

Vuk Bogdanović, PhD¹

E-mail: vuk@uns.ac.rs

Valentina Mirović, PhD¹

E-mail: plast@uns.ac.rs

Jelena Mitrović Simić, PhD¹

E-mail: mjelena@uns.ac.rs

Nemanja Garunović, MSc¹

E-mail: garunovic@uns.ac.rs

Ana Vujičić, MSc¹

E-mail: ana.vujicic@uns.ac.rs

Miodrag Počuć, MSc²

E-mail: miodrag.pocuc@adomne.rs

Igor Vukobratović, BSc²

E-mail: igor.vukobratovic@adomne.rs

¹ Faculty of Technical Sciences, University of Novi Sad

Trg Dositeja Obradovića 6, Novi Sad, Serbia

² "ADOMNE" d.o.o.

Šumadijska 1, Novi Sad, The Republic of Serbia

IMPROVEMENT OF PARKING CONDITION ON THE TAXI STANDS IN THE CITY OF NOVI SAD – CASE STUDY

Key Words

Taxi stand;
Parking
characteristics;
Vehicle
detection
technology;
Case study

Abstract

Characteristics of a quality taxi transport are efficiency, being economical and functional, which are provided by, among others, an adequate distribution and capacity of taxi stands in accordance with the needs of the passengers. The lack of parking space at a taxi stand affects the occurrence of additionally covered distance and unprofitable use of working hours which taxi drivers spend cruising, trying to find another vacant parking lot. Within this paper, the methodology of the taxi stand assessment from this point of view has been described, and the analysis of the cost effectiveness of the introduction of contemporary vehicle detection technology at the taxi stands as a measure for the reduction of the consequences of lack of parking capacity.

1. INTRODUCTION

Parking problems in urban environments are one of the main problems of contemporary society. The research studies show that drivers spend a lot of their time trying to find vacant parking lots. Previous research studies have shown that drivers waste between 3.5 and 14.0 min to find a parking lot in congested centres, therefore between 8 and 74% of vehicles in the flow cruise trying to find a vacant parking lot [1]. During last two decades different ITS systems have been implemented in the field of parking in the form of different devices, applications and software packages which would increase the level of service and reduce the cruising time spent in an attempt to find a vacant parking lot. ITS systems in the field of parking serve to give the drivers all necessary information on the available parking places. Traditional systems of traffic management towards parking lots connect detectors at the entrances and exits of the parking with the signs with changeable contents, while lately applications on mobile devices have been more and more used enabling an immediate insight into available parking places.

Apart from passenger cars, in many cities there is a lack of parking places for the vehicles of commercial or public transport. Taxi vehicles spend a significant part of their working hours in the state of inaction at parking places. In order to have an efficient, economical and functional taxi transportation, it is necessary to provide the distribution of taxi stands in accordance with the needs of passengers and enough parking lots at the taxi stands. In the situation when there is not enough parking space at the taxi stands, taxi drivers are forced to find another vacant parking, to stop the vehicle temporarily on the roadway, making a traffic offence or to park their vehicle on parking places intended for citizens or other surfaces, which is also not allowed.

Within this paper there is a short methodology of analysis of the taxi system in the city of Novi Sad from the aspect of possibility of finding a vacant place at taxi stands and defining the cost incurred in the system due to the impossibility to find a vacant parking place and from the aspect of the assessment. Subject analysis is a part of case study [2] whose aim was determining the possibility and the needs for the introduction of new technologies and benefits which would be achieved with the introduction of contemporary systems for vehicle detection at taxi stands, users informing and the control of system functioning.

2. GENERAL PARKING CHARACTERISTICS ON THE TAXI STANDS IN THE CITY OF NOVI SAD

In the city of Novi Sad there are totally 39 locations with 393 taxi stands [3]. Efficient and quality taxi transportation, apart from efficient inner organization and communication among the members of the association, demands a regular and equal distribution of parking places within the city. A good organization and spatial distribution of parking places enable the reduction of the taxi vehicle driving time to the beginning of the realization of transportation service, the increase of efficiency and reduction of costs of zero rides. The city of Novi Sad has a relatively well

developed taxi transportation and spatial distribution of parking places on the level of the city. However, it is noticeable that at certain locations, in certain periods of the day, the demands for taxi vehicles parking exceed the capacities of the predicted parking places. Due to this, taxi vehicles are stopped or parked on the roadway, as well as on regular parking places, and very often drivers give up from parking and move to another location. On the other hand, some parking places for taxi vehicles are in certain periods insufficiently used, therefore, there is an excess capacity.

Characteristics of parking at taxi stands have been determined through 24-hour counting of vehicles at the taxi stand. After the conducted counting, a set of data on characteristics of vehicles arrivals and departures from the taxi stand was formed, which was the basis for further determined basic characteristics of parking (turn, delay time, accumulation, etc.). Apart from this, a classification of vehicles has been done for the vehicles which use the taxi stand into: taxi vehicles (TX), private automobiles (PA) and delivery vehicles (DST). During the period of 24 hours at the taxi stands on the territory of the city of Novi Sad, 11,364 arrivals/departures of taxi vehicles have been recorded.

Simultaneously with the vehicles counting at taxi stands, the survey of taxi drivers was also conducted. During the period of the survey, 2,363 questionnaires were collected. The survey at each location determined whether it was the first stand for the driver after the last passenger they drove, and if it was not, to state at which stand he tried to stop but did not find the vacant place. On the basis of this data, the travel time was determined, as well as the distance covered as a consequence of the lack of parking place at certain taxi stands and the percentage of the unmet demands for parking. After that, drivers were asked to assess the possibility of finding a vacant parking lot at the arrival at a taxi stand in the part of the day when they were surveyed, and to state which taxi stands in the city are the most difficult for finding a vacant parking lot. On the basis of the last two questions there was a ranking of the stands by the possibility of finding a vacant place and the average probability of finding a vacant place for each analyzed stand.

2.1. Assessment of the current state

The assessment of the current state of parking is based on the results of parking characteristics, taxi drivers survey and specific characteristics of taxi stands on the territory of the city of Novi Sad. The assessment of the taxi stand capacity and position was conducted on the basis of the following parameters:

- Real capacity of the taxi stand achieved by dimension measuring on the field;
- Maximal values of average hour accumulation of taxi vehicles;
- Maximal values of average hour accumulation of all vehicles which use the analyzed stand;
- Percentage of taxi vehicles which stop outside the stand;

- Participation of all vehicles (private cars and delivery vehicles) in the structure of all vehicles which use the stand.

For the assessment of the stand capacity and position, a multicriteria assessment has been defined for evaluation according to which the current capacity and position of the stand are considered to be acceptable if the following conditions have been fulfilled:

- Criterion 1a. Maximum values of average hour accumulation of taxi vehicles does not exceed 85.0 % of values of the stand capacity
- Criterion 2a. Maximum values of average hour accumulation of all vehicles does not exceed 85.0 % of values of the stand capacity
- Criterion 3a. Percentage of taxi vehicles which stop outside the stand is lower than 50.0 %.
- Criterion 4a. Other vehicles in total number of arrivals participate with less than 10.0%.

If the first criterion has not been fulfilled, it is considered that the capacity of the taxi stand is not appropriate and it is necessary to conduct certain technical and regulative measures which means the introduction of the system for determining free places at taxi stands, parking space reorganization of space for parking or the change of number of places for parking in accordance with specific characteristics of the location. Also, at certain number of taxi stands due to a high turnover of vehicles, there are sudden changes of accumulation which exceed the stand capacity although the maximum value of an hour capacity meets the first criterion, therefore these locations are considered as potential for the introduction of certain technical and regulative measures. If the second criterion has not been fulfilled, it is considered that the stand capacity is reduced due to the occurrence of the other vehicles at the taxi stand. If the third or the fourth criterion have not been fulfilled, it is considered that the taxi stand position is not acceptable, that is, taxi vehicles do not use the taxi stand enough. In case when only the fourth criterion has not been fulfilled, (and the third has been fulfilled) the use of taxi stand is not acceptable and it is necessary to conduct control measures and prevention of parking by the vehicles which do not provide the service of taxi transportation. Based on this analysis, certain taxi stands have been determined as stands with a problem related to parking conditions.

2.2. Assessment of possibility of finding a vacant parking place at taxi stands

On the basis of the counting results and the survey with the taxi drivers, the assessment of possibility of finding a vacant parking lot at taxi stands on the territory of the city of Novi Sad was conducted. The basic goal of this part of analysis was to separate those stands which by their basic parking characteristics of possibility of finding a vacant parking lot represent a priority for the introduction of vacant parking lot detection system. The assessment of this state, that is, the

need for the introduction a detection system and control at taxi stands was conducted by the following criteria:

- Criterion 1b. The relation between maximal hour accumulation of taxi vehicles in the day and maximal available number of places at the taxi stand. Criterion 1 has been met if the value of the stand usage is higher than 85.0 %.
- Criterion 2b. The percentage of the unmet demands for the parking at the stand incurred due to the lack of vacant parking lots.
- Criterion 3b. The average value of hour probability of finding a vacant parking lot based on the subjective assessment of the interviewed taxi drivers in the survey. Criterion 3 is fulfilled by the taxi stands where the average probability of finding a vacant parking lot is lower than 0.80.
- Criterion 4b. Frequency of reporting a stand as a problematic one from the aspect of finding a vacant place has been determined on the basis of subjective assessment of the interviewed taxi drivers in the survey.

Taking into consideration the results of the previous analysis, the priority stands are the ones which meet the conditions by at least two out of four possible criteria. By applying the above mentioned criteria, 11 taxi stands on the territory of the city of Novi Sad stand out as unfavourable regarding the possibility of finding a vacant parking lot at the taxi stand. Analysis determined that taxi vehicles which due to the lack of vacant parking lot at these stands during the day totally cover additional 1,060 kilometres trying to find a vacant parking lot at other stand. In order to find a parking place on other taxi stands, these vehicles during the day totally waste 56.4 working hours.

3. PROPOSAL OF VEHICLE DETECTION TECHNOLOGY AT TAXI STANDS AND EVALUATION OF THE EFFECTS OF THE SYSTEM APPLICATION

Analysis of different technical solutions of the vehicle detection technology at parking spaces and information transmission, analysis of the examples of experiences from the world and taking into consideration the purpose and needs of taxi service and characteristics of the taxi stand location, were taken into account when proposing a system which is to have the following operational and technical characteristics:

- Clear and precise detection of macrolocation - parking space and micro-location - vacant parking lot;
- Without ambient, electronic, time and other interference in the detection procedure;
- Cheap system maintenance and fast replacement of damaged detectors (vandalism, incidents, etc.), without any work interference with other subsystems;

- Forming a unique data base for each parking space and complete system;
- Software part for system functioning tracking – “panel”;
- Software part intended for system users – mobile application.

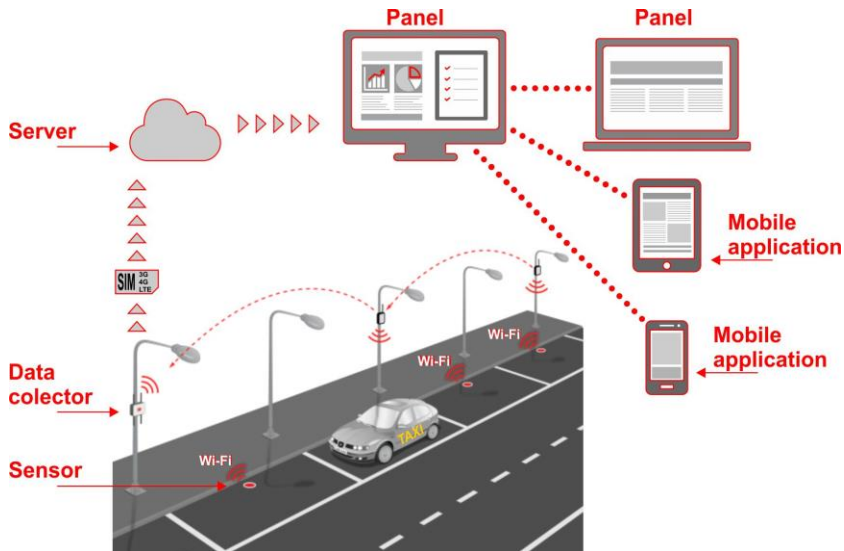


Figure 1. Schematic display of one complete system functioning for vacant places determining, based on experiences from the world [2]

3.1. Evaluation of the effects of the application of detection and parking control system introduction

Analysis of investment cost effectiveness has been conducted in accordance with the determined values of distance prolongation due to parking occupancy, that is, savings of fuel cost and travel time, alongside the benefits which would be achieved through the reduction of emission of gases which cause the effects of green glass, first of all CO₂. On the basis of the data which are the result of the conducted research, pessimistic, realistic and optimistic variants of system using were considered. Due to the fact that all taxi drivers for objective reasons will not be able or will not want to use the information achieved from the proposed system for the reduction of travel distance and time, a realistic variant means that in 70% of rides, drivers will use the obtained information and reduce the unnecessary ride length. A pessimistic variant means that only 60% of taxi drivers will use the information, and the optimistic variant is that 80% of drivers will completely use the possibility of the proposed system and reduce the ride length.

Taking into consideration the market state, the estimated investment costs in the first year would have the structure displayed in the following table.

Table 1. Investment costs in the first year

Investment	Amount
Investment (equipment delivery and installation)	90,000 EUR
System maintenance costs	6,500 EUR
Operational costs	1,200 EUR
Electricity costs	800 EUR

Taking into consideration investment costs, maintenance and business costs, and the savings which can be achieved through the application of the detection and control technology at taxi stands, discount values of costs, income and internal profitability rate for the period of 5 years according to these analyzed variants have been shown in the following table.

Table 2. Business operations for the analyzed variants

Discounted costs/revenues	Pessimistic variant	Realistic variant	Optimistic variant
Management and maintenance costs	38,548 EUR	38,548 EUR	38,548 EUR
Total savings in fuel, travel time and reduced emission of harmful gases	208,181 EUR	242,878 EUR	277,574 EUR
Internal profitability rate	22.1 %	32.9 %	43.1 %

4. CONCLUSION

This paper concisely shows the analysis methodology of the state of taxi transportation in Novi Sad from the viewpoint of parking. The research covers 39 locations of regular parking spaces for taxi vehicles on the territory of the city. For the needs of determining critical taxi stands, the criteria were defined for separating 11 key taxi stands on the territory of the city of Novi Sad. In the research it was determined that due to impossibility of finding a vacant place at certain taxi stands, taxi vehicles cover additional 1,060 kilometres trying to find a vacant parking lot at another stand, that is, they totally all spend additional 56.4 working hours during a work day.

After the performed analyses, system characteristics have been defined, whose aim was to reduce the lack of vacant parking lots at taxi stands and improve the efficiency of parking at the researched locations. Taking into consideration real economic parametres and savings which would incur due to the reduction of fuel consumption, travel time and emission of harmful gases, as well as investment into the system, system operational and maintenance costs and electricity, an evaluation has been performed, that is, a cost and benefits analysis. In analysis, virtually the most unfavourable scenarios were considered. Three parallel analyses were conducted - for realistic, pessimistic and optimistic variant. The analyses

showed that the internal profitability rate for the pessimistic variant is 22.1 %, optimistic 32.9 %, and for realistic 43.1 %. Based on this data, it can be concluded that it would be justifiable to introduce this system at the defined 11 taxi stands.

REFERENCES

- [1] Donald C. Shoup, "Cruising for parking", *Transport Policy*, vol. 13, issue 6, pp. 479-486, Nov. 2006.
- [2] City of Novi Sad - City Administration for Transport and Roads of the City of Novi Sad, "Implementation of vehicle detection systems on parking place on the taxi stands in the City of Novi Sad - Case study" (only in Serbian language), Faculty of Technical Sciences Novi Sad & ADOMNE Ltd, Novi Sad 2019.
- [3] City of Novi Sad - City Administration for Transport and Roads of the City of Novi Sad, "Regulation act about taxi service in the City of Novi Sad ("Official Gazette of the City of Novog Sada", No. 12/2019, 13/2019 - amend., 20/2019 - amend. i 31/2019)" (only in Serbian language)