GENERAL AND TARGETED STRATEGIES FOR TRAFFIC MITIGATION IN CONGESTED URBAN AREAS

Mihai-Flavius GRIGORE [1], Anca BÂRLĂDEANU[2]

Rezumat. *În contextul creșterii continue a populației urbane și a numărului de vehicule personale, congestia traficului a devenit o problemă majoră în multe zone urbane din întreaga lume. Pentru a aborda această problemă, este crucial să explorăm și să implementăm soluții eficiente și inovative care să faciliteze fluxul de trafic și să reducă duratele de călătorie. Articolul studiază soluții generale și particulare pentru a reduce congestia traficului în zonele urbane aglomerate, concentrându-se pe aspecte precum reducerea spațiilor de parcare, promovarea transportului public, implementarea sistemelor inteligente de gestionare a traficului și implementarea de străzi cu sens unic. În prima parte, se analizează soluțiile din literatura de specialitate și se propun modalități de optimizare a traficului. Apoi, articolul se concentrează asupra unei analize de caz specifice, o zonă comercială, prezentând ipotezele și problemele actuale de trafic din zonă, urmate de soluții potențiale adaptate la această locație particulară. Pentru a reduce congestia în zonele urbane, se va acorda atenție atât soluțiilor de organizare si management a fluxurilor de trafic, cât și asupra reducerii nevoilor de deplasare motorizată.*

Abstract. *In the context of the continuous growth of the urban population and the increasing number of personal vehicles, traffic congestion has become a major problem in many urban areas around the world. To address this issue, it is crucial to explore and implement efficient and innovative solutions that facilitate traffic flow and reduce travel times. The article examines both general and specific solutions to reduce traffic congestion in densely populated urban areas, focusing on aspects such as reducing parking spaces, promoting public transportation, implementing intelligent traffic management systems, and introducing one-way streets. In the first part, solutions from the specialized literature are analyzed, and methods for traffic optimization are proposed. The article then focuses on a specific case study—a commercial area—presenting the assumptions and current traffic issues in the area, followed by potential solutions tailored to this particular location. To reduce congestion in urban areas, attention will be given both to solutions related to the organization and management of traffic flows, as well as to reducing the need for motorized travel.*

Keywords: congestion, traffic flow, one-way streets, urban areas

1. Introduction

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In recent decades, the phenomenon of accelerated urbanization has brought numerous challenges regarding mobility and traffic management in large urban areas. With the continuous increase in the number of vehicles on the roads and limited road infrastructure, traffic congestion becomes a persistent issue with a significant impact on the quality of life in urban environments.

Congested urban areas face a series of problems, including traffic delays, increased pollution, stress for drivers, and risks to public health. In this context, finding effective solutions to streamline traffic becomes imperative for local authorities and the urban community as a whole.

In this article, we aim to explore general and specific solutions to address the issue of traffic congestion in urban areas. We will examine a range of strategies and interventions that can be implemented at both macro and micro levels to improve traffic flow and reduce the negative impact of traffic on the environment and public health.

2. General Solutions

2.1. Improving Public Transportation

One of the main approaches to reducing congestion is improving access to and the quality of public transportation services. Expanding metro, tram, and bus networks, along with investing in appropriate infrastructure, can encourage people to use public transport instead of personal cars [1].

Increasing the frequency and punctuality of public transportation services can boost passengers' confidence in the system and encourage its use. Ensuring accessibility for people with reduced mobility and enhancing travel comfort by equipping public transportation with modern amenities (air conditioning, WiFi, luggage spaces, etc.) can make public transport more attractive to a wider range of users.

Implementing real-time information systems about schedules and the status of public transportation vehicles can help travelers efficiently plan their journeys and reduce waiting times at stations. Utilizing modern technologies for ticket issuance and electronic purchasing can streamline the travel process and enhance the experience for public transportation users.

Improving public transportation involves an integrated approach that combines network expansion, service and infrastructure improvement, technology utilization, and promotion of its use. Through adequate investments and strategic planning, public transportation can become a central pillar in traffic management and in creating a more sustainable and accessible urban environment for all city residents.

Traffic congestion is a global issue, particularly prevalent in developing countries. Afghanistan is no exception, especially its capital Kabul, where rapid population growth places it among the fastest expanding cities in the world. Traffic congestion affects not only people's and goods' mobility but also air quality, leading to numerous deaths, approximately 3000 annually [2] [3].

In the city of Seville, the impact of congestion on accessibility mirrors the population distribution and transport demand in the urban center. The Aljarafe area generates a high volume of transport demand during morning peak hours, leading to road congestion [4].

The irony lies in the fact that the main advantage of the Aljarafe area is its proximity to the city center, yet its success in attracting residents who work in central Seville could compromise the initial reasons for this success.

On the other hand, the low population density in suburban areas and limitations in public transportation coverage result in the use of personal vehicles for commuting. Although the Aljarafe area is served by a three-lane highway, the concentrated demand during morning peak hours causes intense traffic.

2.2 Reducing Parking Spaces

Reducing parking spaces can be an effective measure to alleviate traffic congestion in densely populated urban areas. Limiting the availability of parking spaces in congested areas can discourage people from using personal vehicles and instead opt for alternative modes of transportation, such as public transit or walking. By reducing the number of personal vehicles circulating in the city and searching for parking spaces, congestion and pollution can be decreased, thus creating a cleaner and more pleasant urban environment.

Limiting parking spaces can encourage people to seek more sustainable transportation alternatives, such as bicycles or walking, or to use public transit, thereby contributing to traffic flow improvement and reducing pressure on road infrastructure. It is essential that reducing parking spaces be part of a broader urban planning strategy that takes into account the transportation needs of the community and provides adequate alternatives for mobility.

Reducing parking spaces can be an efficient and necessary measure for alleviating traffic congestion in congested urban areas. By discouraging the use of personal vehicles, promoting alternative transportation, and efficiently utilizing urban space, this strategy can contribute to creating a cleaner, safer, and more friendly urban environment. However, it is important for this measure to be implemented within the context of integrated urban planning and to be accompanied by other interventions aimed at improving mobility and accessibility in cities.

2.3 Intelligent Transportation Systems (ITS)

Implementation of intelligent transportation systems is an essential component of modern traffic management strategies aimed at alleviating congestion and improving traffic flow in congested urban areas.

The use of technologies such as surveillance cameras, traffic sensors, and vehicle detection systems can provide real-time information about traffic flows, travel times, and events affecting traffic circulation. Implementing a traffic control center equipped with specialized software allows for efficient monitoring and management of traffic signal networks, adjusting signal synchronization based on traffic flows, and coordinating interventions in case of unforeseen events.

In Latin America, the disorderly growth of cities extends distances and routes, leading to a rapid increase in the number of cars and motorcycles, exacerbating the traffic problem. In this context, intelligent transportation systems represent an alternative for improving traffic, using the internet and advanced algorithms to collect and process data from multiple sources, thereby enhancing transportation flow efficiency. However, processing and modeling traffic data pose a challenge due to the complexity of road networks, space-time dependencies, and heterogeneous traffic patterns. The US Department of Transportation considers traffic congestion one of the biggest threats to economic success. [5]

Traffic congestion is common during peak periods, being a recurrent phenomenon in the morning and at noon (commuting trips) and in the afternoon (recreational trips). A real-time algorithm has been developed to detect congestion using data from intelligent transportation systems. After detecting congestion, traffic participants need to be informed through a message. Coastal road users can be redirected to alternative routes, thus avoiding the congested coastal road. It is expected that port users will benefit from reduced congestion on the coastal road [6].

Traffic simulation software has been used to model traffic diversion rates and estimate resulting benefits based on data and performance indicators such as travel time, delay time, and fuel consumption.

The proposed congestion detection algorithm shows promising results on the congested coastal road in the center of Patras city, demonstrating its potential to detect congestion in real-time and inform users through a variable message sign, which can be installed before the congested road segment [7].

Implementing intelligent transportation systems can bring numerous benefits in traffic management and improve the travel experience in cities. By using modern technologies and real-time data, local authorities can optimize the use of road infrastructure, reduce congestion, and enhance road safety for all traffic participants. [8]

2.4 Implementing one-way streets

Implementing one-way streets or directional lanes is an urban planning strategy used to improve traffic flow and safety in cities, reducing congestion and the risk of accidents.

One-way streets allow vehicle traffic in only one direction, while directional lanes restrict access to certain road segments in a specific direction. Eliminating traffic conflicts from opposing directions and optimizing vehicle distribution on alternative routes can help reduce congestion and traffic jams. Reducing the risk of head-on collisions and eliminating situations where vehicles meet in narrow or crowded spaces can improve road safety for all traffic participants. Implementing one-way streets or directional lanes can allow for route optimization and public transportation frequency, facilitating quick and efficient travel for commuters.

The implementation of one-way streets or directional lanes should be part of a broader urban and transportation planning strategy that takes into account the specific needs and characteristics of each city or community.

Implementing one-way streets or directional lanes can be an effective solution for managing traffic and improving circulation in cities, with benefits such as reduced congestion, improved road safety, and enhanced public transportation efficiency. However, careful planning and impact assessment on the community are important to ensure the success and acceptance of this measure in the urban environment [9], [10], [11].

3. Specific Solutions: Case Study - Mall Commercial Area

The commercial area - Mall is a shopping center located in the northern part of Bucharest, near the neighborhood and Henri Coandă International Airport. It is one of the largest shopping centers in Bucharest and Romania, known for its numerous shops, restaurants, cinemas, and entertainment facilities.

To develop specific solutions for this area, we should focus on improving road access, facilitating public transportation, and promoting alternative modes of transportation to reduce congestion and enhance the experience for both customers and residents in the area.

Due to the explosive increase in motorization and consequently in both dynamic and stationary traffic since the opening of the shopping center, changes have occurred in the socio-economic parameters generating traffic, leading to increasingly difficult traffic conditions. It is evident that the existing traffic regulations are no longer adequate for current needs.

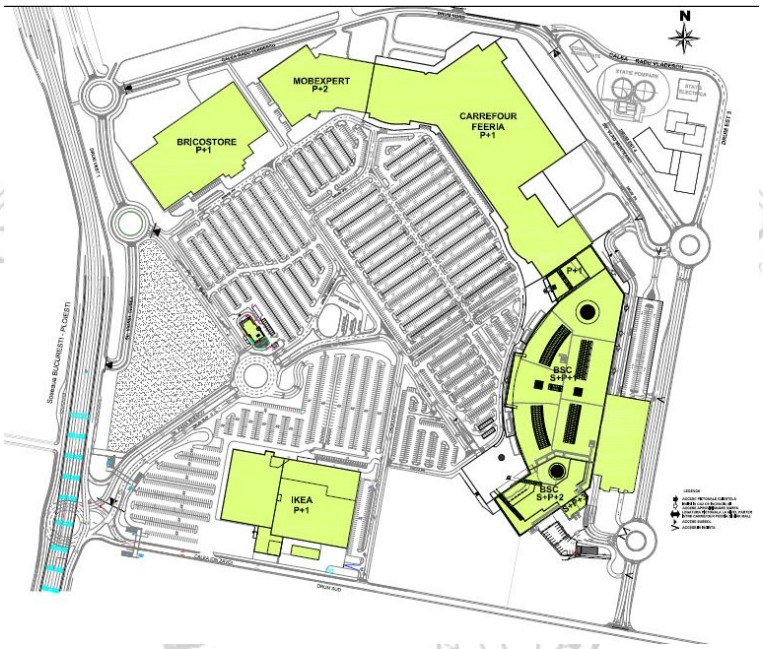


Fig. 1. Study Area – Comercial area

Traffic data collection was conducted through traffic surveys at 9 designated points over 2 days (one weekday and one weekend), considered significant for high traffic volumes. Thus, traffic measurements were conducted during the time intervals of 14:00 – 18:00, identified as peak traffic hours (Fig.1).

For the purpose of modeling the traffic flow as faithfully as possible, the following parameters have been retained for comparative analysis between the models developed:

This parameter, defined by the Webster formula (H.C.M.2010), indicates the level of delays by summing up the following delay levels recorded at intersections: uniform delay (D_i), incremental delay (D_2), residual delay (D_3).

$$D = D_i + D_2 + D_3 \quad (1)$$

In the case of roundabouts or unsignalized intersections, the program calculates the average delay for each access, expressed in sec/vehicle. Additionally, as a

result of the numerical simulation conducted, delays caused by vehicles required to stop at accesses (stop delay/vehicle) are calculated. Based on the delays caused by vehicle traffic, average vehicle speeds are calculated when crossing the intersection. These speeds are calculated for each access.

3.1. Simulating current traffic flows on the road network

Following traffic measurements and running the traffic model on the existing situation, the following values of traffic capacity are obtained at the main intersections in the Commercial Zone (Table 1).

Table 1 Traffic capacities at the main intersections in the ZCB

No	Code	Intersection control type	Traffic flow 14.00-18.00 (2024)
1	I1	Roundabout Circulation	8631
2	I2	Roundabout Circulation	7952
3	I3	Intersection not signalized	1938
4	I4	Intersection not signalized	3260
5	I5	Intersection not signalized	4398
6	I6	Intersection not signalized	5805
7	I7	Intersection not signalized	4415
8	I8	Intersection not signalized	3830
9	I9	Intersection not signalized	3915

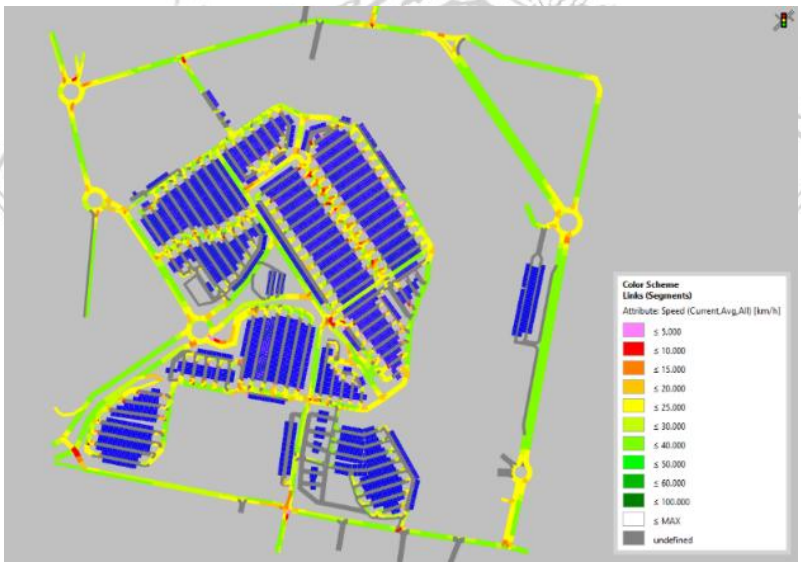


Fig. 2. Average traffic speed in the peak interval

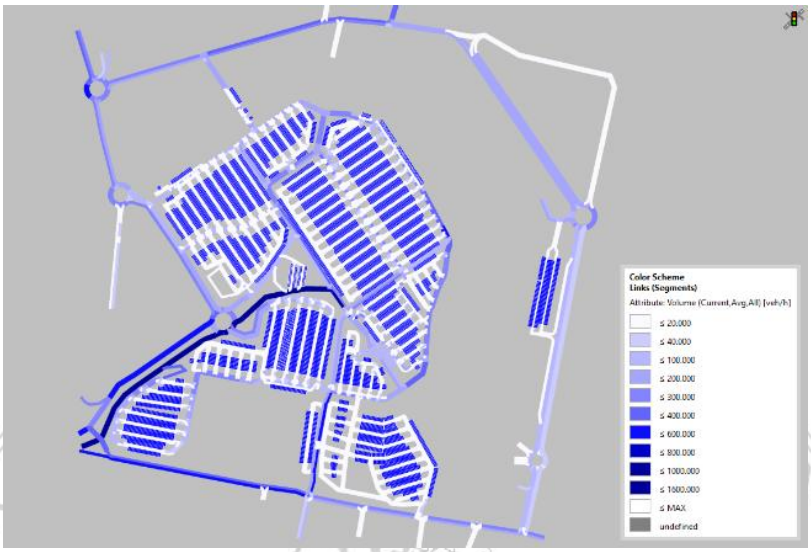


Fig. 3. Traffic flows in the peak interval

The Fig. 2 and Fig. 3 show the results of running the traffic model for the time interval analyzed (2:00 p.m. – 6:00 p.m.).

Table 2 Results obtained for the modeled main intersections

No	Code	Intersection control type	Average delay / vehicle
1	I1	Roundabout Circulation	4,95
2	I2	Roundabout Circulation	3,29
3	I3	Intersection not signalized	1,49
4	I4	Intersection not signalized	2,55
5	I5	Intersection not signalized	6,88
6	I6	Intersection not signalized	4,33
7	I7	Intersection not signalized	1,01
8	I8	Intersection not signalized	3,43
9	I9	Intersection not signalized	1,96

For the entire modeled area (Table 2), an average delay/vehicle of 14.25 seconds and an average vehicle speed (including parking maneuvers) of 16.80 km/h were obtained.

3.2. Critical analysis of mobility in Commercial Zone

Evaluation of the current road traffic situation

The scheme according to which the main traffic network in Commercial Zone is organized is a radial type, with 4 main directions.

Analysis of the current transport network in the Commercial Zone

The road network of the Shopping Center includes 1 category II street (2 lanes per direction), 10 category III streets (one lane per direction) and access alleys to the parking lots with 2 traffic lanes each. The width of the lanes is between 2.5 and 3.5 m

Unique meanings

Currently, inside the Commercial Zone, traffic is regulated by one-way traffic only on the road in front of the commercial premises and is almost non-existent on the other roads.

Pedestrian areas

In the Commercial Zone, pedestrian routes are organized on the sidewalks of the main streets. Inside the parking areas, pedestrian traffic is carried out in a shared-space system (Fig. 4).

Parking

Considering the type of function of the study area (commercial and leisure), 4821 parking spaces are arranged above ground inside it. To these are added 672 places in the underground parking lot.



Fig. 4. Case study

Analysis of public transport

The Commercial Zone is served by the local public transport lines operated by the Bucharest Transport Company.Words joined by a hyphen are subject to a special rule. If the first word can stand alone, the second word should be capitalized.

Conclusions

Following the analysis of the current road traffic situation, the following were found:

- the street network consists of category III and IV streets, with 2 traffic lanes and a category II street, with 2 lanes in each direction;
- the state of viability is good;
- insufficient exploitation of the one-way traffic organization system;
- the lack of traffic signs, but also the non-correlation of vertical and horizontal signaling in certain cases;

- the lack of speed limiters before the main pedestrian crossings, especially those located near the entrances to the shopping center;
- reduced or non-existent visibility of road signs;
- the existence of points of conflict causing road accidents;
- lack of dynamic guidance information to free parking spaces;
- the arrangement of the parking spaces perpendicular to the access path requires that the parking maneuvers completely block the access lanes.

Proposals

- The need to offer specific solutions for intersections where conflicting situations arise due to traffic values and the geometric characteristics of the road infrastructure, solutions that lead to an increase in traffic capacity and, implicitly, to the flow of traffic;
- Development of the one-way traffic organization system;
- Completing the signage and correlating it with the proposed scenarios.

4. Elaboration of circulation reorganization scenario

Considering the conclusions presented in the previous chapter, the list of possible scenarios for eliminating malfunctions includes:

Scenario 1 = reorganization of traffic in the study area by introducing one-way traffic and adapting horizontal and vertical signage.

Scenario 2 = traffic reorganization by reconfiguring certain intersections.

It should be noted that, in order to achieve maximum impact, each scenario contains the measures provided for in the previous one.

Scenario 1 = reorganization of traffic in the study area by introducing one-way traffic and adapting horizontal and vertical signage

The first step in developing this scenario was to complete/modify the horizontal and vertical signage according to the conclusions of the previous chapter. Thus, the table with the new traffic regulations for the current situation is presented in figure 5.

The second step is the organization of traffic in a one-way system. The introduction of single traffic directions must take into account the observance of some basic principles, namely:

- the introduction of a one-way street on a traffic artery is conditioned by the existence of a parallel artery located nearby, on which to introduce the opposite one-way street;

- it is recommended that the circulation arteries on which the single directions are introduced have 2 circulation lanes;

- the introduction of one-way lanes is justified for the arteries with the circulation capacity exceeded or on which it is forecasted to be exceeded in a relatively short term;

- the introduction of single directions is also justified for reducing points of conflict between traffic flows and, therefore, for increasing fluency and safety.Considering the above, we propose the introduction of unique meanings according to the Fig. 5.



Fig. 5. Unique meanings – proposed

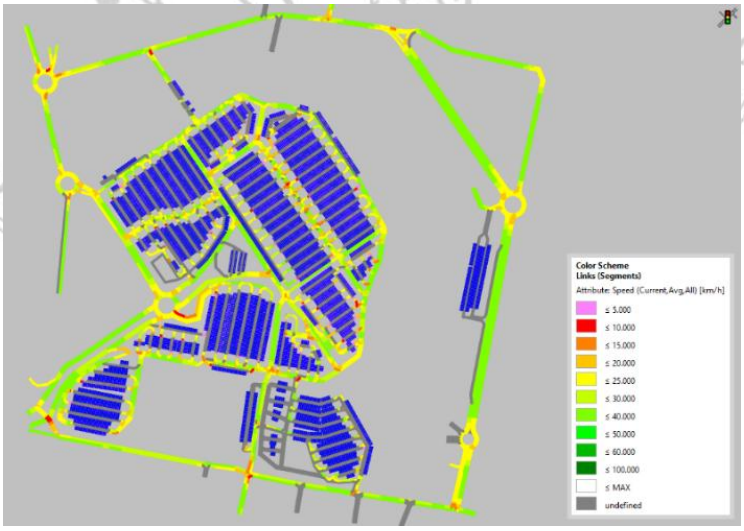


Fig. 6. Average traffic speed in the peak interval, scenario 1

Following the realization of the transport model, the following results were obtained.

The Fig. 6, Fig. 7 and Table 3 present the results of running the traffic model for the time interval analyzed (2:00 PM – 6:00 PM), in the case of scenario 1 implementation.

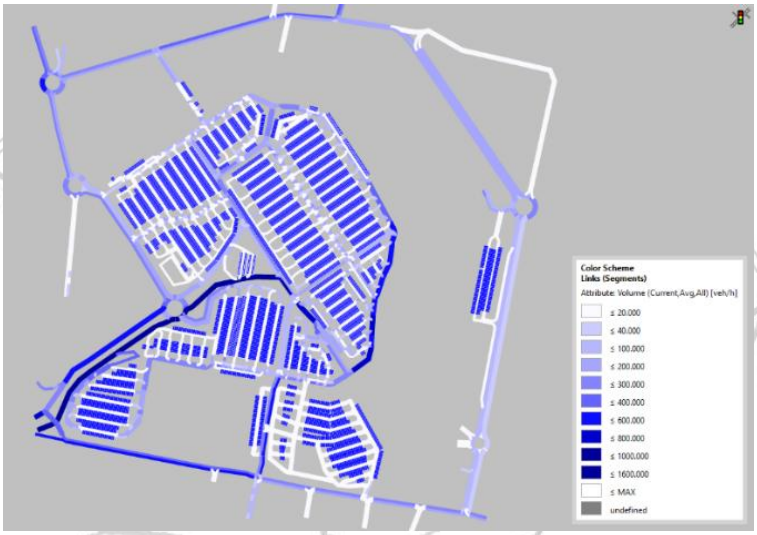


Fig. 7. Traffic flows in the peak interval, scenario 1

Table 3 Results obtained for the main modeled intersections, in the scenario 1 implementation

No	Code	Intersection control type	Average delay / vehicle
1	I1	Roundabout Circulation	6,70
2	I2	Roundabout Circulation	2,62
3	I3	Intersection not signalized	0,92
4	I4	Intersection not signalized	1,78
5	I5	Intersection not signalized	5,39
6	I6	Intersection not signalized	2,21
7	I7	Intersection not signalized	1,30
8	I8	Intersection not signalized	1,97
9	I9	Intersection not signalized	4,54

For the entire modeled area, an average delay/vehicle of 13.97 seconds (a 2% improvement) and an average vehicle speed (including parking maneuvers) of 18.38 km/h (an improvement of 9 %).

Scenario 2 = traffic reorganization by reconfiguring certain intersections

In the development of this scenario, the horizontal and vertical signaling was modified according to the arrangement of two roundabouts in order to streamline traffic. The proposed arrangement can be found in the Fig. 8.

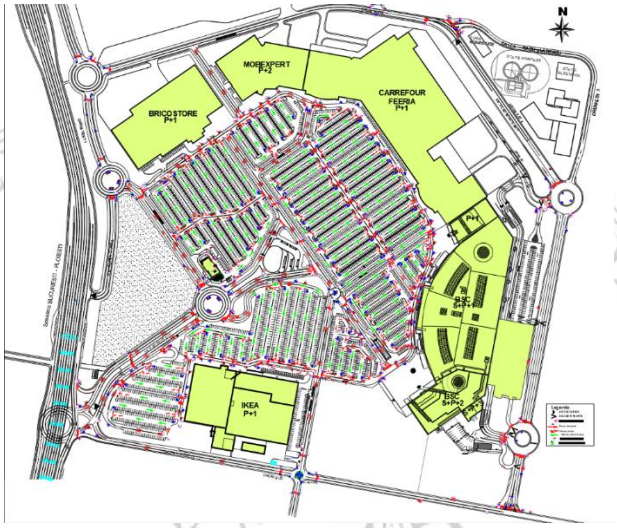


Fig. 8 Roundabouts – proposed

Following the realization of the transport model, the following results were obtained.

The Fig. 9, Fig. 10 and Table 4 present the results of running the traffic model for the time interval analyzed (2:00 p.m. – 6:00 p.m.), in the case of the implementation of scenario 2.

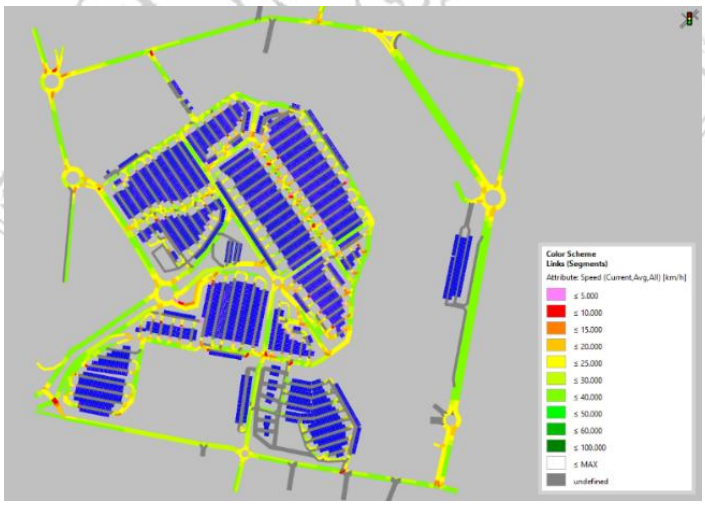


Fig. 9 Average traffic speed in the peak interval, scenario 2

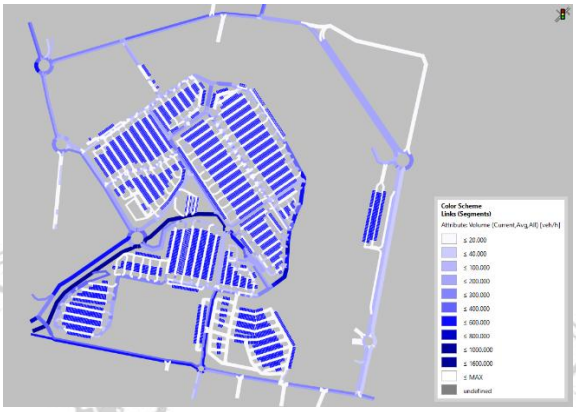


Fig. 10. Traffic flows in the peak interval, scenario 2

Table 4 Results obtained for the modeled main intersections, in the scenario 2 implementation

No	Code	Intersection control type	Average delay / vehicle
1	I1	Roundabout Circulation	5,73
2	I2	Roundabout Circulation	2,68
3	I3	Intersection not signalized	0,99
4	I4	Intersection not signalized	2,48
5	I5	Roundabout Circulation	2,00
6	I6	Roundabout Circulation	3,23
7	I7	Intersection not signalized	0,85
8	I8	Intersection not signalized	1,65
9	I9	Intersection not signalized	3,70

For the entire modeled area, an average delay/vehicle of 13.24 seconds (an improvement of 9%) and an average speed of the vehicles (taking parking maneuvers into account) of 18.43 km/h (an improvement of approx. . 10%).

5. Conclusions. Recommended scenario

Table 5 Comparison of the current situation with the proposed scenarios

Scenario	*Speed*	*Percent improvement*	*Delay*	*Percent improvement*
0	16,80 km/h	-	14,25 sec	-
1	18,38 km/h	9%	13,97 sec	2%
2	18,43 km/h	10%	13,24 sec	9%

Following the analysis of the two scenarios (Table 5), the following time values were obtained: in scenario 1, over the entire modeled area, an average delay/vehicle of 13.97 seconds (a 2% improvement) and an average vehicle speed (taking into account and parking maneuvers) of 18.38 km/h (an improvement of 9%); in scenario 2, over the entire modeled area, an average delay/vehicle of 13.24 seconds (a 9% improvement) and an average vehicle speed (taking parking maneuvers into account) of 18.43 km/h (a improvement of about 10%) A significant improvement is observed in scenario 2 and its implementation is recommended.

Acknowledgments

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