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Analysis of the impact of the sample size on the accuracy of determining the travel time and buffer indices

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Abstract: The article provides a description of such parameters for assessing the quality (efficiency) of the functioning of roads as travel time and buffer indices. A model describing the daily dynamics of travel time along a route, taking into account the possible presence of a traffic light object and an unregulated pedestrian crossing, is proposed. Using the model, the dependence of the accuracy of determining the temporal and buffer indices on the frequency of measurements is determined.

1. Introduction

The question of assessing the quality and reliability of the organization of traffic was raised long time ago and remains relevant to this day [1-10]. According to Federal Law No. 443-FZ [11], the duties of the state authorities of the Russian Federation include establishing the procedure for determining the main parameters of road traffic, keeping their records, using accounting data and generating reporting data of road traffic management. In accordance with paragraph 6 of the Decree of the Government of the Russian Federation, No. 1379, of November 16, 2018 "On Approval of the Rules for Determining the Main Parameters of Road Traffic and Keeping Their Accounting" [12], which is effectives from December 30, 2018, the calculation of the values that main parameters of road traffic should be done with taking into account the guidelines for the development and implementation of measures for the organization of traffic, approved by the Transport Ministry of the Russian Federation. These guidelines should regulate the assessment of the main parameters of road traffic, which the state of the organization of road traffic at the federal level will be analyzed. Among the parameters proposed for consideration are the travel time index (TTI) and the buffer index (Ib). Practical using of these indexes is one of the purpose of our researching.

2. Materials and methods

Various methods are used to calculate the time index [2, 3, 9, 13], the movement time indices are 15, 85, 95% of the availability, or the values of the travel time during the peak period and in free conditions. We use the methodology proposed by the Bureau of Transportation Statistics USA [13], according to which the index is determined:

$$TTI = \frac{T_p}{T_{ff}} \quad (1)$$

where T_p - time required to move during the peak period; T_{ff} - time spent on movement in free conditions.

Buffer index is determined as follows:

$$Ib = \frac{T_p - \overline{T}}{\overline{T}} \quad (2)$$

where $\overline{T}$- average duration of movement.

The definition of these indices implies the existence of a measurements sample which indicators relevant to the calculation are determined. The sample can be formed during measurements or database of tracks obtained from navigation equipment located in automobiles. There are two approaches to minimizing the complexity of data collection for the evaluation of these indices.

The first approach is to minimize the volume of measurements, for example, to calculate the travel time indexes, it is enough to take only two measurements: the first measurement is obtained during the peak period and the second - in free conditions. If in free conditions everything is more or less clear, in the evening-night time the traffic is minimal, then the main problem with the implementation of this approach is to determine the time at which the measurements should be carried out to obtain data during peak periods. The same problem applies to the buffer index.

The second approach is in determining of the minimum size of a representative sample (the frequency of measurements), sufficient to determine the indices with an acceptable error. In addition, the influence of various factors that can affect the duration of movement along the route (traffic lights, unregulated pedestrian crossing, weather conditions, etc.).

To solve the problem which is associated with the second approach, we prepared a variable model of the daily dynamics of changes in the intensity (average speed) of vehicles moving along the route.

3. Results and discussion

The model is based on the initial conditions, which are formulated on the basis of the analysis of the existing database of tracks:

1. Free flow conditions on the route in the period from 22:00 to 5:00.
2. Peak traffic volumes are at 8:30 and 18:30 (± a few minutes).
3. In the period from 5:00 to 8:30 and from 16:00 to 18:30, there is an increase of traffic flow volume and the average speed on the route is reduced to the minimal values.
4. In the period from 8:30 to 9:30 and from 18:30 to 22:00 when the traffic volume reduced an average flow speed along the route increases.
5. The increase and decrease of the travel time on the route in the specified periods occurs nonlinearly.
6. To reflect the influence of random parameters, the model provides for the use of a random number generator, which sets the speeds of individual vehicles on the route, according to the intensity conditions and the deviations of the measured (simulated) movement speed values by a random value from the specified range for each measurement.

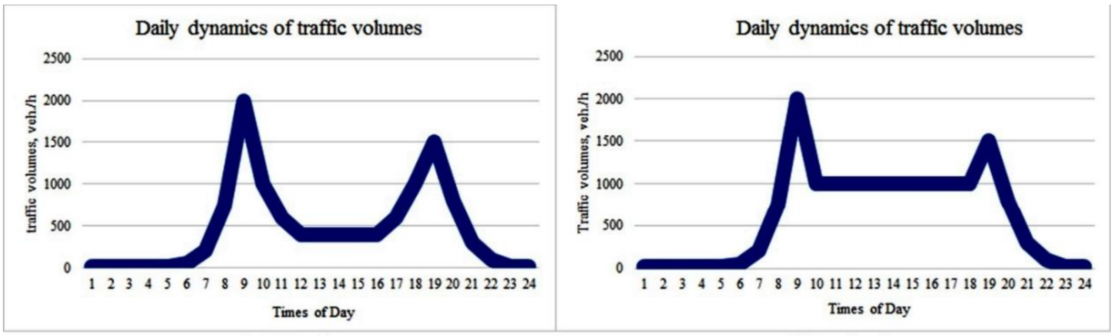
For the experiment, the model laid the following initial parameters:

1. The maximum possible speed (i.e. posted speed) of the route 60 km/h.
2. The volume in free conditions is 20 veh./h and increases to 1,500–2,000 vehicles during peak periods, Table 1, while the maximum (estimated) vehicle speed drops to 20–30 km / hour.
3. As a random value the speed of each vehicle can be reduced down to 10%.
4. The proposed 2 variants of traffic volumes profiles (Table 1). Variant 1 implies the traffic volume reduction to a value 400 vehicles per hour during the midday period, respectively. Variant 2 assumes the reduction of traffic volume to a value 1000 vehicles per hour.
5. For this experiment, we define the index of permissible error 5%.

Daily dynamics of intensity and average speed are shown in Figures 1, 2. Thus, the data on the average speeds of movement along the route for each of 11040 vehicles for 1 variant and for each of 14840 vehicles for 2 variants were collected during the day. With the help of the model, 1000 variants of the daily dynamics of the average speed of each car for each intensity variant were generated randomly, Figures 1, 2.

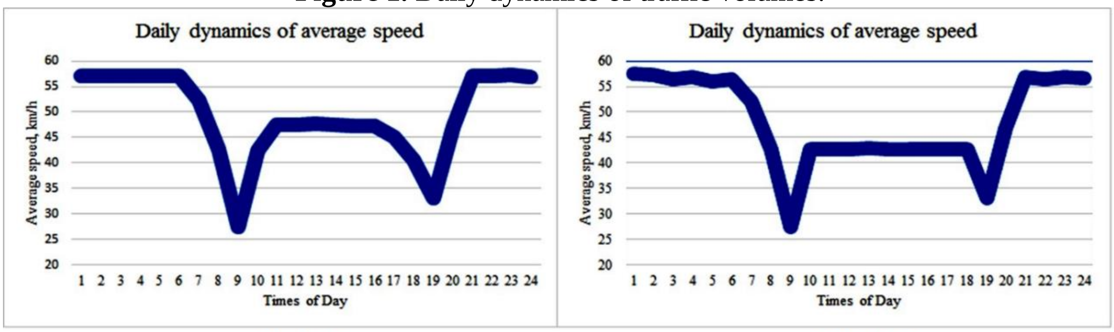
Table 1. Daily profile of traffic volumes

Daily time interval		Traffic Volume var. 1, veh./h	Traffic Volume var. 2, veh./h
0:00	1:00	20	20
1:00	2:00	20	20
2:00	3:00	20	20
3:00	4:00	20	20
4:00	5:00	20	20
5:00	6:00	50	50
6:00	7:00	200	200
7:00	8:00	750	750
8:00	9:00	2000	2000
9:00	10:00	1000	1000
10:00	11:00	600	1000
11:00	12:00	400	1000
12:00	13:00	400	1000
13:00	14:00	400	1000
14:00	15:00	400	1000
15:00	16:00	400	1000
16:00	17:00	600	1000
17:00	18:00	1000	1000
18:00	19:00	1500	1500
19:00	20:00	800	800
20:00	21:00	300	300
21:00	22:00	100	100
22:00	23:00	20	20
23:00	0:00	20	20



a) Variant 1 b) Variant 2

Figure 1. Daily dynamics of traffic volumes.



a) Variant 1 b) Variant 2

Figure 2. Daily dynamics of average speed.

Then a random sample of 100%, 80%, 60%, 40%, 20%, 10%, 5%, 2.5%, 1.25%, and 0.625% of the results from the data collected in each hour was formed. If the number of selected options was a fractional, then rounding to a larger integer value was performed, so the sample for each hour was represented by at least one value of the average speed in the specified range.

Based on the collected data, TTi and Ib were calculated; an example of the obtained results is presented in Table 2.

Table 2. TTi and Ib values for different % of sample.

Sample percentage	TTi	Ib
100%	3.357	1.764
80%	3.357	1.764
60%	3.352	1.762
40%	3.352	1.766
20%	3.302	1.725
10%	3.196	1.642
5%	3.196	1.626
2.5%	3.196	1.626
1.25%	3.196	1.624
0.625%	3.164	1.628

Relative deviation of the index values for each sample relative to the index values at 100% sample for all 1000 variants of the daily dynamics of the average speed for each car for the two options were calculated and the average value of the deviations was found.

Table 3. Average deviation values.

	Variant 1		Variant 2	
Sample percentage	**TTi**	**Ib**	**TTi**	**Ib**
80%	-0.08%	-0.12%	-0.08%	-0.12%
60%	-0.20%	-0.30%	-0.19%	-0.30%
40%	-0.41%	-0.62%	-0.36%	-0.58%
20%	-0.88%	-1.34%	-0.84%	-1.32%
10%	-1.56%	-2.41%	-1.48%	-2.33%
5%	-2.48%	-3.75%	-2.37%	-3.66%
2.50%	-3.57%	-5.25%	-3.51%	-5.24%
1.25%	-5.90%	-8.68%	-5.83%	-8.72%
0.625%	-7.67%	-11.21%	-7.54%	-11.44%

Table 2 shows that the dynamics of the decrease in the accuracy of determining the indices can be traced while reducing the percentage of the sample for both options.

The dynamics of the dependence of the accuracy of determining TTi and Ib at various sample levels is presented in Figures 3.4.

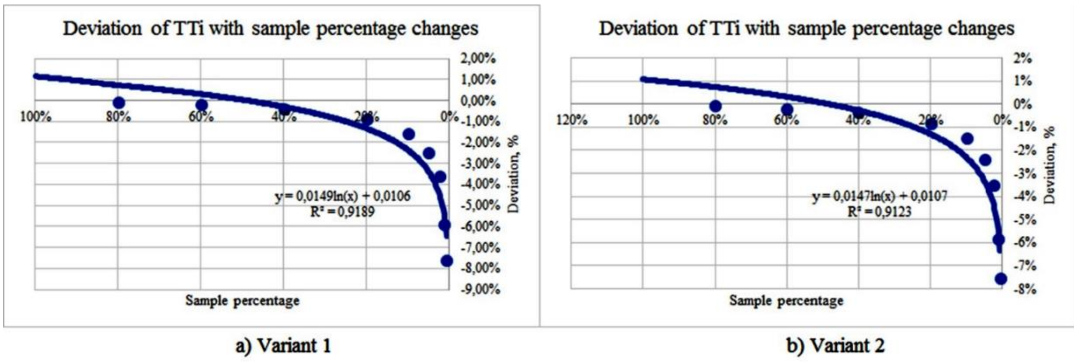


Figure 3. The TTi estimation accuracy as a function of the sample percentage.

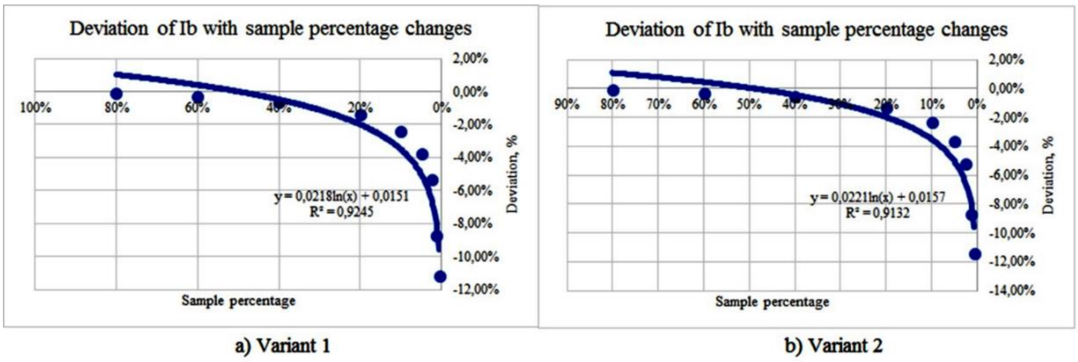


Figure 4. The Ib estimation accuracy as a function of the sample percentage.

After a statistical data analysis, we obtain the set of regression models for TTi (3,5), for Ib (4,6). For the first variant:

$$F(x) = 0.0149\ln(x) + 0.0106 \text{ with } R^2 = 91.89\%. \tag{3}$$

$$F(x) = 0.0218\ln(x) + 0.0151 \text{ with } R^2 = 92.45\%. \tag{4}$$

For the second variant:

$$F(x) = 0.0147\ln(x) + 0.0107 \text{ with } R^2 = 91.23\%. \tag{5}$$

$$F(x) = 0.0221\ln(x) + 0.0157 \text{ with } R^2 = 91.32\%. \tag{6}$$

where *F(x)* is the relative deviation, x is the sample percentage.

According to the results of the experiment, to determine the TTi indicator with 95% accuracy on the basis of the obtained dependencies, a sample for the first variant is not less than 1.72% for the second variant 1.71% from the data on the daily dynamics of the average speed. To determine the Ib index with 95% accuracy, a sample for the first variant and the second variant is necessary at least 4.87%, from the data on the daily dynamics of the average velocity.

The dependences obtained in the course of the research show that a change in the daily dynamics does not affect the sample size necessary for determining the travel time and buffer indices with a given accuracy slightly. At the same time, the buffer index was the most sensitive to the sample size.

Based on the meaning of each of the considered indices, the following suggestions can be made additionally for optimizing the actual measurements. For a travel time index, the values of travel time along a route in free conditions and during peak periods, that is, the smallest and greatest time indicators, are significant, thus, we can exclude measurements during off-peak periods and take several measurements in free conditions in order to determine the minimum time, and then make a sample of results in the amount of not less than 1.72% of the total sample size in the range where the peak period should be marked.

For the buffer index, the largest and average time of movement along the route are significant, thus, the optimization of the survey can be achieved by increasing the measurement periods during off-peak periods, when with a sufficient degree of reliability we can extrapolate the results for a longer period of time for calculating the average speed of movement, for example, at night, when the conditions of movement do not change significantly and can be considered free, in other periods you can measure in the amount of not less than 4.87%.

4. Conclusion.

In addition, this artificial experiment did not take into account the impact of random factors and factors that periodically affect the speed of movement, for example, unregulated pedestrian crossings, traffic lights, etc., the influence of these factors can adjust the volume of the necessary sample.

Further research should involve identifying the dependence and degree of influence of traffic conditions and other parameters on the accuracy of measurements carried out at different intervals.

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