Traffic Flow Analysis of Closely Spaced Roundabouts and Signalized Intersections

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Abstract. Heterogeneous traffic flow conditions in urban areas often result in reduced traffic efficiency, safety issues, and increased environmental impacts. Roundabouts are often seen as solutions to all of these issues; however, when located in close proximity to signalized intersections, their operational advantages may be significantly reduced. The main issue associated with the close spacing of roundabouts and signalized intersections arises from interrupted vehicle movements at signalized intersections, in contrast to the continuous flow characteristic of roundabouts. This paper presents part of a broader research focused on analyzing operational performance and optimizing the distance between roundabouts and signalized intersections. The presented study is based on a real-world traffic network in a small, highly touristic town in Croatia (Poreč). A VISSIM traffic microsimulation model was developed and calibrated, using travel time data, for a network segment consisting of a roundabout and a signalized intersection spaced 125 m apart. Traffic performance was evaluated using selected traffic indicators. The analysis included the existing traffic configuration and a hypothetical scenario in which the roundabout is functioning independently. Both measured traffic demand and a theoretically defined maximum traffic load (ADT 20,000) were considered under identical geometric and location conditions. The results provide insights into the impact of closely spaced intersections on traffic performance and support the need for careful consideration of intersection spacing in urban traffic planning.

Keywords: roundabout · intersection interaction · traffic microsimulations · urban network · signalized intersection

1 Introduction

Roundabouts are often seen as solutions for both traffic flow and traffic safety challenges in urban road networks. However, when located in close proximity to signalized intersections, their operational advantages may be significantly reduced. The main issue associated with the close spacing of roundabouts and signalized intersections arises from interrupted vehicle movements at signalized intersections, in contrast to the continuous

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flow characteristic of roundabouts. Although this problem has been recognized by the professional and scientific community, it has not been researched in detail, and there are no clear recommendations regarding the conditions under which roundabouts and signalized intersections can be combined in the same corridor.

Technical guidelines and regulations in Europe and worldwide predominantly address isolated roundabouts, focusing on geometric design elements and performance comparisons with conventional at-grade intersections. A broader international comparison of roundabout design practices was presented by Nikiforiadis et al. [1], who reviewed roundabout guidelines from the UK, France, Germany, the Netherlands, the USA, and Australia. Their study showed that, although similar geometric design elements are commonly considered, the detailed design principles and recommended values differ among countries. They also emphasized that roundabout design involves balancing capacity and safety, since increasing entry, exit, or circulatory lanes may improve capacity but can also increase vehicle speeds and reduce safety. These differences indicate that roundabout performance cannot be evaluated solely on the basis of isolated geometric design characteristics, but must also be considered in relation to local traffic demand, operational conditions, and the wider network context.

A similar analysis of the guidelines from selected EU countries and the USA, from the aspect of the functioning of the roundabout adjacent to the signalized intersection, done in this research, shows that the recommendations generally conclude that such a combination is not advisable, though they often lack more detailed explanations [2–5]. In German [2], Norwegian [5], and UK [5] guidelines the use of a double (or large) roundabout is suggested when the center-to-center spacing is less than 100 meters, with a minimum allowable spacing of 40 meters in the double-roundabout configuration. The US guidelines [6] define a distance of less than 150 m as critical between the roundabout and signalized intersection, and in such cases, a detailed corridor-level microsimulation analysis is recommended.

Research on this topic in the available scientific literature is still limited and relatively recent.

In 2025 [7] a study was published on two corridors in different countries (Italy, France) under similar conditions in which a series of urban traffic signalized intersections were partially or completely replaced by roundabouts. The results showed that corridors composed entirely of roundabouts do not necessarily provide the best balance between traffic performance and safety. In Pisa, the most efficient configuration included four roundabouts and one signalized intersection, while the safest included three roundabouts and two signalized intersections. In Avignon, the best results were achieved with roundabouts combined with strategically placed signalized intersections. Consequently, the study highlights that optimal corridor performance is achieved not through uniformity, but through carefully balanced combinations tailored to local traffic and safety conditions.

Previous research by this group of authors based on a theoretical traffic microsimulation model of the interaction of roundabouts and traffic signalized intersections [8] in different traffic and distance conditions, enabled the definition of parameters that significantly affect the quality of traffic flows when a roundabout is in close proximity to signalized intersection. By varying the distance between intersections (40-120 m), the

volume and distribution of traffic, it was found that all of the above factors affect the quality of traffic flows. The impact of intersection spacing was particularly pronounced when it came to smaller distances (40-60 m), while at a distance of 100 m the intersection combination had almost the same traffic performance as the case of isolated roundabouts under the same traffic conditions. This research motivated the investigation of the interaction of roundabouts and traffic lights based on real traffic conditions presented in this paper.

This study is based on a real traffic network in Poreč, a small tourist town in Croatia. A VISSIM microsimulation model was developed and calibrated using travel time data for a road segment that includes a roundabout and a signalized intersection spaced 125 m apart. Traffic performance was assessed using selected indicators under both the existing configuration and a hypothetical scenario in which the roundabout operated independently. The aim was to evaluate the impact of the signalized intersection on roundabout performance. Both measured traffic demand and a theoretical maximum traffic load (ADT 20,000) were analyzed under the same geometric and locational conditions. The results highlight the effects of closely spaced intersections on traffic performance using real-world data.

The structure of the paper is organized as follows. Sect. 2 details the materials and methods, including field measurements, the development and calibration of the VISSIM microsimulation model, and the definition of the analyzed scenarios. Section 3 presents and compares the simulation results for both the existing roundabout-signalized intersection configuration and the isolated roundabout scenario across varying traffic demand levels. Finally, Section 4 summarizes the key findings, discusses their implications for urban traffic planning, and suggests directions for future research.

2 Materials and Methods

The methodological framework of this study is presented in Fig. 1. Field measurements were conducted in Poreč, Croatia, to obtain design and traffic parameters for the analyzed network segment, which consists of a roundabout and a signalized intersection. Based on the field data, a traffic microsimulation model was developed in PTV VISSIM. The model was calibrated against observed travel time data to achieve a reliable representation of existing traffic conditions. The analysis included the existing traffic configuration, which reflects the interaction between the roundabout and the signalized intersection, as well as a hypothetical scenario in which the roundabout operated as an isolated intersection. For each scenario, two traffic volume levels were considered: the measured real traffic volume and a theoretically defined maximum traffic load of 20,000 vehicles per day (ADT 20,000). Traffic performance was then evaluated using selected traffic indicators.

2.1 Field Measurements

The study area is situated in the city of Poreč, Croatia, within a predominantly residential area adjacent to the historic town center, a shopping plaza, and the main municipal parking facility (Fig. 2).

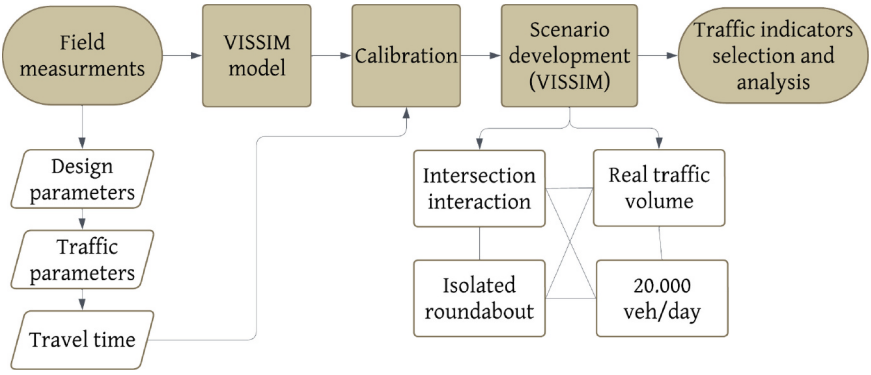

Fig. 1. Research methodology



Fig. 2. Geographical location of the case study area (Google Maps)

The analyzed network segment comprises a roundabout and a signalized intersection located 125 m apart, as shown in Fig. 3.

The measurements were conducted in July and as Poreč is a well-established summer tourist destination, a considerable proportion of traffic at these intersections was generated by tourists, leading to increased variability in driver behavior.

The analyzed roundabout has an outer radius of 18 meters and, according to the Croatian Guidelines for Roundabout Design [9], is classified as a medium-sized urban roundabout. Under these guidelines, the recommended maximum capacity (ADT) for a roundabout of this size is 20,000 vehicles per day. Figure 4 shows the geometric elements of the analyzed roundabout. The adjacent signalized intersection is a four-leg intersection operating with a two-phase signal timing plan. The cycle length is 70 s, with



Fig. 3. Analyzed network segment (Google Maps)

the green interval of the first phase lasting 40 s, followed by 2 s of red-amber, 25 s of red, and 2 s of amber.

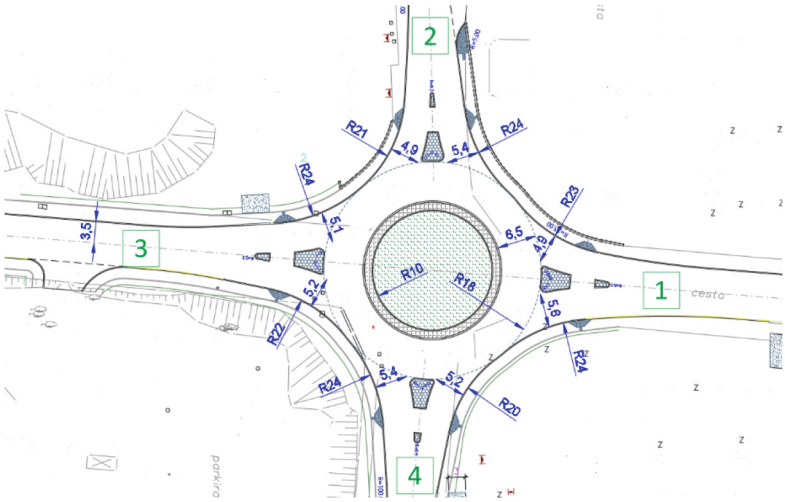

Fig. 4. Design elements of the roundabout

In addition to design elements of the roundabout, field measurements were conducted to collect data on traffic volume and traffic structure using equipment from the Transportation Laboratory of the Faculty of Civil Engineering, University of Rijeka. Traffic counters Datacollect SRD were used to continuously record traffic flow on every approach (in both directions) over a 24-hour period on Tuesday, July 16 2024. The results are shown in Table 1.

Table 1. Traffic data

Approach	Traffic structure			Daily traffic volume	Peak traffic volume (*veh/h)*	
	car	*truck*	*HGV*	*veh/day*	07:00-08:00	15:00-16:00
1	97.3%	2.7%	0.0%	2208	132	141
2	97.7%	2.3%	0.0%	3139	193	275
3	98.1%	1.7%	0.1%	5063	312	357
4	98.8%	1.2%	0.0%	3542	202	218

A daily traffic volume of 13,952 vehicles was recorded, with 991 vehicles observed during the afternoon peak hour, accounting for 7.1% of the daily total. Passenger cars account for the largest share of vehicles, while the proportion of heavy goods vehicles (HGVs) is almost negligible.

Travel time was measured during the afternoon peak hour (15:00 – 16:00) to evaluate the travel times between designated control points, specifically from Point 1 to Point 2, as shown in Fig. 2, along a 300-meter route. The data collection was carried out using the GeoTracker GPS application, which provides high-resolution measurements for both route length and travel duration. A passenger vehicle was driven by three different drivers to collect the data. Travel times were recorded from 15 independent vehicle passes through both the roundabout and the adjacent signalized intersection. Descriptive statistics for the measured travel times are summarized in Table 2.

Table 2. Descriptive statistics of measured travel time

	Nbr. of observations	Minimum	Maximum	Median	Mean	Standard deviation
Travel time (s)	15	47.00	107.00	54.00	60.33	15.32

2.2 Development and Calibration of the VISSIM Model for the Existing Traffic Configuration

Based on field measurements conducted in the city of Poreč, a microsimulation model of a selected segment of the traffic network was developed using VISSIM (Fig. 5).



Fig. 5. VISSIM model of the analyzed traffic segment

PTV VISSIM is a microscopic, multimodal traffic simulation software that models the movements and interactions of individual vehicles, pedestrians, cyclists, and public transport with great detail.

The analyzed network segment was modeled in PTV VISSIM using links and connectors to reproduce the geometry of the roundabout, the connecting road section, and the adjacent signalized intersection. Vehicle inputs were assigned according to the measured approach volumes, while the observed traffic composition was used to define the vehicle classes. The existing two-phase signal-control plan was implemented using the measured cycle length and phase durations. Priority rules and conflict areas were adjusted to reproduce vehicle interactions at the roundabout entries and along the short section between the roundabout and the signalized intersection.

To ensure data accuracy, the VISSIM model was calibrated using travel time data. Travel time was chosen because it encompasses key aspects of driver behavior, including desired speeds, reaction times, vehicle interactions, and queue formation, thereby providing a comprehensive overview of traffic flow dynamics. Moreover, this metric is relatively straightforward and offers precise measurements. Existing research supports the use of travel time as an effective calibration criterion across diverse traffic conditions [10–12].

The model calibration regarding travel time was conducted over a 300 m route connecting designated points 1 and 2 (Fig. 3). This route included traversing a roundabout and a signalized intersection. The calibration process involved comparing simulated travel times with actual travel times recorded during field measurements (Sect. 2.1). The calibration criterion [10] was defined by Eq. (1):

$$\left| \frac{T_{MOD} - T_{MEAS}}{T_{MEAS}} \right| \leq 5\% \tag{1}$$

where T_{MOD} presents the mean model-predicted travel time between reference points, and T_{MEAS} indicates the mean measured travel time between the same points. The model is considered calibrated when the above condition is satisfied.

For calibration, the following parameters were adjusted:

- Random seed increment (default=2, calibrated=6)

- Average standstill distance (m) (default=2, calibrated=2.8)
- Additive part of the desired safety distance (m) (default=2, calibrated=2.7)
- Multiplicative part of the desired safety distance (m) (default=2, calibrated=3.5)

The random seed increment determines the step size for the random number generator, resulting in different stochastic values within the model. The other three parameters pertain to driver behavior as outlined by the Wiedemann 74 car-following model, which is particularly well-suited for urban traffic networks.

The results of the travel time comparison are shown in Table 3.

Table 3. Comparison of travel times – VISSIM models and field measurements

	T_{MEAS} (s)	T_{MOD} (s)	Relative deviation
Route (300 m)	60.33	59.30	1,71 %

2.3 Development of Alternative Scenarios Using the Traffic Microsimulations

Following model calibration, additional scenarios were developed to examine the effects of traffic demand and of the spacing between the roundabout and the signalized intersection on key traffic performance measures.

A total of four scenarios were analyzed, as shown in Fig. 1:

- Scenario 1 (RB-SI) – Existing site configuration with the current traffic volume of 13,952 veh/day
- Scenario 2 (RB-SI_20k) – Existing site configuration with increased roundabout traffic volume of 20,000 veh/day
- Scenario 3 (Isolated RB) – Isolated roundabout scenario with the current traffic volume
- Scenario 4 (Isolated RB_20k) – Isolated roundabout scenario with increased traffic volume of 20,000 veh/day

In the isolated-roundabout scenarios, the downstream signalized intersection was removed from the operational influence of the roundabout while maintaining the same roundabout geometry, approach distribution, and traffic composition. This allowed the effect of the nearby signalized intersection to be isolated from the effects of traffic demand and roundabout geometry (Figure 6).

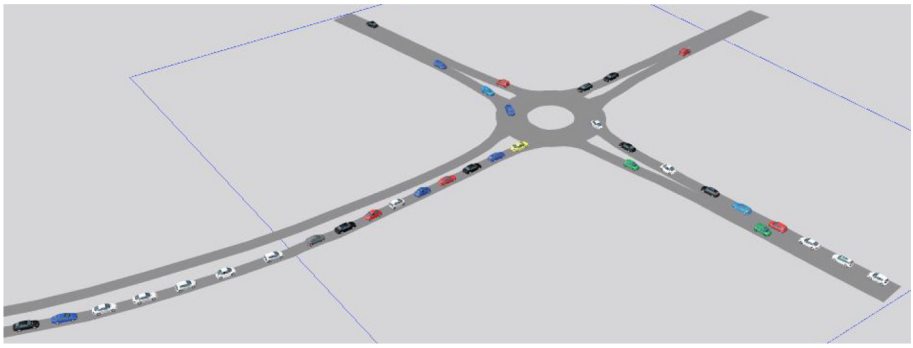

Fig. 6. VISSIM model – Scenario 4 – Isolated roundabout (ADT 20,000 veh/day)

The value of 20,000 vehicles per day was adopted as the maximum recommended Average Daily Traffic (ADT) for roundabout of this size according to the Croatian guidelines [9]. Microsimulations were conducted over a 24-hour period, with 10 simulation runs performed to ensure the reliability of the results.

The traffic performance analysis was based on several measures obtained from the VISSIM simulation model.

Average Queue Length represents the mean queue length observed during the simulation period and serves as an indicator of typical congestion levels at the analyzed location. Maximum Queue Length identifies the highest recorded queue length and is particularly relevant for detecting peak congestion and potential spillback effects.

Level of Service (LOS) represents a qualitative classification of traffic operating conditions based on vehicle delay. It ranges from LOS A, indicating free-flow or very favorable operating conditions with low delays, to LOS F, indicating oversaturated conditions with high delays and poor traffic performance [13, 14].

Vehicle Delay expresses the average time loss per vehicle relative to ideal travel conditions, that is, conditions without interference from other vehicles, traffic signals, or stopping events. As such, it directly quantifies the operational inefficiency experienced by users. Stop Delay specifically measures the portion of this delay caused by stopping.

Travel Time represents the average time required for every vehicle to traverse the analyzed route segment from the roundabout to the signalized intersection.

3 Results

The key traffic indicators obtained from the microsimulation analysis for all four scenarios are presented in Table 4. The comparison includes the roundabout–signalized intersection configuration (RB-SI) and the isolated roundabout configuration (Isolated RB), each under existing traffic demand and under an increased demand level of 20,000 veh/day. The reported VISSIM measures include Average Queue Length (QLen), Maximum Queue Length (QLenMax), Level of Service (LOS, A-F, where A represents free-flow and F represents oversaturated conditions), Vehicle Delay (VehDelay), Stop Delay, and vehicle travel time from roundabout to signalized intersection (Travel Time).

Table 4. Traffic indicators obtained from the VISSIM for the analyzed scenarios

	QLen	QLen Max	LOS	Veh Delay	Stop Delay	Stops	Travel Time
	m	*m*		*s/veh*	*s/veh*		*s*
RB-SI	4.91	88.69	C	17.14	8.05	1.17	60.33
Isolated RB	5.32	88.09	B	13.85	5.76	1.03	54.31
RB-SI_20k	72.42	266.3	F	79.30	42.42	5.16	68.12
Isolated RB_20k	71.71	257.68	F	78.28	37.90	5.62	60.59

The simulation results indicate that, under existing traffic demand, the isolated roundabout outperformed the roundabout–signalized intersection interaction scenario. In the interaction scenario (RB-SI), the average vehicle delay was 17.14 s/veh, travel time was 60.33 s, and the system operated at LOS C. In contrast, the isolated roundabout scenario produced lower delay (13.85 s/veh) and shorter travel time (54.31 s), with an improved LOS B. This corresponds to a 19.2% reduction in vehicle delay and a 10.0% reduction in travel time. Stop delay was also reduced by 28.4%, while the average number of stops decreased by 12.0%. These findings suggest that the nearby signalized intersection adversely affects roundabout performance under normal demand conditions.

When traffic volume was increased to 20,000 veh/day, both configurations operated under oversaturated conditions and reached LOS F. In the interaction scenario, vehicle delay increased to 79.30 s/veh and travel time to 68.12 s, whereas the isolated roundabout scenario yielded slightly lower values of 78.28 s/veh and 60.59 s, respectively. Relative to the interaction scenario, the isolated roundabout reduced vehicle delay by 1.3%, travel time by 11.0%, and stop delay by 10.7%. However, the average number of stops increased by 8.9%, indicating that although vehicles experienced more interruptions, the overall time spent in the system was still lower.

Comparison of the selected traffic indicators is shown in Fig. 7.

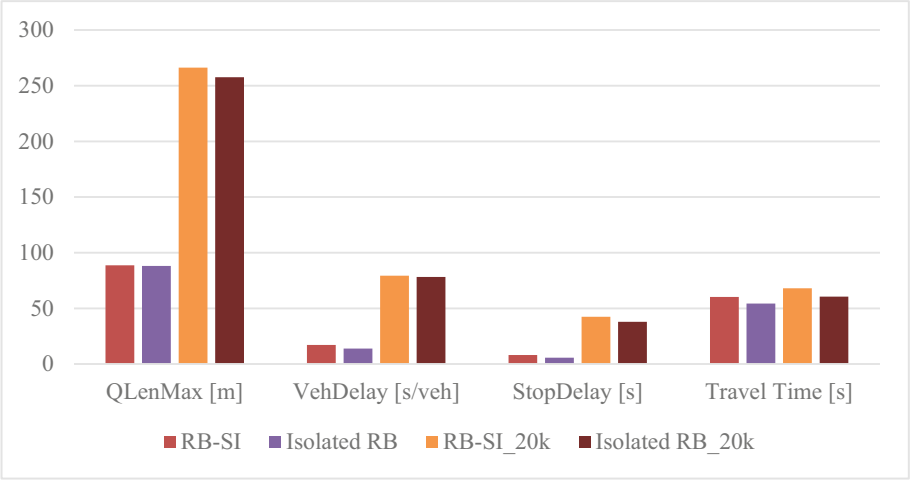

Fig. 7. Comparison of selected traffic indicators for the analyzed scenarios under current and increased traffic demand

Overall, the results show that eliminating the interaction between the roundabout and the nearby signalized intersection improves operational performance under current traffic conditions. However, when traffic demand approaches 20,000 veh/day, both layouts experience substantial deterioration, indicating that traffic demand becomes the dominant factor governing system performance.

4 Conclusion

This study examined the operational performance of a roundabout located in close proximity to a signalized intersection by using a calibrated VISSIM traffic microsimulation model based on experimentally gathered data from the City of Poreč, Croatia. Two traffic configurations were evaluated: the existing roundabout–signalized intersection interaction and a hypothetical isolated roundabout scenario. Each configuration was analyzed under both measured traffic demand and an increased demand level of 20,000 veh/day.

The results showed that, under existing traffic demand, the isolated roundabout performed more efficiently than the interacting configuration. Lower vehicle delay, lower stop delay, fewer stops, shorter travel time, and a better level of service were observed when the roundabout was not affected by the nearby signalized intersection. This suggests that closely spaced intersections can reduce the operational benefits typically associated with roundabouts, which is consistent with previous studies [8, 15, 16].

Under increased traffic demand, both configurations reached oversaturated conditions and operated at LOS F. Although the isolated roundabout still provided slightly better results in terms of delay and travel time, the differences between the two configurations became much smaller. This suggests that once traffic demand approaches the practical capacity of the roundabout, the effect of intersection interaction becomes secondary to the overall traffic volume. This is consistent with previous research [8, 17, 18], which confirms that traffic volume is the dominant factor affecting the operational

performance of a roundabout. Although the Guidelines [9] specify a maximum daily capacity of 20,000 vehicles/day for a medium-sized roundabout, in this case, with 7.1% of the daily traffic occurring during the peak hour, this traffic volume resulted in an unacceptable level of service, LOS F. These results suggest that, in addition to total daily traffic volume, the percentage of daily traffic occurring during the peak hour is also a highly influential factor, and further research is needed in this area.

The study has several limitations. It is based on a single case study with a fixed spacing of 125 m and specific geometric, traffic, and signal-control conditions, so the findings cannot be directly generalized to all urban networks. In addition, pedestrian flows and pedestrian–vehicle interactions were not analyzed, although they may affect traffic performance in urban areas.

The results highlight an important implication for urban traffic planning: the suitability of a roundabout cannot be reliably assessed using isolated-intersection analysis alone; it should be evaluated in relation to its position within the wider urban traffic network. This is especially relevant when a roundabout is located near a signalized intersection, as their interaction may significantly affect delays, queue formation, and overall corridor performance. Accordingly, corridor-level evaluation is essential, while microsimulation represents a practical tool for capturing these interdependent effects. Future research should further explore these relationships under different traffic demands, control strategies, and network settings.

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Disclosure of Interests The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Nikiforiadis, A., Nikiforiadis, A., Mitropoulos, L., Basbas, S., Campisi, T.: International design practices for roundabouts. In: Lecture Notes in Computer Science, vol. 14111, pp. 308–326. Springer, Heidelberg (2023). https://doi.org/10.1007/978-3-031-37126-4_21/SAVE-RESEARCH
2. Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV): Richtlinien für die Anlage von Kreisverkehren. FGSV, Köln (2006)
3. Centre d'études et d'expertise sur les risques: l'environnement, la mobilité & l'aménagement (Cerema): Guide des carrefours urbains. Cerema, Lyon (2010)
4. Centrum voor Regelgeving en Onderzoek in de Wegenbouw en de Verkeerstechniek (CROW): Richtlijn rotondes (Publicatie 257). CROW, Ede (2015)
5. National Highways: Geometric design of roundabouts. National Highways, UK (2023)
6. Wisconsin Department of Transportation: Facilities Development Manual (T439). WisDOT, Wisconsin (2022)

7. Brocchini, L., Pratelli, A., Josselin, D., Losa, M.: A microsimulation-based methodology for evaluating efficiency and safety in roundabout corridors: case studies of Pisa (Italy) and Avignon (France). Infrastructures. **10**, 186 (2025). https://doi.org/10.3390/INFRASTRUCTURES10070186
8. Klobučar, M., Deluka-Tibljaš, A., Šurdonja, S., Ištoka Otković, I.: A theoretical model for optimizing signalized intersection and roundabout distance using microsimulations. Future Transp. **5**, 28 (2025). https://doi.org/10.3390/FUTURETRANSP5010028
9. Hrvatske ceste: Smjernice za projektiranje kružnih raskrižja na državnim cestama. Hrvatske ceste, Rijeka (2014)
10. Ištoka Otković, I., Tollazzi, T., Šraml, M., Varevac, D.: Calibration of the microsimulation traffic model using different neural network applications. Future Transp. **3**, 150–168 (2023). https://doi.org/10.3390/FUTURETRANSP3010010
11. Park, B., Qi, H.: Development and evaluation of a procedure for the calibration of simulation models. Transp. Res. Rec. **208**, 208–217 (2005). https://doi.org/10.1177/0361198105193400122
12. Toledo, T., Ben-Akiva, M.E., Darda, D., Jha, M., Koutsopoulos, H.N.: Calibration of microscopic traffic simulation models with aggregate data. Transp. Res. Rec. **1876**, 10–19 (2004). https://doi.org/10.3141/1876-02
13. PTV Group: PTV VISSIM 10: User Manual. PTV Group, Karlsruhe (2022)
14. Nedevska, I., Ognjenović, S., Murgul, V.: Methodology for analysing capacity and level of service for roundabouts with one lane (HCM 2000). Procedia Eng. **187**, 797–802 (2017). https://doi.org/10.1016/J.PROENG.2017.04.442
15. Hallmark, S., Fitzsimmons, E.J., Isebrands, H.N., Giese, K.: Roundabouts in signalized corridors: evaluation of traffic flow impacts. Transp. Res. Rec. **2182**, 139–147 (2010). https://doi.org/10.3141/2182-18
16. Akçelik, R.: Modeling queue spillback and nearby signal effects in a roundabout corridor. In: Proceedings of the TRB 4th International Roundabout Conference (2014)
17. Retting, R.A., Mandavilli, S., Russell, E.R., McCartt, A.T.: Roundabouts, traffic flow and public opinion. Traffic Eng. Control. **47**, 268–272 (2006)
18. Li, H., Li, J., Yang, Z., Wu, J., Chen, X.: Micro-simulation study on capacity of roundabout. In: Proceedings of the IEEE Conference on Intelligent Transportation Systems (ITSC), Washington, pp. 852–857. IEEE (2011)