The Study of Transport Systems of Urban Agglomerations of the Russian Federation by the Method of Remote Satellite Monitoring

A A Testeshev\textsuperscript{1}, V D Timokhovets\textsuperscript{1}, I E Loshchinina\textsuperscript{1}, Y I. Chichilanova\textsuperscript{1}

\textsuperscript{1}Federal State Budget Educational Institution of Higher Education « IUT », Ural Federal District, Tyumen Region, Tyumen, Volodarsky, 38, 625000

E-mail: verochka1987@mail.ru, miss.chi4ilanowa2014@yandex.ru

Abstract. The critical threshold of spatial growth in the largest cities of the Russian Federation does not allow to reach a new level of economic development. It sets the trend for the megapolises formation in the agglomeration scenario. Consequent changes in the conditions for the urban infrastructures functioning lead to multi-network transport systems. That dynamics are the driver of both newly formed and developing agglomerations.

To improve the quality of the urban environment it is necessary to proportionally develop transport systems, based on the traffic flows representative characteristics. Nowadays, the monitoring of the traffic flows in multi-system urban facilities is difficult, and therefore the authors recommend to use the remote satellite monitoring method. The article considers the RF agglomerations’ features which spread to the largest cities transport infrastructures. The RF megapolises urbanization parameters have been estimated, which allowed to identify the regional development features of each multi-network region and their transport systems. In the development of the proposed method, the software complex DiSMID was developed, allowing to decode the satellite image in the automated mode. Such software can also determine the primary and secondary characteristics of the transport stream.

1. Introduction

The urban processes of the last decades have quantitatively and qualitatively transformed the way of life and functioning of the largest cities inhabitants [9]. The state policy on urbanism is based on a new paradigm of the economy spatial development, embodied in the RF social and economic development programme until 2030. According to this programme the country can develop under innovative or conservative scenarios, each scenario corresponding to a specific spatial settlement strategy [14]. At the current stage of development, the most characteristic is the growth of megapolises due to the integration of satellite settlements into its structure.

The search for professional skills application in such vast urban areas increases the movement and mobility of the workforce using integrated transport networks (TN). The formation dynamics of the TN agglomerations depends on mass, labor, domestic, cultural and recreational trips and differs significantly in the territory of the Russian Federation.
2. Main part
To create comfortable living conditions and a proper public services level, it is necessary to be guided by urban and development significates. Those are the urban population percentage, the population distribution between urban settlements of different populousness; the territory proportion occupied by the urban land; purchasing power; density of the TN; number of inhabitants; average wages and motorization level (table 1) [4] [6].

Table 1. The calculating results of the urban indicators and agglomerations development
(a fragment)

| Group | City          | Urban population percentage, % | The population distribution between urban settlements of different populousness, man / km² | The territory proportion occupied by urban land | Purchasing power, rub / 1000 man | Number of inhabitants, thousand people | Average wages, thousand roubles | Motorization level, auto / 1000 man |
|-------|---------------|--------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------|---------------------------------|---------------------------------------|---------------------------------|----------------------------------|
| 1     | Moscow        | 81.67                          | 4834.31                                                               | 1/100                                          | 1/177                                           | 1,41                                  | 12380                           | 40                              |
| 1     | St. Petersburg| 64.04                          | 3764.49                                                               | 1/320                                          | 1/104.7                                          | 2.3                                   | 5282                           | 45                              |
| 2     | Novosibirsk   | 79.04                          | 2783.8                                                                | 1/162                                          | 1/100.2                                          | 2.75                                  | 1603                           | 26                              |
| 1     | Ekaterinburg  | 84.78                          | 3110.9                                                                | 1/67                                           | 1/100.2                                          | 2.84                                  | 1456                           | 40                              |
| 2     | Nizhny Novgorod | 79.53                      | 2712.6                                                                | 1/23                                           | 1/100.9                                          | 3.22                                  | 1264                           | 23                              |
| 1     | Samara*       | 79.98                          | 2515.5                                                                | 1/39                                           | 1/100.22                                         | 2.34                                  | 1170                           | 28                              |
| 3     | Omsk          | 72.67                          | 2060.1                                                                | 1/167                                          | 1/105.9                                          | 2.5                                   | 1178                           | 23                              |
| 2     | Chelyabinsk   | 82.7                          | 2262                                                                  | 1/25                                           | 1/102.3                                          | 2.08                                  | 1199                           | 29                              |
| 1     | Rostov-on-Don | 68.04                          | 3233.62                                                               | —                                              | 1/100.1                                          | 3.9                                   | 1125                           | 18.5                            |
| 3     | Ufa           | 62.7                           | 1577.88                                                               | —                                              | 1/100.4                                          | 2.16                                  | 1116                           | 33.5                            |
| 2     | Volgograd     | 76.95                          | 1182.29                                                               | —                                              | 1/102.4                                          | 1.46                                  | 1016                           | 23                              |
| 3     | Permian       | 75.8                           | 1311.65                                                               | 1/78                                           | 1/100.1                                          | 2.03                                  | 1048                           | 26                              |
| 3     | Krasnoyarsk   | 77.39                          | 3067.8                                                                | —                                              | 1/100.4                                          | 2.98                                  | 1083                           | 25                              |
| 3     | Voronezh      | 67.55                          | 1744.6                                                                | —                                              | 1/100.3                                          | 2.14                                  | 1040                           | 23                              |
| 2     | Kazan         | 76.79                          | 2898.54                                                               | 1/55                                           | 1/102.8                                          | 4.07                                  | 1232                           | 28                              |

Marks: * – agglomerations formed by several cities

Due to the significant variation in the values of the indicators under analysis, the cities’ groups with the highest (1 group), medium (2 group) and low (3 group) development rates were identified. Data are presented in Figure 1 [7] [12].
Figure 1. Analysis of the urbanistics characteristics and indicators of the urban growth dynamics:
a) the level of motorization, the number of cars per 1000 people; b) increase in the motorization level, the number of cars per 1000 people; c) number of cars per 1 km SRN; d) TN density, km² / km²

Despite the significant differences in the urban development characteristics of different groups. The developed diagrams demonstrate the common problems of the road transport system development in the considered agglomerations. In all urban structures under the study, there is a high motorization level per unit length of the street-road network (SRN) and the lack of choice of an alternative travel route which results in traffic congestions in case if critical values are reached.

The changes in the transport networks density analysis showed the imbalance in the ratio of the SRN lengths to the occupied lands areas of the main and joined settlements (figure 2).

Figure 2. Evolution of the area and street-road network extent of the Moscow agglomeration

The evolution analysis in the area and SRN extent (1999 - 2015) showed the quantitative indicators leap caused by the agreements regarding the borders changes of the largest cities in the Russian Federation regions [2][3].

The uneven regional changes in urban significative and agglomeration development indicators requires the development pace of transport systems assessment to implement successful urban planning policies.

To analyze the transport systems development, the detailed data on the transport flow (TF), traffic density and traffic volume, motion path and motion changes along intersections are needed. Sensitive
information will allow to improve the public service quality within the operational management of transport systems with low expenses and instant response about the TF characteristics.

Data on the TF characteristics in macro- and micro-scales are needed to study agglomeration transport structures [8]. The micro-scale characteristics are used to plan individual elements of TN, and macro-scale studies are made to plan network transport systems (table 2).

Table 2. The objects distribution by scales and planning levels

| Levels       | Microscale                  | Macroscale                                                                 |
|--------------|-----------------------------|-----------------------------------------------------------------------------|
| Road planning| Local streets               | Continuous movement Multilane street                                          |
| Element planning | Parking places, Crossroads, Transport interchanges | Transport interchanges system management, transportation facilities located on a large area (of the city) |
| Network planning | SRN of the micro district   | SRN of the district, SRN of the city                                           |

Within the micro- and macro-scales, it is possible to collect the data with the existing methods of network monitoring, such as inductive sensors, video surveillance and aerial photography [5] [10]. Inductive sensors and cameras allow to obtain objective information only in case of sufficient development of reporting checkpoints network [1].

In the developed European countries, Great Britain for example, a macro-scale survey is carried out with a video surveillance checkpoints network, including 2 million cameras (figure 3).

Aerial photography methods have not found wide application because of several reasons. One of them is the limited survey area due to the limited shooting area for the uncrewed aerial vehicles. Another reason is the high operation cost using controlled aircraft. If the air transport infrastructure is not developed and irregular surveys are taken, the representativeness of the information obtained is reduced to unacceptable limits.
3. Research results

As it appeared impossible to apply traditional methods to study RF megapolises SRN, it requires new methods, including the TN satellite monitoring method. The method is based on the online image decoding visually identifying the density ($\rho$) and the subsequent traffic intensity calculation ($N$) by means of the functional relationship of the TS theory. Functional relationship takes into account the streets’ typing and the meteorological variability, road and transport conditions [11] (formula 1.):

$$N = \frac{-A_T \cdot (P_{T,R}^M \cdot S_T^M \cdot O_T \cdot \rho)^2 + A_T \cdot P_{T,R}^M \cdot S_T^M \cdot O_T \cdot \rho}{P_{T,R}^M \cdot S_T^M \cdot O_T}$$ (1)

where $A_T$ — is the coefficient of determination of the traffic intensity during peak hours;

$P_{T,R}^M$ — is the reduction factor of the calculated number of one-way lanes ($R_j$), the road surface condition ($M_j$), the streets type ($T_i$) to the reference lanes number ($R_1$);

$S_T^M$ — is the reduction factor the actual road surface condition ($M_j$) and the type of streets ($T_i$) to the reference coating state ($M_1$);

$O_T$ — the reduction factor of streets and urban roads types.

The developed mono-dependence allows to determine the value of TS intensity for any weather conditions, design road surface conditions and traffic conditions.

To reduce the calculations complexity when accounting the variability factors and the possibility of obtaining results by hardware, a software product (SP) DiSMID had been developed.

When developing the SP a program listing in the Embarcadero RAD studio 10.1 development environment in the Object Pascal programming language was compiled.

The SP algorithms include the snapshot import, choosing of the city, the street’s type, the road surface condition and the lanes number, determining the site length and the cars amount per groups. The calculation result is displayed in an automatic mode and includes information on the traffic intensity both total and by individual groups (figure 4).

![Figure 4. The interface of the program](image_url)
Application of the proposed program to determine the TS primary and secondary parameters allows to reduce the time and financial costs by 40 and 45%, respectively.

4. Conclusion
At the present time, the developed SP is being registered with the Federal Service for Intellectual Property (Rospatent).

For further studies, it is planned to expand the database of the TS parametric values and the road conditions of new agglomerations, automated determination of the distances length without non-program vector maps of third-party developers and the possibility of the automated identification of the TS composition.

5. References
[1] Order of the Ministry of Internal Affairs of Russia dated 02.03.2009 No. 185 in accordance with the note to paragraph 43 of the Administrative Regulations of the Ministry of Internal Affairs of Russia on the performance of the state function to monitor and supervise the observance of traffic safety requirements by road users
[2] Agreement on the modification of the border between the subjects of the Russian Federation by the city of Moscow and the Moscow region of June 30, 2011
[3] Resolution of the Council of Federation of the Federal Assembly of the Russian Federation of July 13, 2011 N 347-SF "On the approval of the change in the border between the city of federal significance by Moscow and the Moscow region"
[4] Code of Regulations 42.13330.2016 Town planning. Planning and development of urban and rural settlements. Updated version of SNiP 2.07.01-89, 2016
[5] IPC G08G1 / 123, Patent "Method of transmission of location and condition data in transport monitoring systems", Shchurov Andrey Vladimirovich, 02.07.2010
[6] Russian Statistical Yearbook 2008 Moscow: FSGS p. 847.
[7] Macroeconomic indicators for the Russian Federation for 1991-1999 2009 Questions of statistics vol. 3 p. 51.
[8] Vuchik, V.R. 2011 Transport in cities that are convenient for living. Publisher: Territoriya buduschego p. 551.
[9] E.A. Kolomak. 2011 Evaluation of the effects of urbanization on Russia's economic growth. IEEPP SB RAS Economics and Sociology pp. 51-69.
[10] Testeshev A. A. 2017 Methodology of traffic flows remote monitoring in the Ural Federal District largest cities using satellite monitoring data. AIP Conference Proceedings.
[11] A.A. Testeshev, V.D. Timokhovets, T.G. Mikeladze 2018. Development of multiparameter equations for satellite monitoring analysis of traffic flow. MATEC Web of Conferences vol. 143.
[12] [Electronic resource] / Wikipedia - the free encyclopedia - Access mode: https://ru.wikipedia.org/wiki/Child_Page. Date of circulation: 8/04/2018 - 25/04/2018
[13] [Electronic resource] / Cameras of the State Traffic Safety Inspectorate on the map 2016,2017. - Access mode: https://www.driver-helper.ru/. Date of Circulation: 15/04/2018 - 20/04/2018
[14] [Electronic resource] / "Consultant-Plus" "Forecast of long-term socio-economic development of the Russian Federation for the period until 2030" - Access mode: http://www.consultant.ru/law/hotdocs/24844.html/. Date of Circulation: 04/20/2018
[15] [Electronic resource] / Top 12 megapolises by the number of CCTV cameras on the streets - Access mode: http://droider.ru/post/top-12-megapolisov-po-kolichestvu-kamer-videoonablyudeniya-na-ulitsah-01-07 -2016). Date of circulation: 04/22/2018