouts have been proven to reduce traffic congestion and improve safety, integrating them into a network of signalised intersections can pose challenges for maintaining efficient traffic flow. This preliminary study examines acceptable signalised intersection-roundabout distance using microsimulation analysis. The VISSIM model was designed using field data from seven roundabouts in Rijeka, Croatia, and various traffic parameters, including vehicle delay, queue lengths, fuel and CO emissions, were analysed. The findings reveal that roundabout performance improves with lower peak-hour traffic, while closer proximity to signalised intersections worsens congestion. This research underscores the importance of careful planning and consideration of traffic dynamics in optimising roundabout functionality within urban road networks.

Keywords: roundabouts, microsimulations, traffic models, roundabout-signalised intersection distance, VISSIM

1 Introduction

Roundabouts are effective solutions for reducing traffic congestion, improving travel time [1], safety [2], and reducing maintenance costs [3]. However, not all intersections are suitable for roundabouts, especially those with unbalanced traffic flows or located in a network of traffic signals [4, 5]. Croatian Guidelines [5] recommend evaluating various aspects before choosing a roundabout. Recent research has focused on the interplay between intersections, especially in the United States [6]. Placing a roundabout between two adjacent signalised intersections can disrupt traffic flow and reduce corridor efficiency [7]. To assess the impact of roundabouts on traffic flow, microsimulations are used to model individual vehicle movements and calculate variables such as capacity, delays, queue lengths, and safety issues [8, 9]. While literature [5, 6] advises against placing a roundabout between two adjacent signalised intersections, there is a lack of clear guidance on the optimal - or rather, acceptable signalised intersection-roundabout distance. The idea of this research is to explore the problem by applying the traffic microsimulation method.

2 Materials and methods

The study analysed seven medium-sized urban roundabouts in Rijeka, Croatia, to build a microsimulation model in VISSIM. Data was recorded continuously using Datacollect SRD radar traffic counters for 24 hours on an average day (Wednesday and Thursday). The analysis showed that between 10 000 and 23 000 vehicles pass through the roundabouts daily. The field tests provided insights into traffic volumes, vehicle composition and peak-hour traffic.

DOI: https://doi.org/10.5592/CO/CETRA.2024.1735

The microsimulation model was built as a standard urban roundabout of medium size, featuring an outer radius of 17 m, circulatory roadway width of 6 m, entry radius of 15 m, and exit radius of 16 m. The defined approach speed for the main flow is 50 km/h, while for the minor flow, it is 40 km/h; all approaches are two-way. For less complex and more relevant results, the ideal approach position without pedestrian interference was used (as shown in Figure 1).

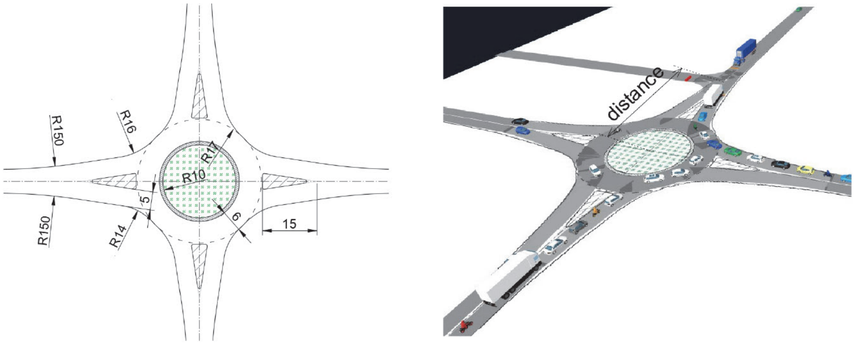

Figure 1 Geometry of the microsimulation model (left); VISSIM model (right)

The Guidelines [5] recommend against using a roundabout if more than 75% of daily traffic passes through the main direction. Ideally, the traffic should be uniformly distributed between directions. The Guidelines, however, do not specify any limitations on the number of vehicles during peak hours. Based on limitations and field data, this preliminary study analysed the least favourable scenarios of 70:30 major-to-minor flow radios in two variants: 6% and 9% of the maximum capacity of a medium-sized roundabout (Table 1).
The next step involved conducting a microsimulation to evaluate the effect of a signalised intersection on the adjacent roundabout (Figure 1). A three-leg signalised intersection was added to the network, located at a distance of 40-120 meters from the roundabout's central point. To ensure that both intersections were properly integrated, a minimum distance of 40 m was established, while the upper limit of 120 meters was determined based on previous research [10], which indicated that mutual influence no longer exists beyond that distance. The optimal LOS for signalised intersection was obtained for a cycle of 70 seconds. In accordance with recommendations [11], ten simulations of the process were carried out for each variant, with the average value being utilised. In total, 20 simulations of a single roundabout and 60 simulations of the impact of a signalised intersection on an adjacent roundabout were carried out.

Table 1 Microsimulation models

Model	**Var**	**Distance**	**Capacity** [veh/day]	**Peak hour traffic** [%]	**Peak hour volume** [veh/h]	**Ratio** [%]
1	A	40 m	20 000	6%	1200	70:30
	B	120 m				
2	A	40 m	20 000	9%	1800	70:30
	B	120 m				

3 Preliminary findings

The analysis was done in two steps. Firstly, the functionality of the single roundabout was evaluated under a given traffic load. The results included Average Queue Length, Number of vehicles, Level of Service (LOS), Vehicle Delay, Stop Delay, Number of stops, Emission of CO and Fuel Consumption. The study revealed that Model 2 experienced significant traffic congestion, with 320 vehicles (18%) unable to pass through the roundabout. Additionally, Model 2 showed higher values of all parameters, with vehicle delay being 3.12 times higher and emission of CO and fuel consumption being 2.83 times higher than Model 1. LOS for Model 1 is acceptable (class B), while for Model 2, it is unacceptable (class E).
The second step involved observing the influence of the signalised intersection on the adjacent roundabout's capacity. Model 1, which had lower peak-hour traffic, showed no signs of traffic congestion. Interestingly, the distance between intersections didn't have a significant impact on traffic flow. A smaller distance of 40 meters resulted in a 1.1-second reduction in vehicle delay (Figure 2). In Model 2, the closer intersection distance led to significantly higher values of the traffic parameters. During peak hour, 18% of vehicles were unable to pass through the roundabout. In Model 2A, vehicle delay increased by 4.3 seconds, and the queue length was 3.2 meters longer. Comparing Models 1 and 2, it is evident that lower peak-hour traffic corresponded to significantly better values. Model 1A has a 25.3 m shorter queue length, 33.5 seconds lower vehicle delay, and 2.6 times lower fuel consumption and CO emission.

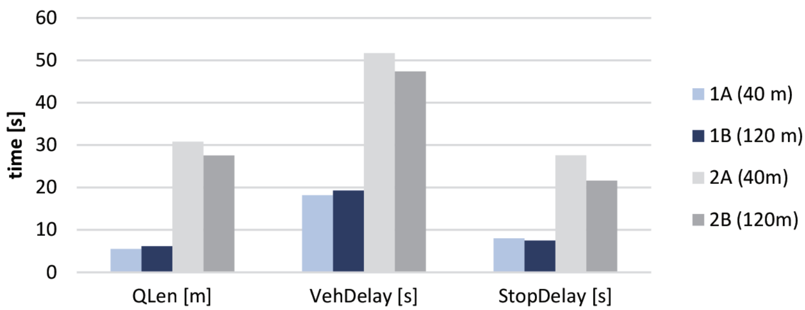

Figure 2 Traffic parameters: signalised intersection-roundabout influence

4 Conclusion and future remarks

During peak hours, the distance between a roundabout and an adjacent signalised intersection can have a significant impact on the roundabout's capacity. While Croatian Guidelines for Roundabouts only provide recommendations for daily capacity, research has shown that peak load can cause underperformance of the roundabout, as evidenced by 9% peak-hour daily traffic results. At a 40 m distance, up to 353 vehicles were unable to pass through the roundabout during peak hour due to queueing at the red light. However, a model with the same daily capacity and traffic structure but a lower peak load of 6% (Model 1) demonstrated uninterrupted traffic flow. This model boasts a stable B free flow LOS, a 34-second reduction in vehicle delay, a 25-meter decrease in queue length, and a 20-second reduction in stop delay. The preliminary study found that lower peak-hour traffic at the same daily capacity resulted in significantly better traffic parameters. Additionally, the distance between intersections played a significant role in Model 2 but not in Model 1.

Future research will further explore the impact of intersection distance on roundabout capacity and determine the extent of negative effects based on various traffic conditions. The study will also include pedestrians in the model, as small and medium-sized roundabouts are mainly found in urban areas. Finally, the model will be validated by comparing it with the roundabout's performance in a real situation.

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