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ESTIMATION OF A PARKING LOT OPTIMAL CAPACITY UNDER CONDITIONS OF STOCHASTIC DEMAND

Parking lots are the necessary element of contemporary urban transport systems. Use of parking lots eliminates traffic jams caused by decrease of road capacity due to vehicles parked on a roadway. Interceptive parking lots allow minimizing the traffic intensity in central part of the cities, which significantly reduce air and noise pollution. Parking lots are obligatory element of any entertainment, office or shopping center; they enhance the attractiveness of the commercial objects for the clientele. On the other hand, parking lots are the sources of water pollution because of their extensive impervious surfaces. As a rule, parking lots need more land area than the respective office or shop buildings, this leads to covering of large areas with asphalt and results the excessive accumulation of heat. The heat from paved areas in urban zones could even change the weather locally. It also should be mentioned, that parking lots functioning demands a certain amount of funds; as objects of commercial activities, they should be profitable. Thus, the capacity of parking lot should be sufficient to ensure the implementation of main purpose of the parking lot as an element of transport system. At the same time, it should not be excessive in order to eliminate the negative effects of parking lots functioning.

In this paper a parking lot is considered as an element of city transport system on the one hand; on the other hand, a lot is treated as a commercial object (as far as drivers pay a fee for the parking services). Developing of a new model aims to consider stochastic nature of demand on parking services while solving problems of parking lot parameters optimization. A problem of estimation of parking lot optimal capacity is being resolved with the use of proposed conceptual model; however, it's not the only optimization task where the model could be used.

Demand on parking services could be characterized by a number of vehicles, parked on a lot during the certain time period, and by duration of parking per one vehicle. For the given time period instead of a number of parked vehicles it's proposed to use an interval between arrivals of two cars in a row. Thus, parking demand could be described by a pair of stochastic values – parking interval and parking duration.

As an efficiency criterion to measure a parking lot functioning, it is proposed to use a profit of an enterprise which provides the parking services. Profit as a numerical measure accounts an income and total costs of functioning, so it makes possible to consider factors of different origin. In a common form profit P_{PL} from a parking lot functioning could be presented as follows:

$$P_{PL} = T_m \cdot T_{1hr} \cdot \frac{\mathrm{M}_t}{\mathrm{M}_{ж}} \cdot p_s - c_0 - c_s \cdot C_{PL}, \quad (1)$$

where T_m – duration of a modeling period, hrs; T_{1hr} – tariff per 1 hour parking per a vehicle, \$/hr; μ_t – mathematical expectation of a random variable of parking duration, sec./veh.; μ_ζ – mathematical expectation of a random variable of time interval between arrivals of two vehicles in a row, sec./veh.; p_s – probability of the event, that a vehicle, arrived at a parking lot, would be serviced (because the parking lot has enough free space); c_0 – constant component of parking lot functioning costs, \$; c_s – costs per one parking space maintenance, \$/unit; C_{PL} – parking lot capacity, units.

To provide a tool for identification of consistent patterns of a parking lot functioning, the simulation model was developed in bounds of this research. The simulation model was implemented on the base of object-oriented approach with the use of C# programming language; its programming code could be downloaded at [1].

With the use of developed simulation model, the full factorial experiment was conducted in order to determine the $p_s = f\left(C_{PL}, \mu_\zeta, \mu_t\right)$ dependence. On the base of regression analysis tools of Microsoft Excel the coefficients for a set of hypotheses on a form of the $p_s = f\left(C_{PL}, \mu_\zeta, \mu_t\right)$ dependence were estimated. Among all the considered hypotheses, according to a value of the coefficient of determination (R^2 = 0,9686), the following dependence fits the best way:

$$p_s = 0{,}1096 \cdot \ln C_{PL} + 0{,}1676 \cdot \ln \mu_\zeta - 0{,}1008 \cdot \ln \mu_t . \qquad (2)$$

Taking into account (1), the efficiency criterion of a parking lot functioning could be presented in a form

$$P_{PL} = T_m \cdot T_{1hr} \cdot \frac{\mu_t}{\mu_\zeta} \cdot \left(0{,}1096 \cdot \ln C_{PL} + 0{,}1676 \cdot \ln \mu_\zeta - 0{,}1008 \cdot \ln \mu_t\right) - c_0 - c_s \cdot C_{PL} . \qquad (3)$$

Differentiating the expression (3), and taking into account, that for the extremum the result must be equal 0, we obtain the equation, which root in regard to C_{PL} is the optimal value of a parking lot capacity:

$$\hat{C}_{PL} = 0{,}1096 \cdot \frac{T_m \cdot T_{1hr}}{c_s} \cdot \frac{\mu_t}{\mu_\zeta} , \qquad (4)$$

where $\hat{C}_{PL}$ – optimal parking lot capacity, units.

The obtained optimal parking lot capacity formula is recommended to be used for estimation of a parking lot capacity. This expression, however, could be clarified and supplemented with the help of proposed simulation model.

References

1. Naumov V. C# Code for Simulation of a Parking Lot Functioning [E-source] https: // www.academia.edu / 15674088 / C_code_for_simulation_of_a_parking_lot_functioning