Designing an integrated modern parking in a crowded city area – a case study

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Abstract
Problems with parking places occur everywhere, especially in the cities. The purpose of this research is to design a concept of a modern parking place which can offer various services. With the rise of the world motor vehicle fleet and the emergence of new models, the infrastructure of major cities must be developed accordingly. The latter is increasingly affected by the needs of the population subject to mobility and the transport of various goods, which leads to crowded traffic. Our approach included the collection and analysis of real data regarding flow of traffic, simulation and designing a conceptual model of the parking place. Our findings focused on the advantages and disadvantages of developing such a solution and can be used for further development. The present study can be used in a variety of areas – for practitioners as a source of information and ideas, for academics and researchers as a model methodology. The study presents a methodology for designing a modern parking place taking into consideration various factors. This approach can be used to further increase the quality of life for the citizens living in the cities.

Keywords: traffic, transportation, smart parking, quality of life.

1. Introduction
Today's society faces multiple challenges. The increase in living standards has led to positive effects, such as increasing the quality of life, but also to negative effects, such as high energy consumption, pollution, waste. An area with a significant impact on the general balance in a positive sense, but also in a negative sense, is the field of transport. In a positive sense, transport contributes to the movement of goods and people, access to resources, the development of consumer markets, fast and safe movement from one location to another. On the other hand, this field is related to a series of negative effects, such as: increase in the number of vehicles, air pollution, noise pollution, agglomerations, congestion, road accidents. The need for economic development and the need for mobility are factors that work to find solutions by which the positive elements are strengthened and the negative elements are reduced as much as possible.

Mobility in cities comes with various problems. With the increase in the number of automobiles, cities are being invaded by drivers who want to move quickly from one place to another. When they arrive at their destination, car users need parking spaces. If parking spaces are insufficient, the result is overcrowded streets, long waiting times in traffic, delays, stress. These problems have been analyzed by researchers for a long time, they are the subject of many scientific works. Thus, in the paper [1] the authors present the following effects resulting from the location or lack of parking: degradation of the functioning of the public transport system, increase in the risk of accidents, increase in the level of pollution, increasing fuel consumption. Other negative effects are mentioned in the

paper [2]: thus due to the lack of parking spaces, situations of illegal double parking occur, which leads to an increase in congestion by 50% to 200%, respectively an increase in the level of pollution caused by CO emissions by 20%-25%. Other researchers confirm the negative effects, such as time lost in traffic, pollution, stress, congestion/traffic congestion. [3],[4].

To reduce the problems caused by the low number of parking spaces, various solutions have been proposed: improved parking management systems, creation of new parking spaces by identifying modern solutions (e.g. multi-storey car parks, underground car parks, automated car parks), optimizing the way of occupying existing parking spaces, influencing vehicle users to limit their journeys in central areas or congested areas, using public transport and alternative means of transport.

Various approaches to the proposed solutions can be found in the scientific literature, these being presented in the following. In the paper [5] the authors propose a method for optimizing the placement of parking spaces in an area where drivers travel that area in search of free parking spaces. In the paper [3] a smart infrastructure for parking is proposed which is based on the detection and location of vehicles, bidirectional vehicle-infrastructure communication, reservation of parking spaces, optimal allocation of parking spaces. An intelligent parking system architecture is presented in the article [6]. The authors propose solutions for an intelligent parking system based on IoT (Internet of Things), a system that can lead to a reduction in energy consumption and the time needed to find a parking space. The authors also propose reducing congestion in terms of parking spaces, by proposing a system in which the owners rent their parking spaces, for a fee, during the periods when these spaces are not used [6]. Other applications based on IoT technology are presented in the paper [7], where with the help of this technology information on free/occupied parking spaces can be transmitted through a mobile application or [8] by using sensors connected through an Arduino UNO platform. The structuring and operation of an intelligent parking assistant architecture is used for the optimal use of parking spaces [1]. Modern technologies can be used to make predictions regarding the occupation or freeing of a parking space, such a variant based on the use of sensors from a mobile phone is described in the paper [9]. Identifying a free parking space in real time is a major challenge, to solve this problem is proposed an intelligent solution that uses an algorithm that takes into account a number of factors: the distance to be traveled to the parking space, the cost of parking, traffic congestion [10]. The policy of reducing traffic by increasing parking fees in central areas can also be a solution to parking related problems [11]. The development of new parking lots should be done strategically, in a comprehensive approach [12]. One of the proposed solutions for congested spaces is the creation of an automated parking lot with elevators for dense parking of vehicles [13].

As can be seen from the proposed solutions, they are grouped into two large categories: optimizing the existing situation and creating new modern parking spaces. In our study, the approach aims at the second group of solutions, namely the realization of a modern parking concept that will increase the number of available parking spaces in a congested area.

2. Designing an integrated modern parking in a crowded city area – a case study

2.1. Context of the study

The city of Sibiu is one of the most important cities in Transylvania, being an historical city. The town is located at 45°47' north latitude and 24°05' east longitude. With 155,000 permanent residents and 25,000 temporary residents, especially students, Sibiu is the largest city in the county [14]. The structure of the city is typical for a historical city, the building development starting from the central historical area, continuing to the periphery.

The city of Sibiu is a tourist, cultural, industrial and university city. The streets of the city of Sibiu add up to a length of approximately 150 km. The infrastructure is characterized by many narrow streets, especially in the central area. The types of roads are characterized by two-way roads, one-way roads, roads with one or two lanes per direction. Most of the large intersections in Sibiu are configured in the form of roundabouts, few of them being signalized. The city has a modern urban transport system, the fleet of vehicles includes buses with internal combustion engines, engines running on CNG and electric buses. Other travel possibilities are realized with the help of taxis, respectively alternative means of transport - bicycles, electric scooters. For the alternative transport system there are rental services and special tracks dedicated to this type of transport.

Traffic in the city of Sibiu is congested, especially during peak hours - morning (7-9), noon (around 12) and evening (15.30 - 18.30). The three intervals mentioned coincide with the following types of travel: the movement of employees to their workplaces, the movement of pupils and students to schools and faculties in the morning and vice versa, at noon and in the evening. Added to these movements are the flows of tourists visiting or transiting the city, especially on weekends or when there are cultural events in the city. During weekends and evenings there is traffic congestion in the peripheral areas of the city where there are shopping centers.

All these traffic flows combine with the need for parking spaces, whether for short-term or long-term activities. On top of this necessity, parking spaces for residents are added. Due to the structure of the city, especially in the central area, there are limited possibilities for the configuration of road arteries, so for the creation of new parking spaces, in addition to the parking lots adjacent to the existing roads, the only solution is to identify alternative options.

2.2. The analyzed area

The analyzed area is the area adjacent to the Faculty of Engineering within the Lucian Blaga University in Sibiu (fig. 1). Our study started from a simple finding: in the analyzed area we noticed the difficulty of finding a parking space, especially during peak hours. This issue was raised by the Faculty of Engineering students and teaching staff.

The analyzed area is located at a distance of approximately 800 meters from "Piata Mare", considered the center of Sibiu, which is also the historical center of the city. In close proximity to the Faculty of Engineering, there are other points that lead to increased congestion. These are: two banks, three schools/high schools, three faculties, ULBS rectory building, three hotels, one department store, City Hall building, spectacle building, theater.

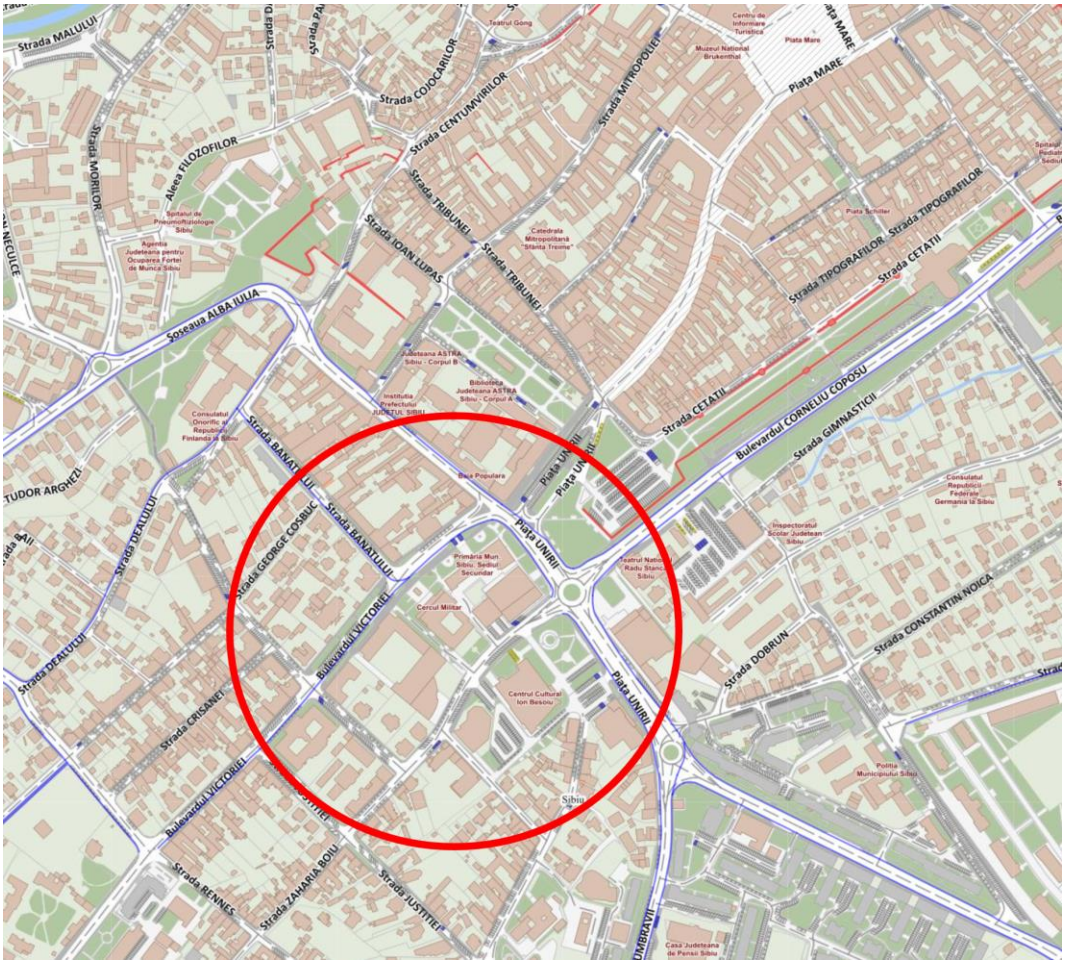

Fig. 1. Analyzed area.
Source: City Hall Sibiu https://www.sibiu.ro/hip/

The parking lots are arranged on the side of the road, there are also two parking lots on places specially arranged for this purpose. All parking lots in the analyzed area are paid parking lots. Our objective was to identify a solution by which additional parking spaces can be created, especially for the students of the Faculty of Engineering. This is where the idea of the study starts, namely to create a concept for a modern parking lot.

2.3. Study methodology

To carry out the study, the following steps were taken: analyzes were made regarding the availability of parking spaces in the analyzed area, a study was carried out to establish the degree of loading of parking lots in the area, an analysis of traffic in the area was made to identify the possibility of location of the parking lot, the location of the parking lot was established, the design of the parking lot was realized, establishing the type, structure, dimensions and functionalities.

2.3.1. Disponibility of parking places around the analyzed area

In order to analyze the current situation regarding the number of parking spaces, we have chosen an area in the proximity of the Engineering Faculty. The situation of the number of parking places is presented in figure 2.

Fig. 2. Number of parking places around studied area.
Source: Google Maps https://www.google.com/maps/

To identify the occupancy level of the parking places, we have monitored the free places for 22 days on three daily intervals: morning, noon and evening. The results were collected in tables organized as follows (Table 1).

Table 1. Collecting data for free parking places

Parking name	Piața Teatrului			Cazarma 90			Piața Unirii – H. Continental		
TOTAL places	156			205			117		
Parking type	street			barier			street		
tax /tax free	tax			tax			tax		
Moment of the day	morning	noon	evening	morning	noon	evening	morning	noon	evening

Source: Author own work

In our study, the findings show that during noon period almost all parking places are occupied in a percentage of 80% to 100% and the little occupancy periods are during weekends, that is on Saturdays and Sundays. To vizualize the flow during a day we have collected data from one of the biggest parking from the central area, known as ”Cazarma 90”. The occupancy level is shown in figure 3.

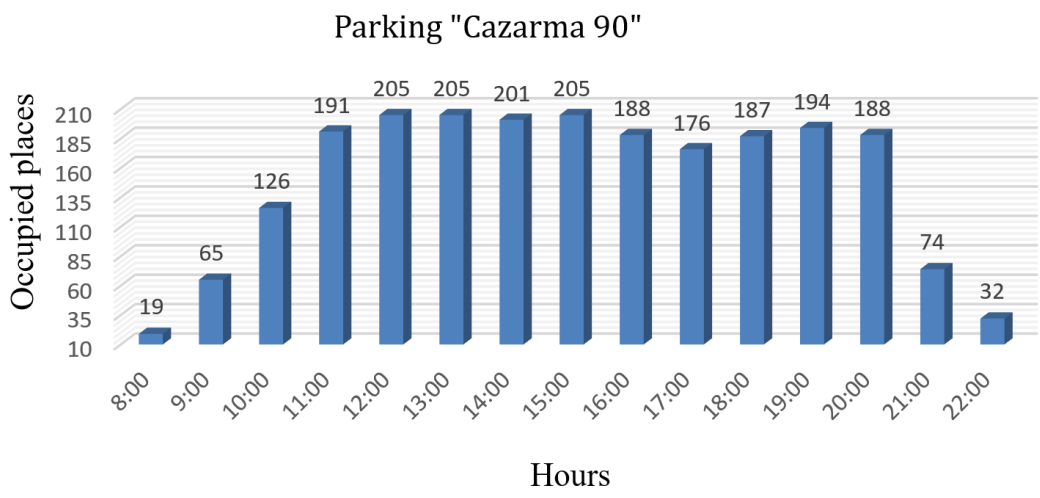

Fig. 3. Occupancy level during one day.

Analyzing the data, we can see that the parking is working at full capacity from 11.00 to 20:00 interval.

2.3.2 Traffic analysis

Since our area of interest for the location of the parking lot is in the area of the Faculty of Engineering, on Emil Cioran street, we have carried out a traffic analysis for two intersections that can produce a traffic load on this street, namely the roundabout in Piața Unirii and the intersection between Justitiei street and Emil Cioran street (fig. 4).

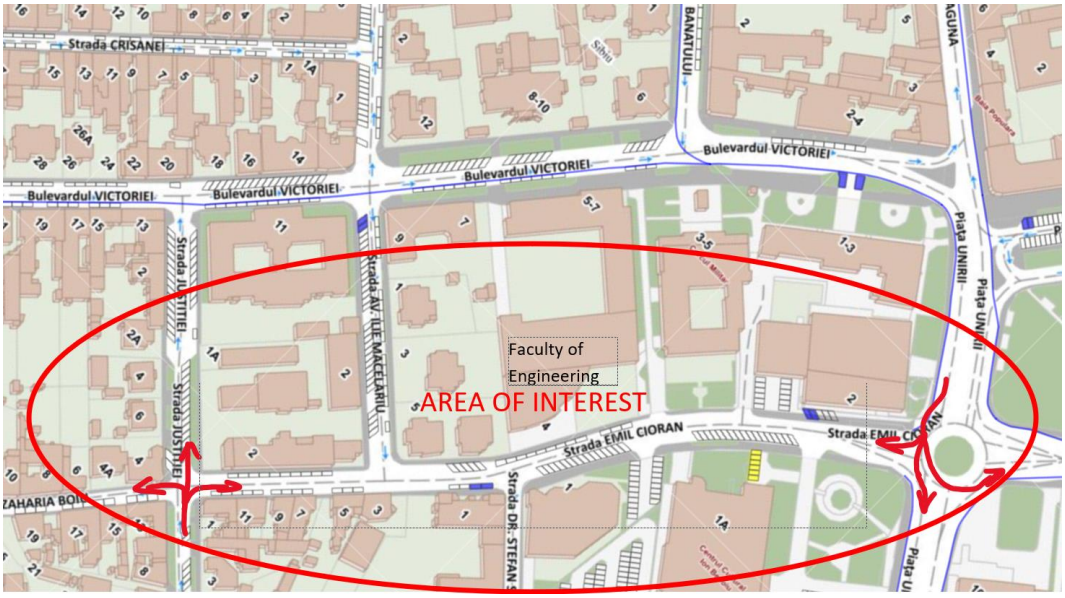

Fig. 4. Analyzed intersections.
Source: City Hall Sibiu https://www.sibiu.ro/hip/

The data were collected to establish the traffic volumes of the two intersections. To collect the necessary data we have quantified the hourly traffic volumes in the three periods of the day, morning, noon and afternoon, in one hour groups, split in pieces of fifteen minutes. The categories of traffic participants taking in consideration were: bicycle, motorcycle, car, microbus, bus. All the traffic participants were converted on passenger car unit based on SR 7348-2002 [15]. The results are presented in figures 5 and 6.

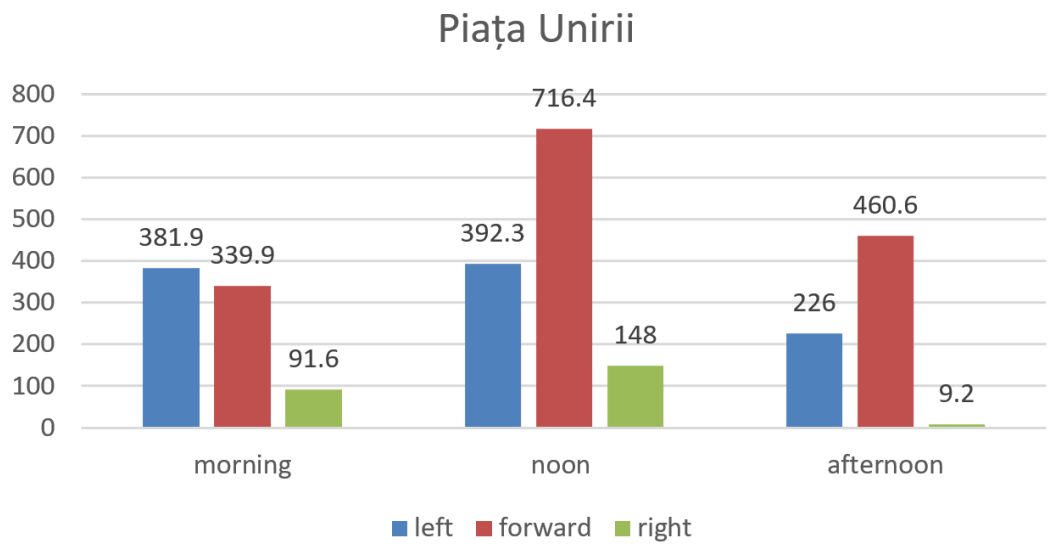

Fig. 5. Hourly traffic volumes – passenger car unit, Piața Unirii intersection.

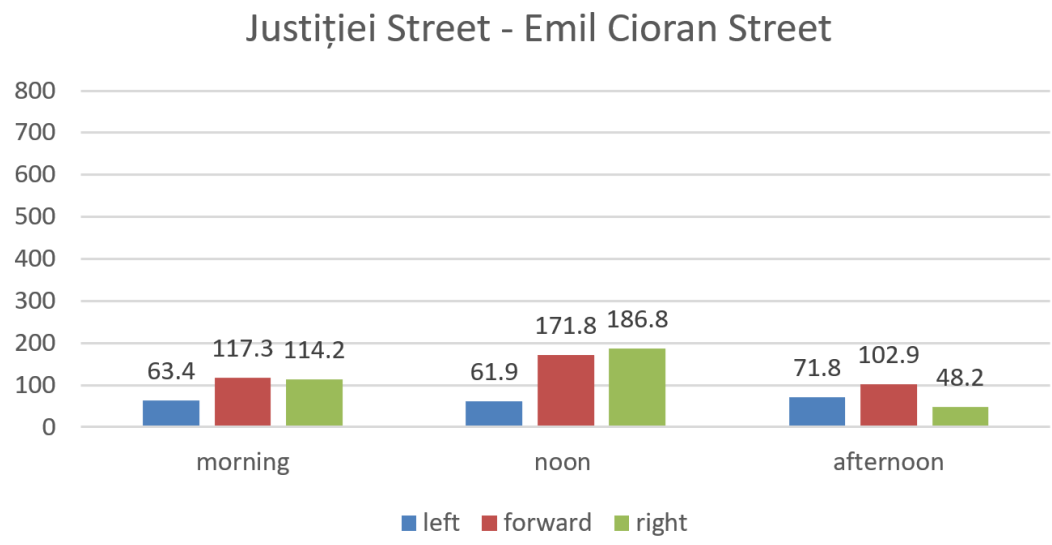

Fig. 6. Hourly traffic volumes – passenger car unit, Justiției street-Emil Cioran street intersection.

We were interested in vehicles turning right from the both analyzed intersections, and we have concluded that the number is pretty low from the Piața Unirii intersection, with higher values from Justiției-Emil Cioran intersection. The collected data were used to create a simulation in Synchro 8 software (fig. 7) [16]. The simulation confirmed us that the traffic on Emil Cioran street is low and the ideea of placing a parking on this street is the correct solution.

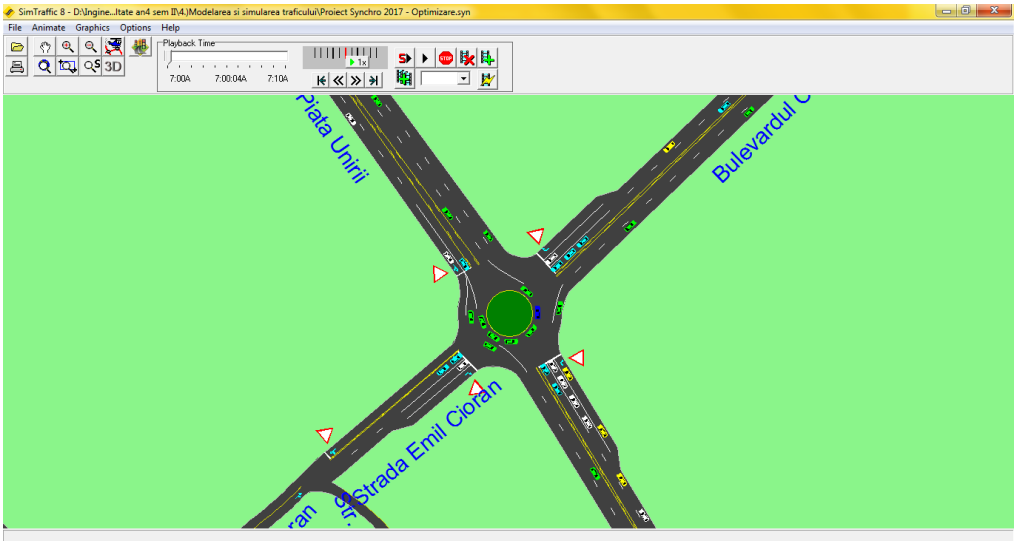

Fig. 7. Synchro 8 software simulation.

After analyzing the available areas on Emil Cioran street, we have chosen the location near the Faculty of Engineering, which currently is used as a street level parking place (fig. 8).

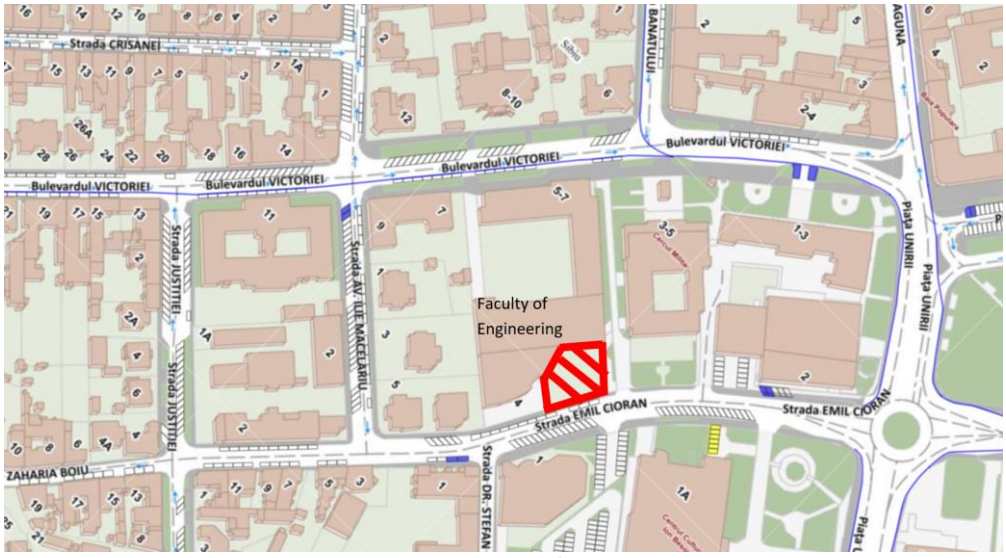

Fig. 8. Selected place for parking.

2.3.3. Parking design

The surface area for the parking is approximately 500 square meters. Because the space is narrow we have chosen a solution that best fit in a situation like this. Our solution is to design a smart, automated, multi-storey car park, which is based on a lift-type platform that moves in three directions to position the car at a certain level. In order to obtain the greatest possible capacity, the surface is occupied by three sets of tower parking lots of three rows each, on four levels. In our vision, the parking will have a structure based on steel beams. To determine the dimensions of the parking lot, we have analyzed the dimensions of several brands of vehicles. The maximum allowed dimensions and weight for one vehicle are: length 5 meters, width 2 meters, height 1.8 meters and weight 3 tons. According to our design, the new parking place will have 66 parking lots, which is almost triple the existing parking lot number. The solution we propose is presented in figures 9 and 10.

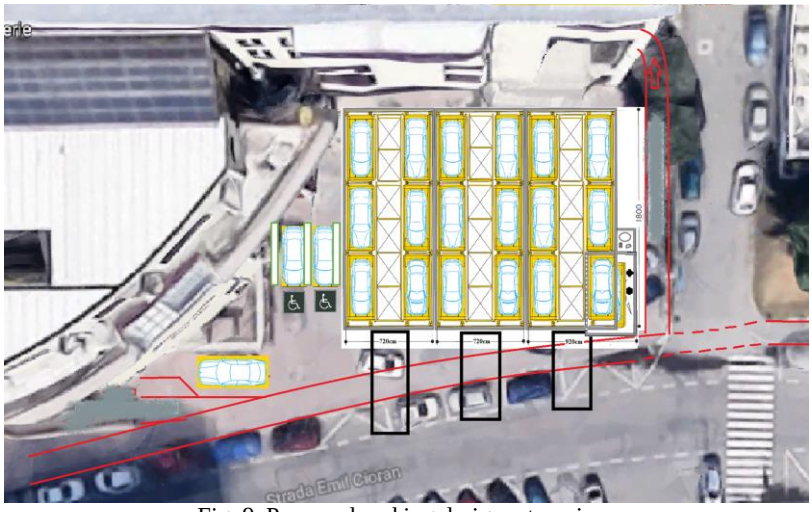

Fig. 9. Proposed parking design – top view.

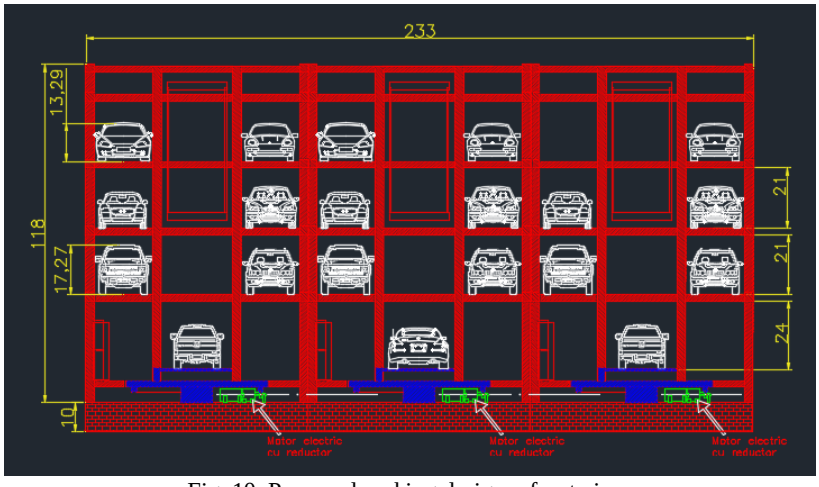

Fig. 10. Proposed parking design – front view.

The access to the parking lot can be done through one of the three entrances/exits. The car is entered through one of the access gates, after which the driver and passengers leave the vehicle. An automated lift system transports the vehicle to one of the available spaces. At each of the three entrances/exits there is a car turning platform, (fig. 11) so that the driver does not have to leave the parking lot backwards, which would increase the possibility of an incident.

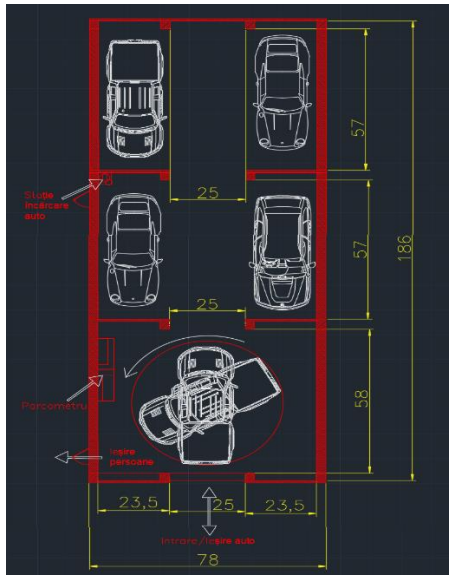

Fig. 11. Parking entrance/exit.

2.3.4. Parking facilities

We have taken into account that there are no parking spaces for disabled people in the area, so we will have two such special spaces at ground level.

The operation of the parking lot is ensured and coordinated by a command and control unit. This unit will manage the following parking systems and functions:

- displaying the number of available spaces on a display accessible at the entrance in the parking lot and on the adjacent roads;
- constantly updating the information available on an online software application that can be used by drivers;
- barrier access system that allows automatic vehicle identification based on the registration number;
- coordination of the sensors and mechanisms necessary for the automated functioning of the parking lot;
- safety system for parking lot users in order to avoid any type of incident;
- the charging and payment system that allows paying for parking, online, via SMS, with a bank card or cash;
- the monitoring and surveillance system provided by video cameras;
- six charging stations for electric vehicles located on the ground floor;
- the function of supplying electricity produced with the help of photovoltaic panels mounted on the roof of the parking lot.

3. Conclusions

The present study pursued a dual objective: to identify a practical solution to the problem of parking spaces and to present a methodology that can be used to generate other solutions of this type.

The solution we proposed aimed at the realization of the conceptual project of a modern parking lot that would solve the problem of insufficient parking spaces in the area of the Faculty of Engineering. We have designed a smart, automated, multi-storey car park, which is based on a lift-type platform that moves in three directions to position the car on the level where there is the availability of a parking space. The design thought by us presents the advantage of offering three times the number of parking spaces compared to the existing one. They can be used not only by students and teaching staff of the Faculty of Engineering, but are also useful for people who use the services of institutions in the area and for tourists. The car park has multiple facilities for users, all managed through a centralized system. The operation of the parking lot is designed to comply with environmental protection and sustainability standards, with part of the electricity required for operation being provided by means of photovoltaic panels.

One of the potential obstacles in the implementation of such a solution can be the cost of the parking lot, an aspect that was not the specific object of this research. Although the proposed solution generates an increase in the number of parking spaces in the area, it is still only a partial solution to the problem in question.

The modern parking lot designed in the framework of this research is currently a theoretical concept whose functionality needs to be verified and possibly optimized at a later stage, in the framework of future applied research.

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