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ANALYSIS OF TRAFFIC PATTERNS AND INTERSECTION PERFORMANCE AT RETAIL FACILITY ACCESS POINTS

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Abstract

Optimizing urban transport systems in conditions of increasing motorization implies careful planning and design of transport infrastructure in places of new land use to ensure conditions not only for motorized but also for other forms of mobility – pedestrian and bicycle traffic. This paper presents a preliminary traffic study conducted at the locations of retail buildings located in the city center. The goal was to determine the temporal distribution of traffic load at peak hour that should be considered when designing intersections through which a retail building connects to the road network. The results of this analysis were further used to analyze the impact of a retail building in combination with a business/residential building on the existing traffic system. Analyses of experimentally collected data have shown that the weekly and daily time distribution of traffic to and from a commercial facility varies depending on the location of the facility. The results of the analysis of the connection to the existing road network in conditions of different combinations of land use on the plot (residential/business/commercial) have shown that a roundabout is the optimal solution for motorized and pedestrian traffic. However, microlocation has to be analyzed before the solution is adopted.

Keywords: land use, retail facility, traffic time distribution, intersection optimization

1 Introduction

Retail facilities represent strong attractors of all forms of traffic, which is why, in conditions of increasing motorization and awareness of the undesirable effects of motorized traffic on the environment, their optimal planning is particularly important.

The modal split for access to retail facilities is influenced by several factors, including the level of motorization, living standards, and city size, as well as transport system characteristics such as parking availability and the capacity of the surrounding road network [1]. Planning new retail content requires assessment of the selected location and evaluation of traffic conditions for all expected access modes, including the facility's impact on motorized traffic within the existing road network and conditions for non-motorized users on approaches to the site. As a rule, ensuring the accessibility of a shopping facility implies a sufficient number of parking spaces. The developed models for defining the optimal number of parking spaces are usually based on the size of the commercial building, expressed in m^2 of usable commercial space, but the size of the building, the number and the type of shops in larger centers also play an important role [2, 3]. The predicted number of parking spaces has also been identified as an important factor influencing trip attraction to large shopping centers [2, 4]. Research conducted in Dhaka (Bangladesh) shows that trip attraction is more pronounced in smaller shopping facilities [2].

City size, travel behavior, and transport system conditions significantly influence models used to estimate future traffic demand, both in general and for commercial facilities; therefore, such models are not universally applicable. In the paper by Breški et al. [3], a trip generation model for commercial facilities with floor areas ranging from 20, 000 to 70, 000 m² was developed based on data collected at five commercial facilities in Split, Croatia, and the results were compared with those obtained using equations from the American ITE Trip Generation Manual. The authors developed regression models based on the shopping center's gross leasable area and adjacent street traffic volumes, with separate models specified for weekdays and Saturdays. A comparison of the results of the models developed based on local data and the American model shows that the American model provides an average of 40% higher forecasts. This confirms the need to develop, or rather, verify traffic demand models developed for other urban environments in local conditions. It is shown that, in addition to defining traffic demand, an element that is extremely important for analyzing the impact of a commercial facility on the existing road traffic network is the temporal distribution of traffic towards the facility, which can significantly affect the peak loads that can be expected on the approach to the facilities and the surrounding area.
This paper presents a study of the impact of land use (commercial in combination with residential and business) on the optimal connection of the location to the city road network. In the first part of the study, the temporal distribution of traffic was analyzed for four selected commercial facilities in the wider area of the City of Rijeka (Croatia) to determine peak hours for different locations of shopping centers - within the city center and outside the center and detect the one relevant for City center. These data were used to develop traffic load scenarios for different combinations of mixed-land use that include commercial facilities with a large number of parking spaces. The connection of the planned location to an existing secondary urban road network with standard geometric characteristics and traffic demand was analyzed for intersections designed as standard unsignalized, signalized, and roundabout intersections.

2 Materials and methods

The research presented in this paper was conducted in two phases:
- Phase I comprised field investigations at the locations of existing retail facilities (supermarkets) to analyze parking conditions and the temporal distribution of traffic demand.
- Phase II involved the development of a scenario for a selected urban location where the construction of a multi-storey building is planned, as well as a garage–parking facility serving the retail component. All elements are planned within the same plot, with a single vehicular access point to the existing urban road.

2.1 Field research

Field research was conducted at four commercial facilities (supermarkets): two located within the urban area of the City of Rijeka (locations A and B in table 1), one situated in an industrial retail zone (Kukuljanovo – location C), and one at the entrance to the residential area of a smaller municipality (Kostrena – location D). At all locations, multi-day traffic counts were conducted during April, covering both weekdays and Saturday, which is traditionally the peak shopping day. Traffic volumes were continuously recorded using automatic traffic counters, enabling the identification of the busiest day, the daily peak hour, and the proportion of traffic occurring during the peak hour. In addition, the number of available parking spaces and the location of access points connecting the retail facility plots to the public road network were analyzed.

Table 1 Basic data on location, parking and access conditions

	Netto /parking area [m²]	Number of parking spaces	Location	Connection to	Distance to nearest intersection [m]
Location A	1373/3565	119	urban	Secondary road	97
Location B	2446/2714	92	urban	Main city road	22
Location C	4321/8168	254	Commercial zone	Main road	101
Location D	5846/8323	231	Sub-urban	State road	66

2.2 Analysis of the impact of land use and parking on the optimal connection design

In the second part of the research, partly based on the results of the first phase (presented in more detail in section 3.1), an analysis of the optimal road access configuration to the existing road network was conducted for three different land-use combinations within the newly planned area:

- commercial and residential use
- commercial and business use
- commercial, residential, and business use.

Traffic load calculations for these three scenarios were based on an actual planned site in the City of Rijeka, specifically for the planned number of parking spaces: 240 spaces allocated to residential, business, or mixed-use buildings and 150 spaces allocated to the commercial building. The traffic demand on the road serving the newly planned facility was assumed to be 300 and 400 veh/h/lane, based on traffic measurements at the site and the anticipated increase in traffic volumes over the planned period. This traffic demand corresponds to typical traffic load for secondary (collector) urban roads [5]. Detailed information on the site cannot be disclosed, as the development is currently in the design phase.

Table 2 Adopted traffic load distributions based on the planned number of parking spaces and facility use

	Business		Residential		Business / residential building		Commercial center	
	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit
MPH (7-8 a.m.)	70%	10%	20%	65%	38%	46%	87%	80%
APH (3-4 p.m.)	15%	60%	70%	30%	44%	42%	158%	143%
MPH – morning peak hour, APH – afternoon peak hour								

For residential and business buildings, the traffic distribution reflects the expected start and end of working hours, corresponding to typical peak periods. For commercial buildings, the forecast distribution is based on measured data obtained in the first phase of the study, assuming a vehicle turnover time of 30 minutes during the afternoon peak hour, which results in traffic demand exceeding 100% of the parking facility capacity (table 2).

Specifically, four typical intersection access solutions connecting to the existing urban road were analyzed: standard intersection (figure 1a), standard intersection with dedicated lanes (figure 1b), a signalized intersection with dedicated lanes (figure 1b), and a compact roundabout (figure 1c).

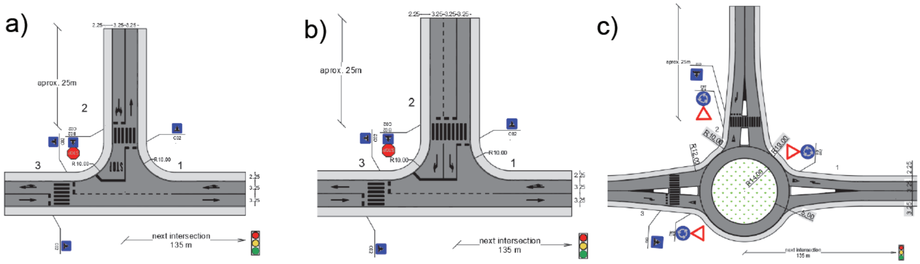

Figure 1 Analyzed solution for intersections: a) standard intersection, b) standard or signalized intersection with dedicated lanes, c) roundabout

Based on the distribution of traffic load shown in table 2 and the specified number of planned parking spaces, the traffic load for the morning and afternoon peak hours was calculated for each scenario. In the case where the signalized intersection was analyzed as the access solutions to the existing urban road, the cycle length taken into account was 70 or 80 s depending on the total traffic load. For the selected critical traffic demand levels, a level-of-service (LOS) analysis was performed using the SIDRA Intersection software to assess traffic (motor-vehicle) operating conditions. All analyzed variants are described in detail in [6]. Pedestrian traffic quality was evaluated based on the provision of direct and safe pedestrian movement, considering crossing lengths and the implementation of additional pedestrian safety measures, such as traffic signals and pedestrian refuge islands.

3 Results and discussion

The results of the first phase of the research, which established how to estimate relevant traffic demand for retail facilities based on the number of parking spaces and site location, as well as the results of the second phase, which focused on optimizing the type of at-grade intersection in relation to the traffic requirements of the newly planned land use, are presented below.

3.1 Determination of relevant traffic demand at the access intersection for a commercial facility

The established weekly and daily temporal distributions of traffic to and from the retail facilities differed depending on site location, as shown in table 3 (detailed results are provided in [6]).

Table 3 Temporal distribution of traffic at the analyzed facilities

	Location	Busiest day of the week	Peak hour	Occupancy during peak hours
Location A	urban	Wednesday	10-11 a.m.*	36%
Location B	urban	Tuesday	3-4 p.m.	107%
Location C	Commercial zone	Saturday	10-11 a.m.	67%
Location D	Sub-urban	Tuesday	4-5 p.m.	75%
*Due to vicinity of the Clinical Hospital				

Given the characteristics of the site analyzed in this paper, data collected at location B – a commercial (retail) facility situated in the city center near a primary urban road – were adopted as the representative temporal traffic distribution for the analyses presented in the remainder of the paper. Figure 2 presents 24-hour traffic volumes measured over five days (Tuesday to Saturday), indicating higher traffic levels on weekdays – particularly Tuesdays and Fridays – and identifying the afternoon peak hour (15:00–16:00) as the critical period in the daily traffic distribution.

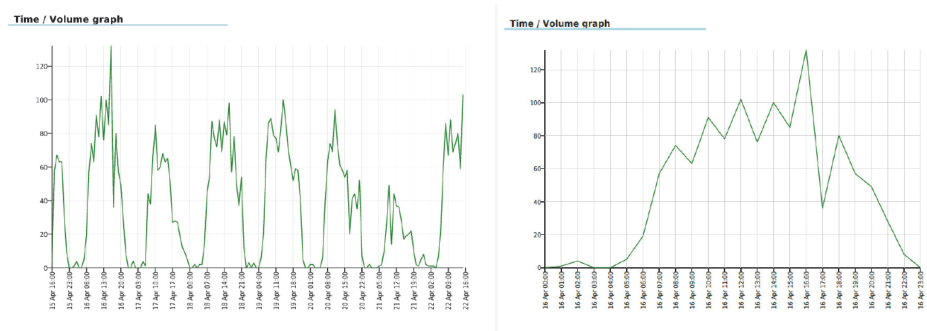

Figure 2 Temporal distribution of traffic volumes for a facility located in the city center: all days (left) and the representative day – Tuesday (right)

For other planned land uses, temporal traffic distributions were defined as follows: for residential use, vehicles are expected to predominantly depart the site during the morning peak period and return during the afternoon peak hour, albeit in a smaller proportion; for business use, the opposite pattern was assumed, with a slightly more extended distribution of entry and exit traffic to account for flexible working hours.

3.2 Analysis of the impact of land use on the method of forming connections to the existing city road network

The analysis of alternative land-use scenarios – combining commercial use with exclusively residential or business use, and mixed residential–business use – indicated that differences in temporal traffic distributions lead to significant variations in traffic demand. These variations are reflected both in traffic volumes and directional patterns: predominantly residential use generates higher traffic volumes toward the intersection during morning peak periods, whereas commercial use produces higher demand during the afternoon peak hour, consequently affecting the level of service at the nearest intersection. In the scenario combining commercial and business uses, the afternoon peak hour was identified as the critical period, as parking associated with business activities is predominantly vacated while demand at the commercial facility simultaneously reaches its peak. Analysis conducted for two traffic load levels on the existing road, representing the primary movement direction, indicated that a roundabout provides the optimal solution. In contrast, in the case of standard intersections, the level of service of the access from the planned site was assessed as LOS C or D, corresponding to operating conditions under which congestion may occur.
For the scenario combining commercial and residential uses within the same plot, the critical peak hour also occurs in the afternoon. Under unsignalized conditions, the approach from the newly developed area is expected to operate at LOS D, while the introduction of traffic signal control improves performance to LOS C and a roundabout solution enables the achievement of LOS A on all approaches. The mixed-use scenario combining a commercial use with a residential–business use was evaluated for the critical afternoon peak hour.

Among the four intersection types analyzed, the standard intersection resulted in LOS D, the signalized intersection in LOS C, and the roundabout in LOS A or LOS B. Results for all scenarios are summarized in table 4.

Table 4 LOS of access from the planned site for different combinations of land-use and traffic load (on the main direction) for the afternoon peak hour

	Combinations of land-use and traffic load					
	Commercial /business		**Commercial / residence**		**Commercial / business / residence**	
	300 veh/h/ lane	**400 veh/h /lane**	**300 veh/h/ lane**	**400 veh/h/ lane**	**300 veh/h/ lane**	**400 veh/h/ lane**
Standard intersection	D	D	C	D	C	D
Standard intersection with dedicated lanes (right/left lane)	A/C	B/D	A/C	A/D	A/C	A/D
Signalized intersection with dedicated lanes (right/left lane)	n.c.	C/C	n.c.	C/C	n.c.	C/C
Roundabout	A	A	A	A	A	B
n.c. – not considered						

The analysis generally indicates that access from the newly planned site should be provided with separate left- and right-turn lanes to ensure more favorable traffic flow conditions, particularly for right-turning vehicles. The introduction of traffic signal control does not significantly improve the level of service and instead results in substantially longer delays for right-turn movements. From the perspective of motor vehicle traffic performance, a roundabout represents the optimal solution.

The evaluation of the proposed intersection configurations from the perspective of pedestrian traffic on approaches to the planned site indicates that, to ensure acceptable operating conditions for motor traffic on the main road, a pedestrian crossing must be provided on one of the approaches (not both), which is not optimal from a pedestrian perspective. Under these conditions, a standard intersection without dedicated lanes – where pedestrian crossing distances are shortest – or a roundabout – where pedestrians are exposed to potential vehicle conflicts for the shortest duration – can be considered more favorable options. However, given that the standard intersection without dedicated lanes performs poorest in terms of motor traffic operations, the roundabout may be regarded as the optimal overall solution under the described conditions.

4 Conclusion

The integration of new urban land uses that include commercial facilities – particularly strong attractors of both motorized and pedestrian traffic – requires careful spatial and traffic analysis prior to approval. For motorized traffic, it is essential that such analyses be based on the most realistic possible estimates of future traffic demand, including both the expected volume of attracted traffic and its temporal distribution. The analysis of different locations for commercial (retail) buildings has shown that peak traffic demand is strongly dependent on-site location and, in some cases, is not dependent only on the primary intended use of parking facilities, underscoring the importance of detailed analysis at the microlocation level. In the continuation of this research, the optimal intersection infrastructure solution under altered traffic conditions resulting from the new land use, which includes a commercial facility, was examined. The results indicate that existing traffic flows are not adversely affected by the additional demand provided that hourly traffic volumes correspond to expected levels for secondary urban roads (300–400 vehicles per hour per lane) and that traffic generated by the new facility remains lower than volumes on the existing main direction. To reduce delays on the facility approach, a roundabout was identified as the optimal solution, as it also offers the most favorable conditions for pedestrian traffic. Under real-world conditions, however, the analyses presented in this paper should be complemented by an assessment of site-specific spatial constraints and potential interactions between the proposed roundabout and nearby intersections, particularly if those intersections are signalized.

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References

[1] Maršanić, R.: Kultura parkiranja: organizacija, tehnologija, ekonomika, ekologija, pravo, IQ+, Rijeka, 2012, pp. 44-45 (in Croatian language)

[2] Mamun, M.S., Rahman, S.M.R., Rahman, M.M., Aziz, Y.B., Raihan, M.A.: Determination of trip attraction rates of shopping centers in Dhaka city, 2nd International Conference on Advances in Civil Engineering, 2014, pp. 913-917

[3] Breški, D., Maljković, B., Senjak, M.: Trip Generation Models for Transportation Impact Analyses of Shopping Centers in Croatia, Infrastructures, 10 (2025) 4

[4] Kikuchi, S., Felsen, M., Mangalpally, S., Gupta, A.: Trip attraction rates of shopping centers in Northern New Castle County, Delaware, 2004.

[5] Legac, I., Hozjan, D., Dimter, S., Šimunović, L., Benigar, M., Nikšić, M., Marković, S.: Gradske prometnice, University of Zagreb, Faculty of Transport and Traffic Sciences, 2010. (in Croatian language)

[6] Milosavljević, L.: Optimiranje planiranja i projektiranja parkiranja uz objekte trgovačke namjene, master thesis, University of Rijeka, Faculty of Civil Engineering, 2024. (in Croatian language)