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Definition of perspective scheme of organization of traffic using methods of forecasting and modeling

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Abstract. In the environment of highly developed urban agglomerations, one of the main problems arises - inability of the road network to reach a high level of motorization. The introduction of intelligent transport systems allows solving this problem, but the main issue in their implementation remains open: to what extent this or that method of improving the transport network will be effective and whether it is able to solve the problem of vehicle growth especially for the long-term period. The main goal of this work was the development of an approach to forecasting the increase in the intensity of traffic flow for a long-term period using the population and the level of motorization. The developed approach made it possible to determine the projected population and, taking into account the level of motorization, to determine the growth factor of the traffic flow intensity, which allows calculating the intensity value for a long-term period with high accuracy. The analysis of the main methods for predicting the characteristics of the transport stream is performed. The basic values and parameters necessary for their use are established. The analysis of the urban settlement is carried out and the level of motorization characteristic for the given locality is determined. A new approach to predicting the intensity of the traffic flow has been developed, which makes it possible to predict the change in the transport situation in the long term in high accuracy. Calculations of the magnitude of the intensity increase on the basis of the developed forecasting method are made and the errors in the data obtained are determined. The main recommendations on the use of the developed forecasting approach for the long-term functioning of the road network are formulated.

1. Introduction

Transport planning is one of the most important directions for the effective functioning of the entire state. The transport system of cities is one of the directions for assessing economic efficiency, therefore, its coordinated work should be developed taking into account the long-term period of operation. Today in the Russian Federation, transport planning and transport systems are given special attention. Due to the fact that the planning of many cities was carried out without calculating the current level of motorization, today this leads to a number of acute problems. In addition to effective functioning, special attention is paid to road safety. To date, the Russian Federation has a long-term federal target program, whose main goal is to reduce road deaths by 28% by 2020 [1]. Achieving this goal should be carried out in a comprehensive manner, with consideration of all possible factors that have a negative impact on the transport situation.

The main goal of this work is to consider possible approaches to forecast the changing of the transport situation taking into account the long-term period of operation. Regulatory documents are already in force in the Russian Federation, which recommend using integrated schemes of traffic management in transport planning [2]. These schemes imply the development of several possible scenarios for the development of the transport situation in urban agglomerations and their evaluation by many criteria in order to determine the most possible (optimal) scenario for the development of the transport system. The main issues in the implementation of transport planning in urban agglomerations is the long-term functioning, which can be determined using the method of forecasting the increase in intensity.

2. Research methods of forecasting

One of the most important aspects of road projects on the basis of which the public or material expediency of construction, reconstruction or major repairs is estimated is the intensity of the traffic in the future. The main difficulty in using this value lies in the magnitude of its growth in the long-term period, it is necessary to know with the greatest accuracy what it will be in 15-20 years. Today, domestic and foreign scientists have been offered the basic methods of forecasting [3-5].

According to Doctor of Economics, Professor of Moscow Automobile and High-way Technical University (MADI) Dinges EV. The greatest application should be extrapolation methods, which are based on the analysis of data on the intensity of past years [6].

There are 3 main extrapolation methods used to predict the traffic at a road construction site: simple moving average method; weighted moving average method; the mean method.

The basis of the simple moving average method is the assumption that the predicted value of the traffic intensity for a certain year can be obtained by calculating the average value of the specified parameter for a certain period of time. The formula for the simple moving average method can be presented in the following form:

$$N_{t+1}^{p} = (N_t + N_{t-1} + \cdots + N_{t-n+1})/n \qquad (1)$$

Nt is the actual value of the indicator of traffic intensity for period t; n is the length of the time interval adopted to calculate the moving averages; N_{t+1}^{p} is the predicted value of the intensity index for period t + 1.

The accuracy of this method is determined using two indicators: the mean absolute deviation (Kabs) and the mean relative error (Krel). The average absolute deviation is the ratio of the sum of the deviations of the predicted indicators from their actual values to the number of forecasts. The average relative error is the quotient of the ratio of the deviations of the predicted indicators to their actual values by the number of forecasts.

Forecasting traffic intensity using simple moving averages is advisable to use when forecasting on secondary roads, on certain sections of roads or in places with low population density and low mobility of vehicles.

In all other cases, it is necessary to use methods that take into account both the monotonous nature of the growth in traffic intensity and the sharp jumps (drops) of these parameters in connection with the influence of various factors.

One of these methods is the weighted moving average method. The essence of this method is that the authors assign to each value in a year a specific weight (expressed in fractions of one), thereby assessing the significance of the year in question for the value of the predicted parameter, in connection with certain events of those years (be it a cataclysm or a sharp population growth, In connection with the construction of a new microdistrict).

In mathematical form, this method looks like this:

$$N_{t+1}^{p} = \gamma_1 N_t + \gamma_2 N_{t-1} + \cdots + \gamma_i N_{t-i+1} + \gamma_n N_{t-n+1} \qquad (2)$$

γ_i- the coefficient characterizing the specific weight (expressed in fractions of a unit) of each indicator in the accepted time interval.

There is also a third method - the mean method. The essence of the method consists in minimizing the sum of the quadratic deviations between the observed and calculated values. The calculated values are found from the selected equation - the regression equation. The smaller the distance between the actual values and the calculated values, the more accurate the forecast based on the regression equation.

Theoretical analysis of the essence of the phenomenon being studied, the change of which is displayed by a time series, serves as a basis for choosing a curve. Sometimes considerations about the nature of the growth of the series levels are taken into account. So, if output growth is expected in an arithmetic progression, then smoothing is performed in a straight line. If it turns out that the growth is in a geometric progression, then the smoothing should be performed according to the exponential function. This method can be represented as the following formula:

$$Y_{t+1} = a \cdot X + b \quad (3)$$

t + 1 - the forecast period; Y_{t+1} - predicted indicator; a, b - coefficients; X is a symbol of time.

Calculation of the required coefficients is calculated by the formula:

$$a = \frac{\sum_{i=1}^{n}(Y_{act} \cdot X) - (\sum_{i=1}^{n} X \cdot \sum_{i=1}^{n} \cdot Y_{act})/n}{\sum_{i=1}^{n} X^2 - \left(\sum_{i=1}^{n} X\right)^2/n} \quad (4)$$

$$b = \frac{\sum_{i=1}^{n} Y_{act}}{n} - \frac{a \cdot \sum_{i=1}^{n} X}{n} \quad (5)$$

Y_{act} - actual values of a number of dynamics; n - the number of levels in the time series.

To assess the changes in the main parameters of the traffic flow in order to determine the prospective direction of using certain schemes of traffic management, especially when taking into account their complexity, it is necessary to determine these parameters taking into account their prospective growth, taking into account the forecasting methods. For the analysis of each of the methods presented, a city settlement in the Russian Federation of the Belgorod Region was chosen.

3. Analysis of the transport situation of the urban settlement

Apart from the regional center, the Belgorod agglomeration includes the settlements of 5 more districts: Belgorod, Korochansky, Shebekinsky, Yakovlevsky, Borisov. Including settlements Northern, Reasonable, Dubovoe, Streletskoye, Maisky, Tavrovo and other nearby settlements, the total population of the metropolitan area is about 600 thousand people.

The Belgorod agglomeration grows at a speed of 8-10 thousand people a year. This is facilitated by the fact that the input of housing in the Belgorod agglomeration is more than 1.5 square meters per inhabitant per year. The specific weight of the economic potential of the Belgorod agglomeration is about 41 percent of the potential of the whole region.

More and more houses are being built every year on the territory of the village. Proceeding from this, the population also grows. According to the statistics of previous years, it is possible to compile a table of the number and density of the population, broken down by year (Table 1).

Table 1. Population and population density of the urban settlement Dubovoe

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of population, people	7650	7915	8504	9177	9708	10391	10714	10807	10872
Population density, people/km^2	588	609	654	706	747	799	824	831	836

Proceeding from the fact that the area of the village of Dubovoe has practically not changed since 2008, with the population growth, the population density is also increasing rapidly. Since 2008, density has also increased by 42%, which by 2016 was 836 people per km^2. Oak is an actively developing village, which has a very high population and population density and as the analysis of population statistics shows, every year the number of people in Dubovoe increases; respectively, by 2030 these numbers will only increase. Proceeding from this, it is necessary to give due attention to the organization of traffic on the most loaded intersection of Shchorsa Street - Vatutina Avenue, this intersection is circular. The object is located in the southern part of Belgorod. This circular intersection is 6.3 kilometers from the city center and is part of the Belgorod-Nikolskoe highway-Crimea-Clear Zori-Arkhangelskoye

During the research it was established that at the current level of motorization of the population, this section of the transport network can not cope with the intensity of the traffic flow, during which time on the site in question there are harsh situations. To determine the necessary method of organizing traffic, it is necessary to take into account the increase in the intensity value. For this purpose, within the framework of this study, a new method for predicting the investigated value was developed, based on the level of motorization and the population of the urban settlement.

4. Development of a method for predicting the amount of traffic flow intensity

Extrapolation is a method of scientific research, which is based on the dissemination of past and present trends, patterns, links to the future development of the forecasting object. Extrapolation methods include the moving average method, the exponential smoothing method, and the mean method.

According to information on forecasting methods for calculating the population increase, the average method was chosen. For further work with forecasting, it is necessary to calculate the required coefficients a and b. Using the available statistical data on the population, let us calculate the coefficient: a=453,3; b=7259,944.

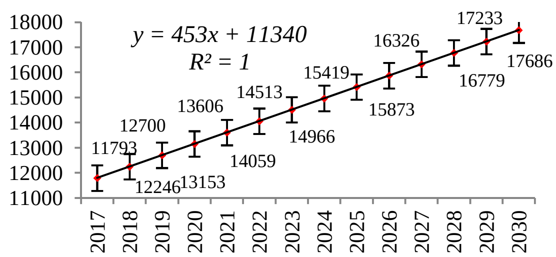

Figure 1. Projected population

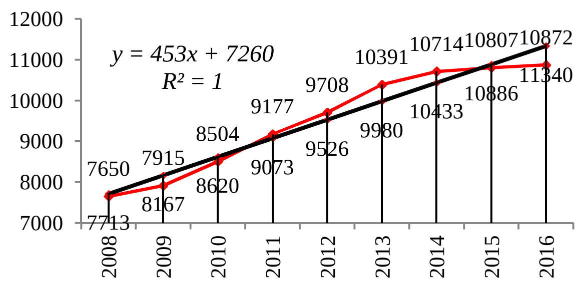

Figure 2. Projected and actual population (2008-2016)

Next, using the calculated coefficients, let us find the predicted values of the population until 2030 (fig. 1).

As one can see in fig. 1 on the chart, in the village of Dubovoe, taking into account the forecast, by the year 2030, there will be 17686 people, which in turn exceeds the number of people living at the moment by 62.7%, which may lead to the idea: how big is the error of our calculations? In order to verify the magnitude of the calculation error, it is necessary to give population values for the period from 2008 to 2016 and compare how far the forecast values differ with the statistics values.

The graph (fig. 3) clearly shows that population values in some places even overlap and this in turn means that at these points the values of the forecast and statistics coincide, which implies that the forecast using this method is very accurate. To estimate the magnitude of the error, there are a large number of methods [7,8]. The average relative forecast error is calculated by the formula:

$$\varepsilon = \frac{1}{n} \cdot \sum_{i=1}^{n} \left[\frac{Y_{act} - Y_{\mathrm{p}}}{Y_{act}} \cdot 100 \right] \qquad (6)$$

Y_{act}- actual values of a number of dynamics; Y_p- the predicted values of a number of dynamics.

$$\varepsilon = \frac{1}{9} \cdot (0{,}82 + 3{,}1 + 1{,}3 + 1{,}13 + 1{,}87 + 3{,}95 + 2{,}62 + 0{,}73 + 4{,}3) = 2{,}2$$

In the case of this study, the prognosis is highly accurate since the value of ε <10.

Having predicted the size of the population in the future, it is necessary to find out what the intensity of the traffic flow will be in the previously difficult area of the urban transport network.

In the course of the research within the framework of a specific facility, a direct relationship between population growth and the level of motorization was established, which makes it possible to determine the coefficient of increasing traffic intensity for a long-term period:

$$k = \frac{\frac{\sum_{i=1}^{n}(Y_{act}\cdot X)-(\sum_{i=1}^{n}X\cdot\sum_{i=1}^{n}\cdot Y_{act})/n}{\sum_{i=1}^{n}X^2-\left(\sum_{i=1}^{n}X\right)^2/n}}{\frac{\sum_{i=1}^{n}Y_{act}}{n}-\frac{a\cdot\sum_{i=1}^{n}X}{n}Y_{\mathrm{p}}} \quad (7)$$

k - coefficient of a number of dynamics for a long-term period; Y_{act} - actual values of a number of dynamics; Y_p - the predicted values of a number of dynamics.

Using the values already available, let us calculate k: k = 1.55

The use of this forecasting method allows us to determine the level of growth in motorization and express it through the rate of intensity increase, which makes it possible to establish the predicted magnitude of the intensity for a long-term period. Taking into account the obtained value of the coefficient of a number of dynamics, it is possible to determine the prospective intensity of the urban settlement in question and the most difficult part for the movement.

Based on the data obtained, it is possible to develop a new scheme for organizing traffic, which will provide access to vehicles and minimize delays on the transport network, taking into account the long-term period of operation.

After analyzing the obtained data on the intensity of the traffic flow of the intersection, Shchorsa Street - Vatutina Avenue, with confidence one can say that the most loaded direction will be the direction leading from the village of Dubovoe to the city of Belgorod. Only in this direction the intensity in peak periods will be 3093 un/h, which in turn will increase the delays of vehicles at the intersection and create a congestion situation on the road. The overall intensity of the other directions will also increase: for the first direction, 1481 un/h, for the third 967 un/h and for the last, the fourth 837 un/h. For the successful operation of this site, two scenarios of development are possible:

1. Organization for this intersection implies the introduction of a channeled traffic flow of right-hand lanes, as well as the construction of overground pedestrian crossings. They were chosen aboveground pedestrian crossings on the basis of the fact that during their construction there is no need to transfer underground communications. This organization of traffic will allow us to completely avoid the pedestrian conflict and cars, as well as allow us to make uninterrupted passage of right-handed flows.

2. At this intersection, it is proposed to build a two-level traffic intersection of the "humpback bridge" type in the direction of Shchorsa Street from the city of Belgorod to the village of Dubovoe. Taking into account the growth of the population of the village of Dubovoe, the need for this direction will only increase. This organization of road traffic will allow us not only to reduce the number of conflict points, but also to divide transport flows along the directions in space. Changes to the direction of Vatutin Avenue are not implied, the organization's structure will remain unchanged.

In the environment of highly developed urban agglomerations, one of the main problems arises - the inability of the road network to a high level of motorization. The introduction of intelligent transport systems allows to solve this problem [9,10], but the main issue in their implementation remains open, to what extent will this or that method of improving the transport network be effective and whether it will be able to solve the problem of vehicle growth especially for the long-term period. The main goal of this work was the development of an approach to forecasting the increase in the intensity of traffic flow for a long-term period using the population and the level of motorization. The developed approach made it possible to determine the projected population and, taking into account the level of motorization, determine the growth factor of the traffic flow intensity, which allows calculating the intensity value for a long-term period with high accuracy.

5. Conclusion

In the course of the study, the main forecasting methods used in the field of traffic management were identified. On the basis of approbation of each of them, the most suitable method for predicting population growth and the level of motorization was identified, on the basis of which a formula for determining the growth factor of the traffic flow intensity was developed, which allows predicting an increase in traffic intensity.

An analysis of the urban settlement was carried out, on the basis of which the most difficult part of the transport network was identified. With the help of the developed approach to forecasting and carrying out field studies, the most promising options for the development of the road network have been determined, on the basis of this, two scenarios for the development of this sector were created, in turn, one of them is less expensive, and the second requires large capital investments. Based on the created two scenarios, the cost of implementing a new traffic organization was calculated, and the economic efficiency of these activities was determined, which would allow developing the transport infrastructure of the urban settlement.

The use of the developed forecasting method allows us to determine the level of growth in motorization and express it through the intensity increase coefficient, which makes it possible to establish the predicted intensity for the long-term period.

To assess the changes in the main parameters of the traffic flow in order to determine the prospective direction of using certain schemes of traffic management, especially when taking into account their complexity, it is necessary to determine these parameters taking into account their prospective growth, taking into account the forecasting methods.

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