Assessment of suburbanized areas transport demand: case study of the Irkutsk Agglomeration

A V Zedgenizov\textsuperscript{1}, A I Solodkiy\textsuperscript{2} and I Efremenko \textsuperscript{3}

\textsuperscript{1}\textsuperscript{3} The Department of Oil and Gas Engineering, Irkutsk National Research Technical University, 83 Lermontov street, Irkutsk, 664074, Russia
\textsuperscript{2} The Department of Transport Systems, Saint Petersburg State University of Architecture and Civil Engineering, 4 Vtoraya Krasnoarmeiskaya Street, Saint Petersburg, 190005, Russia

E-mail: azedgen@gmail.com

Abstract. The article deals with the issues of transport services for suburbanized areas. The significance and topicality of the research are demonstrated. Various solutions to this problem in different parts of the world are described. Currently, the wealthiest strata of society are striving to obtain a higher quality of life due to the permanent residence in the suburbs which gives rise to the demand for daily commuting between the city and its suburbs. In the article this issue is developed within the context of creating a toolbox for quantitative assessment of suburbanized areas influence on the road network load, first of all, on the load of sections providing commuting between suburbanized areas and the city. The article details the sequence of selecting individual gated communities within the transport accessibility zone of the Irkutsk agglomeration; besides, the article presents a sample study of one gated community aimed at determining the number of entrances and exits. Besides, there are results of the regression-correlation analysis that allows determining an empirical dependence making it possible to estimate suburbanized territories transport demand according to their areas.

1. Introduction
The first and subsequent technological revolutions occurred over the past few centuries have significantly changed the ratios of people living in cities and rural areas. The process of urbanization was particularly intense in the late 19th and early 20th centuries. This epoch was marked by global industrialization and required the concentration of a large number of workers living close to production sites. Later, all over the world, including Soviet Russia there appeared both large industrial centers and small towns supporting the activity of core enterprises. Such towns were called single-industry towns. Further automation and computerization of production processes, as well as development of the automotive industry and availability of individual transport (IT), allowed expanding the radius of transport accessibility around cities. The development of suburban areas involving permanent residence is called suburbanization. The fundamental difference between living in rural areas and living in suburbanized ones is that inhabitants of the latter have permanent labor and cultural ties with the city. This circumstance causes daily commuting of suburbanized areas residents to the city in the morning and back to their residence in the evening; given that 90-95\% of cases involves using IT for commuting this circumstance creates significant load on the street-and-road network (SRN) especially in the sections joining an urban area and a suburb. Solving the problems
associated with permanent traffic congestions requires a scientific approach to prove and predict the intensity of traffic flows at the boundaries of cities and suburban areas.

2. **Topicality and Scientific Relevance of the Research**

The transport demand assessment was studied and developed by many Russian and foreign researchers. In particular, I.S. Efremov [6], E.M. Lobanov [12], V.V. Silyanov [14] and others [4] [7] [8] [10] achieved the greatest progress. The urban planning issues, the basic principles of functioning and interacting of urbanized territories were described in the scientific works by Yu.N. Bocharov [1], A.O. Kudryavtsev [1], A.P. Romm [13] and others [5] [2]. Currently, it is possible to predict the intensity of traffic flows using packaged applications of micro- and macromodelling; the input data for such programs are studies based on methods of assessing transport demand which depends on the specificity of permanent residence in the suburbs. A number of parameters should be taken into account (the percentage of residents using IT, irregularity of hours, etc.); they will allow making more accurate predictions of transport demand and, subsequently, of the intensity of traffic flows in the studied sections of SRN.

3. **Problem Statement**

To assess transport demand of any focal points (FP) including suburban areas one should carry out transport inquiries including a complete study of correspondences made during a day. Such studies are of high labour intensity, however, they allow researchers to obtain an extensive range of data used for projections. Studies aimed at determining transport demand should begin with a preliminary estimate of the number of objects composing the general totality of the studied phenomenon; moreover, it is necessary to consider objects with different spatial characteristics, such as remoteness from the city center, area of the suburbanized territory, remoteness from the main road, availability of public transport (PT) and other factors. Each focal point must be thoroughly studied to determine the number of entrances-exits, availability of PT stopping points in the immediate proximity and of the public parking used by residents of this suburbanized area. A sample of a detailed plan of conducting a field study aimed at assessing transport demand of one of the gated communities of the Irkutsk agglomeration is presented in Fig. 1. Further, a daily study of the object is carried out to record the following information: the number of arriving and departing visitors, the number of people using IT and PT and the time of day. Moreover, it is worth recording the registration numbers of the vehicles in order to determine the duration of their parking.

![Fig. 1 The Plan of Conducting the Field Study](image-url)
The site area is 163 ha.
The number of floors in buildings – two-storey houses.
The remoteness of the gated community from the city – about 20 km.
Entrance/exit of the gated community

4. Theoretical Prerequisites
Field experiments are necessary to determine the basic parameters of suburbanized areas functioning; these parameters in combination with additional factors should be used to calculate and predict the intensity of traffic flow generated by visitors of these areas. The mathematical model combining these parameters is presented below:

\[ N_{IT} = \frac{E_{FP}}{P_{IT}} \cdot \frac{d_{IT}}{d_{IT}} \cdot k_{di} \]  \hspace{1cm} (1)

where \( E_{FP} \) stands for the transport demand of the studied FP (a suburbanized area); \( d_{IT} \) means the ratio of people using IT during the definite hour; \( P_{IT} \) – the average number of people in a vehicle (IT); \( k_{di} \) – coefficient of daily irregularity for the definite hour.

The main parameters of Formula 1 are described in Table 1.

| Parameter | Brief Description |
|-----------|-------------------|
| Transport demand, corr./day | The number of correspondences in a focal point of a definite type. As well as the concept of economic demand which is defined on the basis of comparison between the concepts of what is desired and possible, transport demand can significantly depend on the purpose of the trip (work, cultural life, etc.), on its total cost which is understood as time and money investment, on the weather and even mood. |
| Ratio of visitors using IT (involved in transport demand) | It shows the ratio of visitors using IT as a means of arriving at the definite FP. This characteristic depends, first of all, on the state policy in the field of public transport services, for example, in Asia there is a policy of containing the growth of automobilization, whereas in Western countries, especially in the USA and Great Britain, during the 1930s-1970s the growth of automobilization was lobbied by the state which ultimately led to disastrous consequences. Besides, the ratio of visitors depends on the remoteness of FP from the urban passenger transport lines, on the need to transport heavy (bulky) items, or on performing some sequence of correspondences one of which cannot be made using the urban passenger transport. |
| Daily irregularity coefficients | They reflect the ratio of correspondences (transport demand) per hour in question, usually it is a peak hour. The absolute value of transport demand, as a rule, does not present comprehensive information about the modes of FP functioning, it only shows its scale. When assessing the functioning of FP and, first of all, evaluating its impact on the adjacent SRN it is necessary to obtain information about the number of visitors during the one-hour (peak) period, since the operating modes of transport infrastructure are calculated per hour. In transport calculations the coefficient of daily irregularity having the greatest value is called the coefficient of daily maximum. In fact, it represents the relationship between daily and one-hour values of transport demand. |
| Average number of people in a vehicle (IT), persons/car | It reflects the average number of people in one IT when visiting FP in question. This characteristic shows the number of visitors (transport demanders) per car (IT). In fact, this is a relationship between transport demand and intensity of IT driving to/from FP. |
| The average duration of parking, min. | This is an average duration of staying in a parking space near FP. The average duration of parking, first of all, depends on the type of FP, on its area (size), on the duration of service and other less significant factors, for example, the |
remoteness of the parking space from the entrance to FP. This characteristic is basic; it is used for calculating the required number of parking spaces. However, it should be noted that nowadays in the vast majority of cases the absence of parking spaces will lead to reluctant visits to such FPs.

5. Experimental Findings

The selection of suburbanized areas that have the most favorable location in terms of the Irkutsk agglomeration and conducting the daily studies have resulted in the fact that the team of authors obtained the data on transport demand and other parameters of 10 suburbanized territories functioning (Table 2).

| Name of the Area                      | Transport Demand, corr./day | Ratio of Visitors Using IT | Coefficient of Daily Maximum | Average number of people in a vehicle (IT), persons/car |
|--------------------------------------|-----------------------------|----------------------------|-----------------------------|------------------------------------------------------|
| Zui                                  | 1 218                       | 0.768                      | 0.175214                    | 1.645                                                |
| Khomutovo                            | 10 743                      | 0.894                      | 0.119983                    | 1.325                                                |
| Molodyozhny                          | 3 188                       | 0.852                      | 0.105353                    | 1.372727                                             |
| Meget                                | 6 140                       | 0.844                      | 0.115122                    | 1.533333                                             |
| Kaya (inner suburb of Irkutsk)       | 4 398                       | 0.870                      | 0.116906                    | 1.645                                                |
| Milovidy                             | 591                         | 0.940                      | 0.121406                    | 1.594286                                             |
| Pivovarikha                          | 249                         | 0.770                      | 0.12963                     | 1.334667                                             |
| SNT 50 Let Pobedy                    | 160                         | 0.740                      | 0.063                       | 1.355                                                |
| SNT Mechta                           | 364                         | 0.900                      | 0.063                       | 1.381                                                |
| Minimum                              | 160                         | 0.74                       | 0.063                       | 1.325                                                |
| Maximum                              | 10 743                      | 0.94                       | 0.175214                    | 1.645                                                |
| Average                              | 3 005.66                    | 0.842                      | 0.1121                      | 1.465                                                |

The regression-correlation analysis (Table 3) makes it possible to establish the dependence of transport demand on the area of the suburbanized territory.

| Regression Coefficients | t – statistics | 95\% confidence limit |
|-------------------------|----------------|-----------------------|
| Y (corr.)               | 732.68         | 1.24                  | -619.73                    | 2085.096 |
| X1 (m²)                 | 0.00118896     | 6.17                  | 0.00074468                 | 0.0016 |

Thus, to estimate transport demand the following regression equation should be used:
\[ E = 0.00118896 \times S = 11.8 \times S \]  
(2)

where \( S \) is the area of the suburbanized territory, \( \text{m}^2/\text{ha} \). To use this relation in practice it is necessary to remember the limit intervals: 52,000 < \( S \) < 696,000 \( \text{m}^2 \), at the distance not exceeding 20 km from the city center.

6. Conclusion

The obtained regression dependence and the accompanying quantitative characteristics of suburbanized territories functioning will allow evaluating and predicting the intensity of traffic flows as well as of the SRN load including sections of joining the urban territories and suburbs. The obtained regression equation and quantitative characteristics will improve the accuracy and quality of urban planning decisions while implementing road traffic management projects, integrated traffic management schemes and comprehensive program of transport infrastructure in the transport zones of large and metropolitan cities. This problem is especially acute for the sections of SRN connecting suburbanized territories with the city.

References

[1] Bocharov Yu N and Kudryavtsev O K 1972 Planning Structure of a Modern City (M.: Publishing House) of Literature on Construction p 160
[2] Vilner M Ya 2008 On the Town-Planning Foundations of the Innovative Development of Russia Research and Business. Legal Regulation 4 (37)
[3] Volodkin P P 2010 Features of Development of Passengers’ Correspondences with Spatial Self-Organization BULLETIN OF PNU 3 (18) pp 123-133
[4] Vukan R and Vuchik 2011 Transport in Cities Convenient for Life
[5] Gutnov A E 1984 The Evolution of Urban Development p 256
[6] Efremov I S 1980 Theory of Urban Passenger Traffic: a manual for universities p 535
[7] Zhukovsky V S 2012 Overcoming the Investment Crisis in the Construction Sector and Creating Long-Term Investment Resources. Affordable and Comfortable Housing Problems, Searches, Solutions: Materials from an Expert pp 41-48
[8] Zedgenizov A V and Burkov D G 2016 Methods of Assessing Transport Demand Based on Quantitative Characteristics of Functioning of Urbanized Territories. Traffic Organization and Safety in Large Cities A Collection of works (electronic version) of the participants of the twelfth intern. scientific-practical conf. pp 235-242.
[9] Zedgenizov A V 2016 Correspondences Generation as the Main Quantitative Characteristic that Determines the Attractiveness of the Focal Point. Bulletin of ISTU 4 pp 187-192
[10] Zedgenizov A V 2016 Suburbanization of the City of Irkutsk: Scale and Consequences Universities News. Investments. Construction. Real Estate 1 (16) pp 159-165
[11] Lobanov E M 1990 Transport Planning of Cities p 240
[12] Romm A P 2002 Integrated Assessment and Functional Zoning of the Territory in Urban Planning p 206
[13] Silyanov V V 1977 The Theory of Traffic Flows in Road Planning and Traffic Management p 303
[14] Trip Generation 8th Edition. Washington 2008
[15] Wisser L A 1989 Model of Household Interactions in Activity Patterns
[16] Yao L, Guan H 2008 Trip Generation Model Based on Destination Attractive-ness Tsinghua science and technology 13 pp 632-635
[17] Zedgenizov A V and Burkov D G 2016 Methods for the Traffic Demand Assessment Based on the Quantitative Characteristics of Urban Areas Functioning 12th Inter-national Conference Organization and Traffic Safety Management in Large Cities, pp 28-30
[18] Zedgenizov A 2018 Location-Based Transport Demand Forecasting Methods for Suburbanized Areas Proceedings of the international conference: avia mechanical engineering and transport (avent 2018) AER-Advances in Engineering Research 158 pp 458-461