



APPLICATION OF MICROSIMULATIONS IN ASSESSING THE IMPACT OF A GARAGE ON THE FUNCTIONAL AND SAFETY CHARACTERISTICS OF AN INTERSECTION

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Abstract

Parking represents a major challenge for urban planners, as the location of parking facilities significantly influences traffic demand and user behavior. Their availability and spatial distribution affect the choice of mobility modes, travel time, and congestion levels in city centers. Excessive planning of parking capacities may encourage the use of private vehicles, while integrating garages with public transport contributes to a more sustainable transport system. Therefore, analyzing the role of garages in urban planning is essential for developing efficient and environmentally friendly traffic strategies. When selecting optimal locations for garage construction, it is important to consider that such infrastructure acts as a significant traffic pull-factor, requiring an assessment of its impact on the existing traffic infrastructure within the influence zone. This paper analyses the impact of a garage on the functional and safety characteristics of a nearby signalized intersection within the traffic network of the city of Osijek. Functional characteristics of the intersection during peak hour were compared for two scenarios – with and without the garage – using microsimulation traffic modelling. Safety characteristics were assessed through conflict point analysis for both scenarios within the same time frame, using two expert models: a Microsimulation Model and the Surrogate Safety Assessment Model (SSAM).

Keywords: parking, garage, intersection, impact assessment, microsimulation, SSAM

1 Introduction

Parking policy directly influences transport demand and driver behavior, while the availability and price of parking, access to information, distance, and the supply of public urban transport all shape the choice of urban mobility modes [1-3]. Off-street parking offers several advantages that make it an essential component of efficient urban mobility systems [1, 4]. By removing parked vehicles from streets, off-street parking improves traffic flow and overall network performance [2, 5]. Concentrating parking in designated facilities also enhances pedestrian safety and contributes to a more orderly streetscape. Such garages can be managed more effectively, enabling controlled access, dynamic pricing strategies, and real-time information systems that optimize space utilization [2, 3, 5]. In addition, garages support better land-use planning by freeing curb space for public transport, cycling lanes, or wider sidewalks, while also offering potential for park-and-ride integration. Park-and-ride systems have become an increasingly important element of sustainable urban mobility strategies, providing a practical means of reducing congestion and vehicle pressure in dense city centers.

Their effectiveness depends heavily on the quality of integration with public transport, including service frequency, reliability, and the ease of pedestrian access between parking facilities and transit nodes [6]. Empirical studies show that well-located park-and-ride sites, supported by clear information and convenient transfer conditions, can significantly influence travel behavior and reduce traffic volumes in central urban areas [6, 7]. Beyond infrastructural and pricing factors, psychological elements also shape user decisions, as travelers weigh perceived travel time, comfort, and the attractiveness of modal alternatives when choosing whether to use park-and-ride facilities [3]. Understanding these combined spatial, operational, and behavioral determinants is essential for designing systems that effectively support multimodal mobility and contribute to more efficient and sustainable urban transport networks. As cities continue to grow, such approaches become increasingly important for balancing accessibility with sustainability. Optimal garage placement requires analyzing how a facility will affect the existing road network and traffic flows, and the use of simulation models in these assessments has proven to offer multiple advantages [2, 4]. In this study, based on recorded traffic data, the impact of the garage on traffic conditions in Istarska Street (Osijek, Croatia) was assessed - at the entrance/exit and at the nearest traffic-regulated intersection of Vukovarska and Istarska Streets. The analysis of operational and safety characteristics was conducted using the VISSIM microscopic traffic simulation model and the Surrogate safety assessment model (SSAM).

2 Methodology

2.1 Location

The public Eurodom garage is located on Istarska Street, within the Eurodom business center, which covers an area of 85,000 m². Eurodom is situated in the block that includes the intersections Trpimirova–Vukovarska and Vukovarska–Istarska, and all of these roads belong to the primary functional level of Osijek’s urban network. In a broader context, the Eurodom complex is located on Knez Trpimir Street (state road DC 518), which channels incoming traffic into the city – both from the southern bypass and from the north, from the Baranja region. The garage’s location ensures good connectivity with the rest of the city. It is in the immediate vicinity of a bus stop and a five-minute walk from a tram stop, making it a suitable “park & ride” location. Istarska Street, which provides access to the garage (figure 1), was reconstructed in 2021, including the renewal of underground infrastructure, reconstruction of the roadway and sidewalks, and the construction of new parking spaces. The garage has two entrances/exits and extends across four underground levels, with a total of 791 parking spaces – 750 of standard dimensions, while the remaining spaces are designated for persons with reduced mobility. Based on the number of parking spaces, the garage is on the boundary between medium and large categories, as garages with more than 800 spaces are considered large. Near the garage are four secondary schools, a Music school, the City Administration, the central Health Center, the historic Tvrdča fortress, a Recreation center, a Cultural centre, a Concert Hall, the University Rectorate, and several other public facilities, all of which represent a significant pull-factor.



Figure 1 Entrance to the garage in Istarska Street

2.2 Microscopic simulation modelling

Microscopic traffic simulation modelling in VISSIM was used to analyze operational characteristics (mean and maximum queue length and average delay) as well as to generate vehicle trajectories. Four scenarios were examined: the recorded traffic load during the morning and afternoon peak hours, and the traffic load reduced by the number of vehicles entering or exiting the garage (the no-garage scenario). For each analyzed scenario, ten different temporal distributions of the same traffic demand were generated, with an initial random seed value of 42 and a random seed increment of 10.

2.3 Surrogate safety assessment model (SSAM)

Surrogate safety assessment model uses trajectories generated by VISSIM and analyzes safety aspects through the identification of potential vehicle conflicts and their characteristics. The main indicators are: time to collision (TTC) – the remaining time before the paths of two vehicles would intersect at the same conflict point (values below 1.5 seconds indicate high risk, 1.5 to 3 seconds moderate risk, and above 3 seconds low risk); post-encroachment time (PET) – the time difference between two vehicles passing through the same conflict point; DR and MaxD are the modeled and maximum deceleration rates (to avoid a collision, $DR \leq MaxD$) and other. In addition to these characteristics, SSAM provides the total number of conflict points in the traffic scenario and distinguishes three types of conflicts: crossing, rear end, and lane change.

3 Results and discussion

3.1 Traffic counting results

Traffic volume and traffic composition were measured under real traffic conditions on Thursday, 20 March 2025, during the morning peak hour (7:00–8:00) and the afternoon peak hour (16:00–17:00). The figures show the traffic volume, route distribution, and traffic composition for the Vukovarska–Istarska intersection (figure 2) and the entrance/exit of the garage in Istarska street (figure 3).

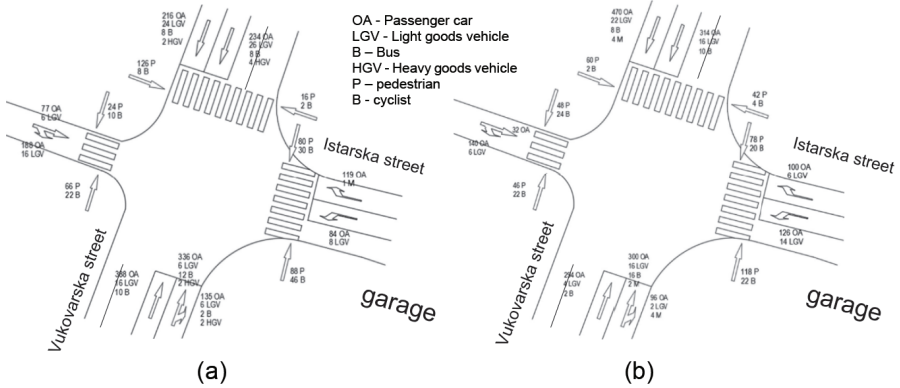


Figure 2 Counted traffic load of the intersection for (a) morning and (b) afternoon peak hours [8]

According to the results of the traffic count on an average working day, during the morning peak hour 123 vehicles entered the garage and 16 exited. During the afternoon peak hour, 18 vehicles entered the garage and 78 vehicles exited.

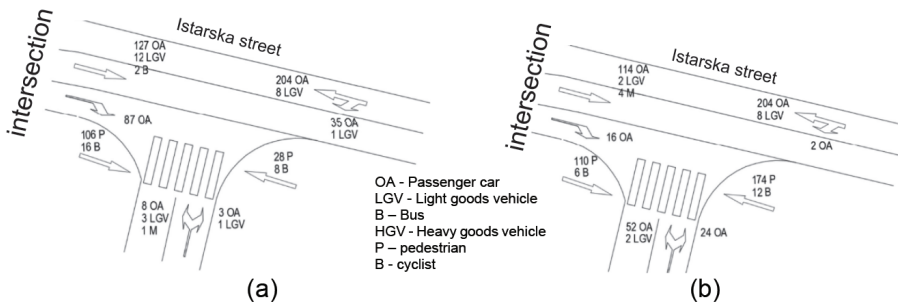


Figure 3 Counted traffic load of the garage entrance/exit for (a) morning and (b) afternoon peak hours [8]

According to the numerical indicators, the entrance/exit on Istarska Street did not reach the theoretical entrance capacity, which for an automatic ticket reader can reach up to 300 veh/h [9], while older studies state a theoretical capacity of up to 150 veh/h [5] for peak weekday demand. According to more recent research [9, 10], the theoretical exit capacity can be up to 500 veh/h (7 sec/veh) under conditions of sports or cultural events for an automatic ticket reader. The counted number of vehicles that entered or exited the garage (figure 3) was used for the analysis of the Vukovarska–Istarska intersection scenario without the garage. Within this study, the probability that some vehicles would enter Istarska Street in search of on-street parking was not analyzed.

3.2 Operational indicators

3.2.1 Vukovarska – Istarska intersection

Average and maximum queue lengths [m] and the average vehicle delay [s/veh] by traffic streams for the counted traffic volume at the Vukovarska – Istarska intersection for the scenario with the garage are shown in figure 4, and for the scenario without the garage in figure 5.

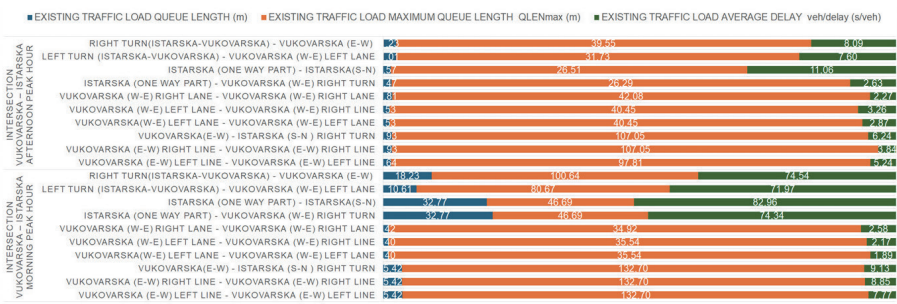


Figure 4 Operational indicators for the scenario with the garage

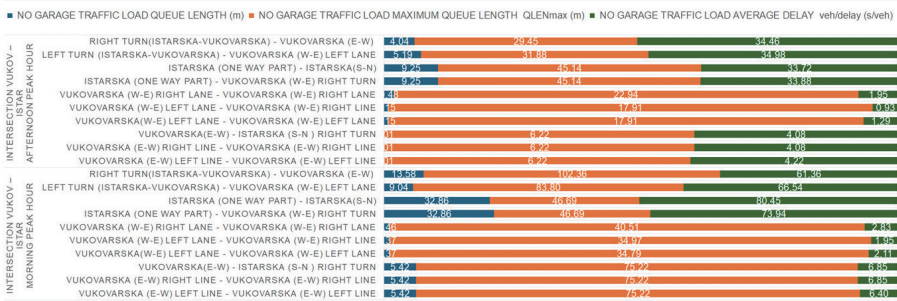


Figure 5 Operational indicators for the no-garage scenario

By comparing figure 4 and figure 5, the impact of the public garage on the traffic load at the Vukovarska – Istarska intersection can be observed. During the morning peak hour, the number of vehicles in the intersection increases by 99 vehicles (2,026 vehicles with the public garage compared to 1,927 without it), of which 87 vehicles enter the public garage and 12 vehicles exit the public garage and merge into the observed intersection. In the afternoon peak hour, the additional traffic in the intersection amounts to 70 vehicles (2,020 with the public garage compared to 1,950 without it), with 16 vehicles entering and 56 exiting the public garage and merging into the intersection traffic. During the morning peak hour, traffic is more pronounced on Istarska Street, resulting in longer queues (up to 132.70 m), while average delays range from 1.89 to 82.96 s/veh. In the scenario without the public garage, queues are shorter (up to 102.36 m) and average delays lower (1.95–80.45 s/veh). A similar situation occurs in the afternoon peak hour, but at that time traffic is more intense on Vukovarska Street. In this period, with the public garage, queues reach up to 107.05 m, with average delays from 2.27 to 15.74 s/veh, while in the scenario without the public garage queues are shorter (up to 45.14 m) and average delays range between 0.93 and 34.98 s/veh.

In the graph in figure 6, a comparison of the average vehicle delay by traffic streams for the morning peak hour is visible, and it can be seen that the impact is greatest on the outbound flows from Istarska (from the garage), where delays decreased by 13%, and on the right-turn movements into Istarska (towards the garage), where the delay decreased by 25%, which is the expected result.

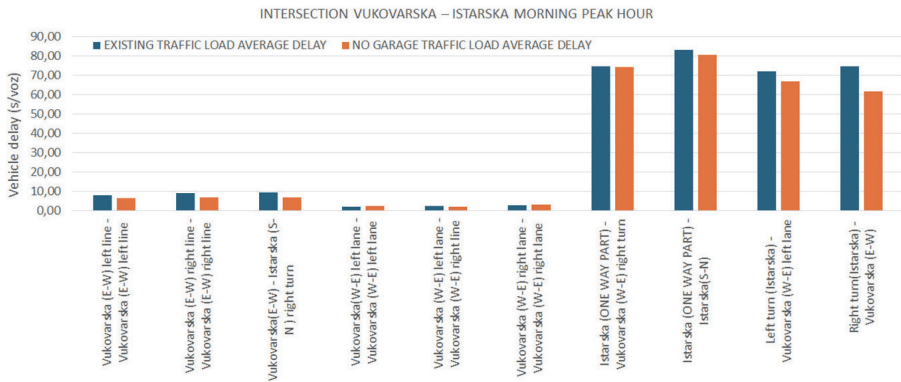


Figure 6 Comparison of average delays for both scenarios

3.2.2 Istarska Street garage entrance/exit

Average and maximum queue lengths [m] and the average vehicle delay [s/veh] by traffic streams for the counted traffic load at the garage entrance/exit on Istarska Street are shown in figure 7.

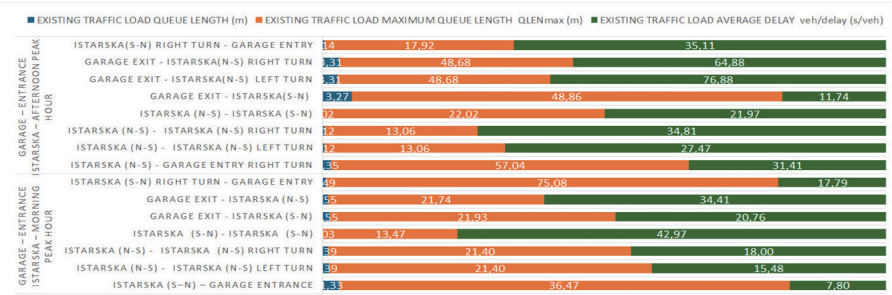


Figure 7 Operational indicators for the garage entrance/exit in Istarska street

In the scenario without the garage, this infrastructural element does not exist, so there are no delays or vehicle queues in Istarska Street caused by vehicles entering or exiting the garage.

3.3 Safety indicators

By applying the Surrogate safety assessment model to the trajectories generated in the VIS-SIM microscopic simulation model, the number, types, and characteristics of vehicle conflicts at the Vukovarska–Istarska intersection were obtained. The scenarios with and without the garage were compared (table 1), and the comparison includes the number of conflicts, their type, the mean time-to-collision, and the mean speed at the moment of conflict. Additional indicators are available in [8].

The results obtained using the Surrogate safety assessment model do not include the modelling of critical vehicle–pedestrian and vehicle–cyclist conflicts, which are notably lower in the no-garage scenario at the pedestrian crossing near the garage entrance, where 134 pedestrians and 24 cyclists were recorded in the morning, and 285 pedestrians and 18 cyclists in the afternoon peak hour.

Table 1 Comparison of conflicts obtained by the model

INDICATOR	Morning peak hour		Afternoon peak hour	
	S1 ¹	S2 ²	S1	S2
Total conflicts	486	447	316	279
Crossing conflicts	161	158	148	146
Rear-end conflicts	273	241	142	110
Lane-change conflicts	52	48	26	23
Average time to collision -TTC [s]	0.60	0.61	0.60	0.61
Average speed in conflict [km/h]	23.26	23.15	26.53	26.40

¹ Scenario 1: existing traffic load
² Scenario 2: no-garage traffic load

4 Conclusion

The choice of a garage location significantly influences its occupancy (attraction factor), which in turn affects the selection of urban mobility modes and the potential use of the garage for a park-and-ride approach aimed at reducing traffic congestion in the city center. Experiences from major cities worldwide [1-7] show that off-street parking is a better solution in terms of both safety and functionality. A mandatory step in planning a garage location is analyzing its impact on the surrounding road network during the planning phase through the use of simulation tools. The segment of the urban road network affected by the garage must be capable of accommodating the increased traffic load; otherwise, the construction of the garage could create more problems than benefits. In this article, the impact of an existing garage on the nearest signalized intersection was analyzed, using recorded peak-hour traffic volumes, both at the intersection and at the nearest entrance/exit of the garage on Istarska Street. The results clearly show that an impact exists, particularly on traffic safety indicators, including vehicle–vehicle conflicts as well as vehicle–pedestrian and vehicle–cyclist conflicts at the garage entrance/exit. The main limitation of this study is that only a single traffic count was conducted, and future research should focus on identifying and analyzing conflicts between vehicles and vulnerable road users in greater detail. The advantage of this approach lies in the use of microscopic simulation and SSAM tools, which enable the analysis of a wide range of potential traffic scenarios and traffic loads.

Acknowledgements

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