

# Application of calibrated vehicle dynamic indicators in city traffic management

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**Abstract.** The number of registered vehicles in the Russian Federation is increasing every year, and the traffic flows of cities consist mainly of cars. The car fleet of the Russian Federation has undergone significant changes in recent decades. In particular, passenger vehicles, their power and design parameters are improving every year. These changes affect the system and the process of movement of cars in the traffic flow. This article defines the parameters that affect the functioning of urban traffic flows and, in a mathematical way, on their basis, found dynamic indicators for a conditional "calibrated" car.

## 1 Introduction

Technical and dynamic parameters of vehicles are primary data that are taken into account in all methods of efficient operation of the transport system (planning, organization, control, management). In urban transport systems, it is the main control method that also takes into account primary data - these are the parameters of passenger cars most often found in transport flows. The automotive market in Russia has undergone significant changes in recent decades - the presence of a variety of brands and models of both domestic and foreign cars. The above vehicles are being improved every year, in particular, dynamic indicators (length, width, height, power, torque, acceleration, etc.) are changing and improving [1,2]. Taking into account these changes, it is necessary to conduct a number of studies to determine the dependence and impact of changes in these indicators on the nature of movement vehicles in the traffic flow. We will consider the impact of dynamic indicators of passenger cars within the framework of this study using the example of the transport system of the city administrative center of Belgorod.

## 2 Materials and methods

To determine the dynamic indicators of a calibrated car, statistical and field studies must be carried out to determine the heterogeneity of the composition of the fleet of passenger vehicles. The statistical analysis of sold cars for the period from 2005 to 2022 based on the

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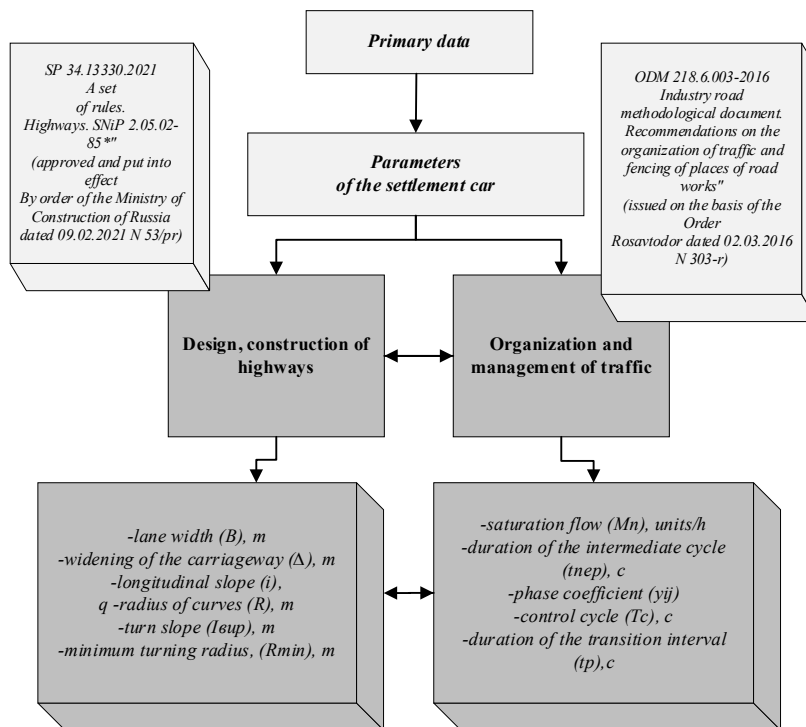
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Avtostat databases confirms the heterogeneity of traffic flows and determines that the sold cars in the Belgorod region are domestic cars: Lada Granta (5.7%), Lada Vesta (4.3%), foreign car industry: Kia Rio (5.3%) [3]. Full-scale studies of the entrance flows of Belgorod were also carried out - these are various sections, which are two-level, circular, regulated and straight sections.

As a result of the study, the total traffic flow was determined, which on weekdays of the week averages 16,000 auth, of which 90% are cars of various brands. At each study site (Fig. 1), common car brands were identified: Lada Granta (19.15%), Kia Rio (18.59%), Renault Logan (18.45%), Lada Vesta (11.84%), Toyota Camry (11.26%), Haval Jolion (5.49%), UAZ Patriot (5.08%), Hyndai Creta (3.94%), Mazda CX-5 (3.53%), Gelly Emgrand (2.67%) [4]. Mathematical calculations are performed for these vehicles to determine their dynamic characteristic [5-7]. The dynamic characteristic is such dynamic parameters as: speed of movement, acceleration speed, tangential thrust force, dynamic factor [8,9]. These parameters allow you to evaluate not only the design features of the vehicle, but also determine the har. These parameters allow you to assess not only the design features of the vehicle, but also determine the nature of its movement. To a greater extent, the change in the composition of passenger cars in the flow had an impact on the dynamics of the movement of vehicles, which certainly must be taken into account when implementing management methods in urban transport systems [10].

### 3 Result and conclusion

Primary data, namely passenger car parameters, are used not only in traffic management, but also at the stages of road design (Fig. 1).



**Fig. 1.** Diagram of application of primary data in case of calculation of ODD indicators

Thus, based on the design parameters of vehicles, it becomes possible to determine control parameters that affect the functioning of urban transport flows - this is the saturation flow, the duration of the intermediate cycle, the phase coefficient, the traffic light control cycle, the duration of the transition interval.

Dynamic indicators have a greater influence on the dynamics of the movement of vehicles in the flow, therefore, it is necessary to determine changes in such a parameter as acceleration of the car. If previously the parameters of the conditional car were taken into account, which included the dynamic characteristics of domestic cars that prevailed in flows more than 50 years ago, at the moment it is proposed to introduce a new indicator as a "calibrated car," which allows expanding the previously used indicator of the conditional car in terms of dynamic parameters, in relation to the control process in urban transport systems. To determine changes in the dynamic parameter - acceleration, a mathematical analysis was performed, which made it possible to obtain a mathematical model for calculating the dynamic indicator of a calibrated car (formula 1), which, in relation to the surveyed territory of the administrative center of Belgorod, amounted to 1.4 m/s<sup>2</sup> (Table 1) [11].

Average acceleration of the calibrated vehicle depending on the gear:

$$\sum j_{am} = \begin{cases} \bar{j}_{ai_1} = \frac{j_{a1} + \dots + j_{an}}{n} \\ \bar{j}_{ai_2} = \frac{j_{a1} + \dots + j_{an}}{n} \\ \dots \\ \bar{j}_{ai_5} = \frac{j_{a1} + \dots + j_{an}}{n} \end{cases} \quad (1)$$

$$j_{ak} = \frac{\sum j_{am}}{n} = \frac{\bar{j}_{ai_5}}{n}$$

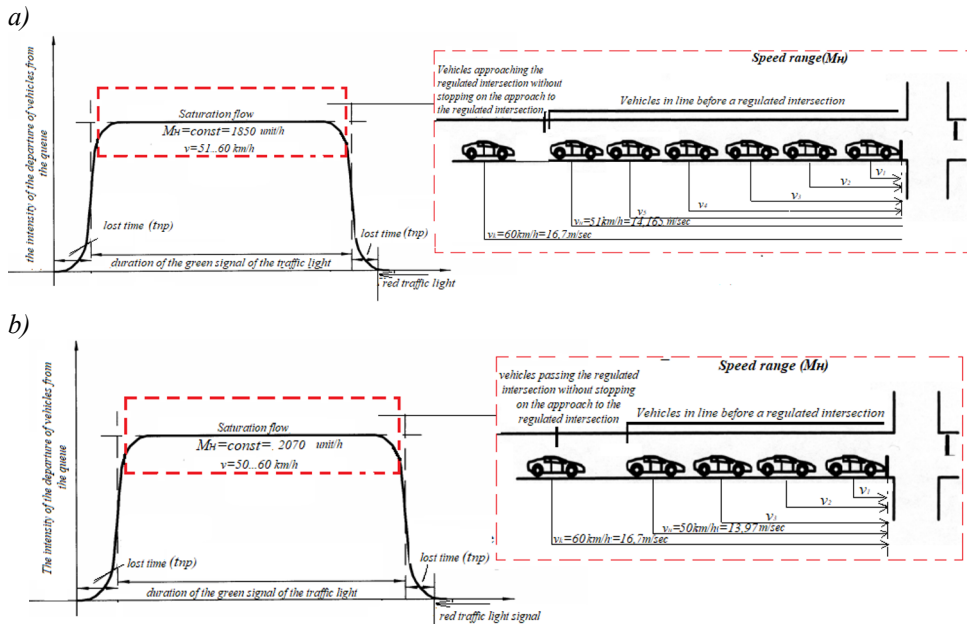
where m - is the vehicle grade, n is a set of values, i<sub>1</sub>- i<sub>5</sub> - is the transmission ratio of the gearbox, j<sub>a1</sub>-j<sub>an</sub> - is the acceleration of the vehicle depending on the transmission ratio of the gearbox, m/s<sup>2</sup> (depending on the speed of movement v<sub>a</sub> ≤ 60 km/h).

**Table 1.** Dynamic parameter (acceleration) for calibrated vehicle

№	Name of the car	Acceleration on transmission (j <sub>ai</sub> )					Overall acceleration (j <sub>a</sub> )
		I	II	III	IV	V	
1	Calibrated vehicle	2,35	1,76	1,26	0,95	0,82	1,42

A comparative analysis of previously used indicators made it possible to establish a difference of 9.23%, which indicates the presence of a certain change in traffic dynamics in cities, despite the adopted speed restrictions.

A study of the traffic process using the example of a controlled section showed that, in fact, taking into account the change in passenger car models, over the past decades, the physics of the process itself has also been modified, as it was established, that taking into account the application of indicators of a conventional vehicle, without the use of new indicators, i.e. the situation as it was the degree of saturation is achieved mainly in 7 cars but taking into account the established changes, observations, mathematical analysis and interpretation have been established that the saturation degree is achieved in 5 cars. As a result, data reflecting values of saturation flow were obtained (Figure 2) [12].



**Fig. 2.** Comparative analysis of saturation flow intensity: a) taking into account changes in the dynamic parameters of vehicles, b) without taking into account changes in the dynamic parameters of vehicles

Traffic management in urban transport systems uses the saturation flow definition, which allows you to determine the maximum lane capacity for traffic lights. The established difference between the dynamic characteristics of the conditional car and the calibrated one, which amounted to 9%, made it possible to determine the change in the process of movement of cars in the flow and determine a new value of the saturation flow (Figure 3). The use of a dynamic parameter of a calibrated car corresponding to modern driving conditions has been established, which makes it possible to obtain a more accurate saturation flow value of 2070 u/h [13].

To assess the effectiveness of the results obtained, a study was carried out on one of the longest streets in the city of Belgorod, pr. B. Khmelnitsky and the existing control modes at intersections are determined (Table 2).

**Table 2.** Duration of control parameter at investigated intersections taking into account dynamic parameters of calibrated vehicle and without

№ n/n	Name of the intersection	Tc, (sec) without calibrated vehicle	Tu, (sec) with calibrated vehicle	Deviation, %
1	st. Kutuzova - pr. Bogdan Khmelnitsky	78	83	6,41%
2	st. Harvest - pr. Bogdan Khmelnitsky	88	90	2,27%
3	st. Privolnaya - pr. Bogdan Khmelnitsky	82	86	4,88%
4	st. Zheleznyakova - pr. Bogdan Khmelnitsky	96	10 0	4,17%

<b>5</b>	st. Student - pr. Bogdan Khmelnitsky	11	10	-1,82%
		0	8	
<b>6</b>	st. Gagarina - pr. Bogdan Khmelnitsky	82	86	4,88%
<b>7</b>	st. Michurina - pr. Bogdan Khmelnitsky	88	90	2,27%
<b>8</b>	avenue Belgorod - pr. Bogdan Khmelnitsky	96	10	4,17%
			0	
<b>9</b>	st. Preobrazhenskaya - pr. Bogdan Khmelnitsky	88	90	2,27%
<b>10</b>	avenue Glory - pr. Bogdan Khmelnitsky	11	10	-1,82%
		0	8	

The difference between the results of the saturation flow in comparison with the classical calculation procedure, namely, taking into account the parameters of the calibrated car, is on average about 9%. The average deviation of the obtained cycle durations at the investigated controlled intersections, taking into account the parameters of the calibrated car and excluding it, was 3.45%, the maximum deviation was 6.84%, the minimum 1.85%. The positive effect of the measures is to reduce the transport delay at intersections by an average of 30%.

## 4 Conclusion

Theoretical surveys of methods of efficient functioning of the transport system have shown that each method is based on primary data based also on passenger car parameters, to a greater extent these parameters are taken into account when organizing management methods in urban transport systems. Traffic flows are heterogeneous and require a comprehensive study [14, 15], due to the fact that their dynamic indicators affect the efficiency of urban transport systems. The performed mathematical calculations make it possible to calculate dynamic indicators of the calibrated car and implement effective traffic control in the urban transport system.

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