Assessment of the impact of the characteristics of the road network on the duration of the route

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Abstract. The “floating” car method using global positioning system (GPS) devices is used to collect data on the duration of traffic on city streets. However, a complete study of the transport network is time-consuming and includes additional financial investments. An alternative source of data collection is the use of rolling stock of public transport. Therefore, this article discusses the relationship between travel time by car and bus. It was found that the travel time of buses is usually more than the travel time of an individual vehicle. The impact of the characteristics of the road network, such as a number of regulated and unregulated intersections, a number of driveways, a number of bus stops, traffic intensity, a number of lanes and a number of turns on the duration of public transport, has been assessed. The results show the relationship between the considered durations of traffic and data from the board equipment of the vehicles of public transport can be used to estimate the duration of movement along the route taking into account the characteristics of the network.

1. Introduction

Duration of traffic plays an important role in choosing the route in the transport network, and for dispatching control helps to plan, control and manage traffic on city streets [1, 2]. Modern geoinformation technologies allow obtaining data on the characteristics of the movement of traffic flows and the vehicles of public transport in the network of streets. Travel time is fixed in regular intervals using board equipment. Its system includes three main components: satellite, information system and data archiving system. The satellite system provides real-time vehicle location information. The obtained data on the location and duration of movement on the route are transmitted to the traffic control centre in real time. They provide increased accuracy in assessing traffic conditions on routes, taking into account the influence of the characteristics of the network of streets [3–5].

To assess the impact of the characteristics of the network of streets and to establish the functional relationship between them and the duration of the movement, GLONASS tracks and GPS equipment are used, obtained in real time from automobile laboratories and on-board public transport equipment in the form of archive data.

The technique of using a car-laboratory is considered in the literature [6–8] under the name “floating” car, which collects data on the duration of movement of vehicles moving along the studied route in the general transport stream. Used automated equipment allows to register and record information about location and speed in a second.

The considered technique is used by INRIX, TomTom to collect data on travel time on city streets with a subsequent assessment of traffic flow conditions [9].

However, time, cost and labor costs limit the ability to assess traffic conditions throughout the transport network in an hour and day intervals.
An alternative source for collecting traffic data is the use of public transport vehicles. This method does not incur additional financial costs, since most of the buses serving city routes are equipped with on-board GLONASS / GPS equipment to determine the location of the vehicle and the arrival time at the stop.

2. Research methodology
The method of data collection is carried out on the city route network, which covers the main streets with steady transport demand associated with high mobility to places of gravity during peak hours.

Urban traffic does not reflect the overall speed of the traffic flow, due to stops for getting on to and getting off, scheduled route [10]. The proposed method allows taking into account the differences between the transit time of a public transport route and the average transit time of a traffic flow, by reasons of:

• stopping time for getting on to and getting off;
• time spent on acceleration and deceleration;
• differences between operational data of the bus fleet and individual vehicles;
• compliance with established speed limits;
• the presence of lanes for public transport.

Obtaining statistical data from the on-board equipment of the rolling stock refers to the remote accumulation of route information. The main difference from the “floating” car method is that the data coming from the public transport on-board equipment are not specific, they are accumulated in archive mode on all routes.

Estimation and prediction of travel time can give statistically significant results in the case of traffic analysis. However, the estimation of travel time is complicated due to traffic control and minor road junctions, as well as other characteristics of the road network. In this regard, a more detailed examination of the transport network is required.

Thus, the aim of the study is to establish the dependencies of the duration of individual and public transport on city streets. In addition, the influence of various factors, such as the number of regulated and unregulated intersections, the number of driveways, the number of bus stops, traffic intensity, the number of lanes and the number of turns on the duration of public transport, is also taken into account.

3. Experimental studies
Analysis and assessment of the impact of the characteristics of the road network on the duration of public transport was carried out on four routes of the city of Angarsk (Figure 1). The choice of routes is due to high passenger traffic and spatial distribution throughout the city.

Duration data was collected using a “floating” vehicle on which a GPS module was installed to collect information. The experiment was performed by using a TOYOTA Vitz passenger car equipped with a Texet 505 GPS navigator from May 26, 2019 to June 11, 2019. The tracks were recorded in gpx format (a text format for storing and exchanging GPS data based on XML format), allowing to store information in arbitrary form, in which only the longitude and latitude of the track points are mandatory. For the initial processing of tracks and transfer of the obtained characteristics to the Excel format, the GPS Track Editor program, which has a simple user interface, was used. Travel time on the studied routes was determined for the peak and inter-peak hours. GPS data were processed to calculate the duration of travel between stops and in the directions of travel.

The bus travel times along the studied routes are presented in the export document in Excel format from the POTOK satellite monitoring and transport control system.
Figure 1. Explored city routes.

4. Study results

The obtained values of the duration of movement were compared for each individual route (on days and hours), in order to establish the differences and accuracy of data. A significant difference in the studied samples can be established using statistical tests.

To study the relationship between the transit time of a "floating" car and a bus, the characteristics of the road network were evaluated (table 1): the number of stopping points; regulated road intersections; unregulated pedestrian crossings; junction of streets and local driveways; lanes; number of turns and traffic intensity. As the length of sections of the road network is different, the characteristics considered were expressed in numerical value per unit distance (density per 1 km).

Table 1. Density of the considered characteristics of the network of streets.

| Route number | Length, km | Density per 1 km |
|--------------|------------|------------------|
|              |            | Bus stops | Regulated intersections | Unregulated pedestrian crossings | Junction of streets and driveways |
| 7            | 13.8       | 1.96      | 1.30                   | 2.32                             | 8.87                              |
| 10           | 13.3       | 1.65      | 1.20                   | 1.80                             | 8.36                              |
| 11           | 14.2       | 2.18      | 1.34                   | 2.75                             | 9.54                              |
| 20           | 13.2       | 1.67      | 1.36                   | 2.73                             | 9.13                              |
| Mean         | -          | 1.87      | 1.30                   | 2.40                             | 8.98                              |

Due to the fact that the routes are located in the central part of the city, the influence of factors such as speed limits and geometry of the road network was not taken into account.

Table 2 shows the average values of the duration of movement on the routes, as well as the relative deviation of the data obtained by two methods. It is noted that the duration of public transport is higher than the "floating" car.
Table 2. Values of bus duration along routes and relative deviations from a “floating” car.

| Route number | The average value of the duration of travel time, min | Relative deviation, % |
|--------------|-----------------------------------------------------|------------------------|
| 7            | 41.55                                               | 11.2                   |
| 10           | 36.20                                               | 8.1                    |
| 11           | 47.78                                               | 19.2                   |
| 20           | 38.38                                               | 10.4                   |

Since the "floating" car did not move along the route simultaneously with public transport, the data were generalized by the time period. Table 3 presents the total range of relative deviations between the durations of movement in time for the studied routes. A relative deviation of less than 10% is observed for the largest number of trips considered (63%).

Table 3. The distribution of the values of the duration of movement in the ranges of relative deviation.

| Range of relative deviations | Number of cases, % |
|------------------------------|--------------------|
| 0 – 10                       | 63                 |
| 10 – 20                      | 12                 |
| 20 – 30                      | 8                  |
| 30 – 40                      | 4                  |
| 40 – 50                      | 9                  |
| > 50                         | 4                  |

To compare the values of the duration of movement, the analysis was carried out with a confidence level of 95 %. The null hypothesis, $H_0$, has been established, which indicates that the duration of movement along the route of the “floating” car and public transport are equal to: $H_{GPS} = H_{Bus}$, while the alternative hypothesis, $H_1$: $H_{GPS} \neq H_{Bus}$. Linear regression models are established based on the ratio of the durations of movement between a passenger car and public transport as a dependent variable, and independent variables are correlation factors. The models for the studied hours — peak and inter-peak — are given in formulas (1) and (2), respectively:

$$TT_c = TT_b(1,3 - 0,15 \cdot SI - 0,25 \cdot TV - 0,0032 \cdot N_l), R^2 = 0,68,$$

(1)

$$TT_c = TT_b(1,0 - 0,12 \cdot N_l), R^2 = 0,51,$$

(2)

where $TT_c$ — individual vehicle duration, $TT_b$ — duration of public transport, $SI$ — number of adjustable intersections, $TV$ — traffic intensity, $N_l$ — number of lanes.

5. Conclusion

Based on the studies, we can conclude that, with the exception of the number of adjustable intersections, the number of lanes and traffic intensity, the other characteristics considered do not significantly affect the duration of the movement. The number of lanes plays a statistically significant role in all periods under consideration; while the numbers of regulated intersections per kilometre and traffic intensity have a statistically significant effect during the peak hours.

The results show that data from the board equipment of the vehicles of public transport can be used to simulate the duration of movement along the route taking into account the characteristics of the network [11, 12].

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