Simulation Model of Parking Spaces Through the Example of the Belgorod Agglomeration

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Abstract

The paper considers various methods to study turnover of parking slots in the framework of traffic flow characteristics, presents analysis of the data of full-scale studies of the intensity and turnover of parking slots, as well as analysis of geometry of vehicle movement during parking and time spent for maneuvers. It is shown that use of Vehicle Tracking application for AutoCAD makes it possible to develop a dynamic simulation model of a parking space on the considered sections of the street and road network and to conduct analysis of paid parking spaces and their impact on characteristics of the traffic flow. It is stated that the model allows predicting vehicle delays under predetermined characteristics.

Keywords: simulation modeling; distribution of traffic flow intensity; turnover of parking slots

Main text

Rational arrangement of parking spaces is one of the key factors in behavior changing when choosing a method of travel in the urban territory. That is why the development of system concepts appears to be relevant for simulation of traffic, analyzing of parking operation, as well as assessment of interaction between parking spaces and the transportation system [Horni and Montini (2012)].

The following characteristics were selected to evaluate operation of parking spaces:

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• loading of the street and road network (SRN) with parked vehicles by studied streets (number of parked cars per kilometer);
• average time of parking at respective road sections (in minutes);
• turnover of parking slots in different vehicle areas (number of vehicles per one parking slot);
• total space of parking, or the total number of cars parked at the stated period of time.

Currently, three methods of studies for analysis and assessment of interaction between parking spaces and the transportation system exist, namely: empirical method, analytical method and multi-agent (MA) simulation [Cao and Menendez (2015)].

Empirical studies are based on data received from polling surveys of drivers, videos, full-scale studies carried out by means of vehicles capturing the required parameters and operating in the test mode while searching for a free parking space or using the GPS satellite navigation system. Since empirical data are specific to a particular area (study object), it is rather difficult to make generalized conclusions. Multi-agent simulation tools are widely used for the development of a behavior model for the majority of road users. These tools allow entering data about non-uniform transportation networks and personal preferences. The result of such simulation may contain detailed conclusions on the impact of vehicles searching for a parking space on parameters of the traffic flow (TF). This method is comprehensive; however, it is based on time-consuming preliminary studies, therefore, the final results depend on a lot of factors [Gallo et al. (2011)].

There is an acute problem of increasing efficiency of the transportation infrastructure in Russia. One of the possible options to evaluate its efficiency is application of simulation modeling of SRN with actual and forecasted parameters [Popov (2006)].

The proposed method is based on the development of a mobility plan. Separate elements of the plan include objects of attraction of the population, such as schools, kindergartens or business centers. These objects generate and absorb transport flows at different time intervals. At that, it is necessary to consider not only technical characteristics of mobility plan objects, but also availability of parking spaces, which can absorb and generate traffic flows within such particular object [Borovskoy and Yablonovskaya (2013)]. Such parking space shall be characterized by the number of parking slots and their turnover during the day, which can be described by the following function according to formula (1):

\[
N_{ij}(\tau) = \left(\frac{N_{\text{abs}}(\tau)}{N_{\text{gen}}(\tau)}\right)
\]

(1)

where \(N_{ij}(\tau)\) is the intensity generated by one element of the parking space during the course of time \((i, j\) are numbers of corresponding parking bays, \(i\) is the street number, \(j\) is the number of a parking space), \(N_{\text{abs}}(\tau)\) and \(N_{\text{gen}}(\tau)\) are the respective intensities of absorption and generation of the traffic flow by a parking bay [Vorontsov and Chekhovich (2013)].

Such an approach makes it possible to predict loads on the adjacent street and road network and develop various options of actions aimed at increase of parking space use efficiency, similar to the method developed by the authors for large centers of population attraction [Arnott and Inci (2006)]. In this case, the required amount of parking slots can be defined as the difference between the absorbed and generated traffic flows. This value shall tend to the maximum capacity of a corresponding parking bay:

\[
N_{ij}(\tau) = N_{\text{abs}}(\tau) - N_{\text{gen}}(\tau) \to M_{\text{max}}
\]

(2)

where \(M_{\text{max}}\) is the capacity of a parking bay.

Construction of such model requires both data on objects of attraction from official sources and actual data obtained during full-scale studies. The full-scale studies carried out to evaluate efficiency of parking spaces included analysis of the intensity and turnover of parking slots, analysis of geometry of vehicle movement during parking and time spent for maneuvers. Besides, full-scale studies were conducted to determine the time of entry and exit from the parking bay in these sections, followed by the development of a simulation model [Gorev et al. (2015)].

A series of studies of parking spaces was carried out in several regional centers, including Belgorod, in order to
determine methods to develop such model.

A simulation model was developed with the help of Aimsun which is an integrated software application for transportation modeling, developed and sold as a unique selling proposition for transport simulation systems based in Barcelona, Spain and used for transport equipment, motion simulation, transportation planning [Trapeznikova et al. (2014)].

Vehicle movement simulation models were developed for each of the considered sections with the help of the mentioned software; information about traffic delays was obtained in the result of simulation modeling.

The following two models were developed to analyze the effect of paid parking spaces at the considered sections: a) with account for availability of parking spaces, b) without account for availability of parking spaces [Cao and Menendez (2013)].

Let us consider the development of a simulation model through an example of a section of Preobrazhenskaya Street in Belgorod.

It is necessary to input the data on the intensity of vehicle movement, obtained during full-scale studies, to develop the model. The intensity of vehicle movement is entered in the form of mobility plans presented in Fig. 1 and 2.
The developed simulation model is presented in Fig. 3.

Fig. 3. Model of the SRN section of Preobrazhenskaya Street.

Since it is necessary to identify correlation between the intensity of vehicle movement and vehicle traffic delays, this model was developed with account of various scenarios when different obstructions were introduced, whereby it became possible to display different obstructions in the form of vehicles entering and leaving a parking lot. Obstructions were created at regular time intervals (2, 3, 11, 15, 22 minutes, one and a half hour). The line was shut off in 10 seconds.

Fig. 4. Scenario of vehicle movement along Preobrazhenskaya Street.
Fig. 5 represents a model with obstructions.

Fig. 5. Model of vehicle movement with obstructions along Preobrazhenskaya Street.

Fig. 6. Model of vehicle movement along Preobrazhenskaya Street in dynamics.

The result of the model development was identification of delay time under different intensities of vehicle movement. This correlation is shown in Figures 7, 8, 9.
Thus, various methods for study of turnover impact on traffic flow characteristics were considered. The most common ones are empirical and analytical methods and the method of multi-agent simulation [Mayorov and Phetisov (2011)]. The proposed study method is based on the development of a simulation model depending on the mobility plan; in the course of full-scale studies, data on the intensity of vehicle movement and the time of vehicle entry to and exit from the parking space were obtained. Thus, analysis of the path of vehicle movement, depending on various positions of the vehicle during parking, was performed with the help of Vehicle Tracking application for AutoCAD. Also, a simulation model of the considered sections of the SRN was developed; analysis of the influence of paid parking spaces on characteristics of traffic flows was carried out. It is noted that increase in the turnover leads to increase of delays in traffic flows; this dependence is represented in the graphs and equations of linear dependence. It is stated that the model allows predicting vehicle delays under given characteristics. Such approach enables efficient use of parking spaces and development of various options of impact during forecasting of loads on the SRN.
References


