Transport Accessibility as a Factor of Regional Development

Liliya V. Erygina[a], Elena V. Belyakova[b]* and Anna A. Ryzhaya[c]

[a ,b,c]Reshetnev Siberian State University of Science and Technology, Krasnoyarsk 660000, Russia

Abstract: The spatial distribution of industrial enterprises is closely related to the development of transport systems that unite them into a single regional complex. Sustainable operation of transport systems is a guarantee of a single space, free movement of goods and services, improvement of conditions and living standards of the region's population.

The transport system ensures the territorial integrity of the region and the unity of the economic space based on the movement of passengers and goods, linking the region's enterprises into a single complex and ensuring the continuity of the processes of development of productive forces. The existing approaches to assessing this indicator are of a complex nature, but they do not take into account the influence of a number of factors associated with the peculiarities of the spatial distribution of the population of certain, for example, northern territories. The lack of objective statistical data does not allow researchers to conduct a comprehensive assessment of transport accessibility. Despite this, many authors are considering the possibility of measuring transport accessibility based on taking into account the costs of movement. The authors of the article propose to use this approach, improving it by refining the formula for the cost of travel time, which makes it possible to objectively compare the transport accessibility of various settlements to the regional center. Thus, this study is devoted to the study of transport accessibility as a leading factor in the development of the regional economy

Keywords: Transport accessibility, transport logistics, logistical maintenance

1. Introduction

Russia's integration into the world economy is ensured by the development of its industrial complex, and the efficiency of the country's economy is ensured by the successful functioning of all sectors of the national economy. However, high rates of economic growth can only be supported by regions with a developed industrial complex and, as a result, ensure a decent standard of living for the population. Modern regional industrial complexes are the result of many years of spatial, technological, economic development, as well as the development of social and industrial relations. In a general sense, the industrial complex is a branch of the national economy that influences the level of development of the productive forces of society and their distribution. The geography of the location of productive forces depends on the structure of industrial complexes and the level of development of the social sphere. The world and Russian experience of creating city-forming enterprises confirms this.

The transport system is one of the most important factors affecting the development of industry and the economy of the region as a whole, and makes social infrastructure facilities more accessible to the population, contributes to the preservation of health, providing residents with the opportunity to take advantage of the health zones and natural values of both nearby and remote areas. The development of the transport system is especially relevant for the socio-economic development of the northern regions, the creation of more attractive conditions for the life of the indigenous population and at least partial leveling of the difficult natural and climatic conditions. In addition, raw materials and energy resources are mainly concentrated in these territories, which largely determine the economy of Russia, which makes it necessary to develop reliable and convenient transport links.

The main indicator characterizing the state of the transport system is the indicator of transport accessibility. Increasing transport accessibility is a task declared in the socio-economic concept of the development of the Russian Federation, federal and regional economic programs. However, at present there is no consensus on the interpretation of the term "transport accessibility", as there is no single methodology for assessing the indicator of transport accessibility.

In this regard, the development of methodological approaches to measuring transport accessibility, including for residents of settlements of a separate subject of the Russian Federation, is of particular interest.

2.Transport accessibility: overview, definitions

Various authors, using the concept of "transport accessibility" as applied to a particular area of the economy, put their own meaning into it.

The availability of transport services can be defined as the ability to obtain these services in the context of the existing transport infrastructure.

Accordingly, the transport accessibility of individual settlements is associated with the transport infrastructure of the region, which is included in the country's unified transport system with integration into the global transport space.

M.V. Ivanov gives the following interpretation of transport accessibility - this is a criterion for the effectiveness of the use of transport infrastructure, reflecting the connectivity of the economic space in the parameters of the volume of transported goods and the number of passengers, time, cost and quality in the process of meeting the needs of society in the movement of goods and population [1, p. 115-117]. Agreeing with his opinion, from our point of view, it is necessary to include the number of transfers in the concept of transport accessibility. For example, in air transportation, due to the lack of direct flights, the passenger chooses feeder transportation using small aircraft to the hub airport. Thus, a feature of the existing transport infrastructure of the northern territories of the Krasnoyarsk Territory is the absence of direct air flights from a number of settlements to the regional center. Consequently, the number of transfers associated with the conditions of access of potential passengers from hard-to-reach settlements to the transport infrastructure of hub airports in the northern territories of the region affects the development of flight schedules. In addition, these circumstances of transfers should be taken into account in the amount of subsidies for air routes.

Thus, the author's interpretation of the concept of "transport accessibility" is proposed - this is a complex concept determined by distance, time, cost, the number of changes before receiving the final transport, market and social services.

A special contribution to the study of transport systems was made by V.N. Bugromenko [2, p.112; 3]. To determine the quality of the transport network configuration, he used the reliability mathematical apparatus, taking into account the indicators of the technical reliability and reliability of the network configuration. The key indicator of Bugromenko's methodology is integral transport accessibility, which takes into account both metric and topological components, and universality of accessibility (the availability of messages from one point of the system to any other). The methods for assessing the level of transport accessibility proposed by the Russian scientist have become one of the most used in domestic practice, since on the basis of a scientific approach, specific solutions could be proposed to improve the connectivity of territories, throughput, communication speed, etc.

Analysis of works [1-12], devoted to passenger transport systems, showed that researchers pay great attention to both the characteristics of transport networks, and qualitative and quantitative characteristics that determine the level of passenger service. In recent decades, works have appeared where transport accessibility is considered as a set of costs that determine not only the theoretical, but also the realizable possibility of reaching points in space. At present, it is becoming relevant to adapt the methods for assessing transport accessibility proposed by researchers to the characteristics of a particular region.

3.Methodology for assessing transport accessibility of settlements in the region of the Russian Federation

The basis for the development of a methodology for assessing the transport accessibility of settlements in the region was the method proposed by P.A. Lavrinenko, A.A. Romashina, P.S. Stepanov, P.A. Chistyakov [12], with the help of which a quantitative assessment of the transport accessibility of the regions of the Russian Federation was obtained. At the same time, it is of interest to calculate the transport accessibility of individual settlements within the region, this is especially true for settlements remote from the administrative center of the region.

The difference between the proposed methodology is the consideration of intraregional routes of movement, which are characterized by the absence of many transport hubs, as well as the seasonality of their use. The transport accessibility of the territory is defined as the accessibility of the settlements in the region. In this regard, the transport accessibility of the territory for the population is proposed to be calculated on the basis of an estimate of the total transport costs, which include the actual cost costs (direct costs, i.e., tariff, gasoline costs, etc.) and indirect costs, taking into account the time in ways and its cost to settlements of the region by different types of transport.

The calculation of the indicator of transport accessibility of settlements in the region includes several stages.

3.1. Stage 1. Determination of travel time

At the first stage, information is collected on travel time and distance between settlements within a separate constituent entity (region) of the Russian Federation by mode of transport, which plays a key role in passenger and cargo transportation (road (including personal road and bus transport); rail; air; water). On the basis of the collected information for each mode of transport and the selected routes, matrices are compiled containing information: settlement, distance, travel time.

The methods for determining travel time for each type of transport are different.

For road transport, travel time should be calculated on the basis of open data from map services that provide information about the real traffic situation (for example, Yandex. Traffic jams service).

When compiling the matrix, it is necessary to take into account the additional hours associated with rest, additional stops and the need for vehicle maintenance.

For railway transport on a direct route, the weighted average time is used for all trains running in this direction. For cases when there are no direct routes between settlements, it is necessary to draw up a complex route of two or three routes by rail. For example, if there are no direct rail flights from point A to point B, then when compiling the matrix, it is necessary to take into account the route first from point A to point C, and then from C to B. In this case, point C is determined in such a way that the total travel time between A and B were minimal.

If there is no railway station in one of the settlements, the travel time by road to the nearest transport hub with the railway station is added to the route time en route.

For air transport, in cases where there are no direct flights between cities, it is necessary to build a complex route: a combination of two or three flights by air transport, the calculation is carried out by analogy with rail transport. If there is no airport in one of the settlements, the travel time by road to the nearest transport center with the airport is added to the route time en route.

Three and a half hours are added for all routes, which includes the following additional time costs:

- An hour to get from the city center to the airport of departure (unlike the train station, it is considered to be remote from the center);

- An hour and a half to complete registration procedures;

- Hour for baggage claim and on the way from the airport of arrival.

For water transport, in the same way as for rail, it is recommended to use the weighted average time for all types of water transport plying in the water area under consideration.

3.2. Stage 2. Determination of the fare

The second component of total transport costs is the actual cost of travel, which is determined separately for each type of transport.

For road transport, it is recommended to calculate it according to the following **Formula 1**:

$$C^{auto}_{a\text{-}в} = L_{a\text{-}в} \times r \times P , \qquad\qquad (1)$$

where: $C^{auto}_{a\text{-}в}$ – actual cost expenses for travel by road transport from region a to region b, rub.; $L_{a\text{-}в}$ – the distance between settlements a and b on roads in the fastest option (the one that is used to calculate travel time), km; r – average fuel consumption for passenger cars per 1 km. (it is recommended to take from the calculation of the average fuel consumption 10 - 12 liters per 100 km); P – average fuel cost in the region, rubles/l.

The cost of depreciation of road transport is not included in the calculation, since this indicator depends on the length of the route and fully correlates with the indicator of fuel consumption. In this regard, the introduction of an additional indicator will not affect the relative level of accessibility of regions when ranking them (it grows proportionally for all correspondence).

For bus transport, as the cost of travel between settlements, the average annual fare between pairs of settlements of the region is used (including taking into account transfers if necessary), which is calculated based on the data of aggregator sites, as well as taking into account the cost of the entrance to the bus station according to the itinerary determined in step 1.

For air transport, the average annual fare for a flight between pairs of cities in the region (including taking into account transfers if necessary) is used as the fare, which is calculated based on data from aggregator sites, as well as taking into account the cost of approaching the airport in accordance with the route defined in step 1.

For railway transport, the actual cost of travel between pairs of cities in the region is based on the average annual cost of travel, as well as the cost of approaching the station in accordance with the route determined in stage 1.

For water transport, the fare is measured in the same way as for rail transport.

The result of the second stage of calculations is the matrices of fares by mode of transport.

3.3. Stage 3. Determination of the ratio of modes of transport

At the third stage, the shares of different types of transport are determined for correspondences of different lengths. These shares are calculated based on real statistics of passenger traffic for all modes of transport.

3.4. Stage 4. Calculation of the cost of travel time (indirect costs)

The unit cost of travel time for passengers is not the same and depends on the mode of transport used and the duration of the trip, as well as the route. The cost of travel time is proposed to be measured by lost profit (lost income), given that during the journey the passenger does not earn money, but spends his productive time on the trip. In general, the cost of travel time, which is a summand in assessing the total transport costs for a trip, is calculated using **Formula 2**:

$$C_{t\,a}^{T}{}_{-в} = d\,/\,n \times N_a^{T}{}_{-в}, \qquad (2)$$

where: $C_{t\,a}^{T}{}_{-в}$ – cost of travel time by transport T between the settlements under consideration in region a and b, rubles/hour; d – average annual income of one person employed in the region, rubles; n – average number of working hours per year, hour; $N_a^{T}{}_{-в}$ – the coefficient of the significance of the cost of time for a passenger on the route from a settlement a to a settlement b when using the mode of transport T.

The $N_a^{T}{}_{-в}$ coefficient differs by mode of transport, since the value of time for a passenger using different modes of transport varies significantly. So, for a passenger using air transport, the cost of an hour of time will be close to the average cost of an hour of working time, while for a passenger using a bus transport, it is multiples of it. To obtain quantitative estimates of this coefficient, it is necessary to study the differences in the income of the population of passengers using different modes of transport.

It should be noted that regional transport systems differ from each other in the structure and quality of transport arteries. So in the center of the Russian Federation, the transport system is saturated with a network of highways, railways, and air communications. At the same time, for example, due to climatic conditions, the northern territories are provided with only one type of transport, then when calculating indirect costs, it is necessary to take into account the peculiarities of movement across these territories. So, for example, according to the flight schedule, departures from the settlement to the regional center occur once a week, in this regard, when departing to solve a problem that requires one day, the passenger has to wait for the return flight within a week, which requires additional costs for food. accommodation, etc. Thus, the cost of travel time must include these costs, then formula 2 is transformed into **Formula 3**

$$C_{t\,a-в} = d\,/\,n \times m + (C_f + C_l) \times m, \qquad (3$$

where: C_f – average cost of food costs per hour, rubles/hour; C_l - average cost of living expenses per hour, rubles/hour; m – number of flight waiting hours, hour.

The total indirect costs in the case of using several modes of transport are calculated using **Formula 4**.

$$IndC_{a-в} = \sum (t_a^{T}{}_{-в} \times k_a^{T}{}_{-в} \times C_{t\,a}^{T}{}_{-в}), \qquad (4)$$

Where $IndC_{a-в}$ – indirect weighted average costs by mode of transport for travel from the considered settlement a to the settlement in the region under study, rubles; $t_a^{T}{}_{-в}$ – travel time from settlement a to settlement c by means of transport T, hours; $k_a^{T}{}_{-в}$ – the share of transport mode T in the passenger traffic between settlements a and b;

3.5. Stage 5. Calculation of the integral indicator.

The integral indicator of transport accessibility within the region, showing the total transport costs, is calculated using the following **Formula 5**

$$\square TC_{a-в}\,/\,D, \qquad (5)$$
$$в$$

where: I_a – integral transport accessibility of the settlement a; $TC_{a-в}$ – total transportation costs for travel from the settlement in question a to the settlement in, rubles; D – average annual income of a resident of the region, rubles.

In this case, the total transportation costs are calculated using **Formula 6**:

$$TC_{a-в} \square DirC_{a-в} \square\square IndC_{a-в}, \qquad (6)$$

Where: $TC_{a-в}$ – aggregate weighted average transport costs for travel from the considered settlement and to the settlement in the region under study, rubles; $DirC_{a-в}$ – actual (direct) weighted average costs by mode of transport for travel from the settlement under consideration to the settlement in the given region, rubles.

Actual (direct) weighted average costs by modes of transport are calculated using the following **Formula 7**:

$$DirC_{a\text{-}в} = \square\square \; (C_a{}^T{}_{\text{-в}} \times k_a{}^T{}_{\text{-в}}), \qquad\qquad (7)$$
$$T$$

Where: $C_a{}^T{}_{\text{-в}}$ – the cost of travel by mode of transport T between the settlements under consideration *a* and *b*, rubles; $k_a{}^T{}_{\text{-в}}$ – the share of transport mode *T* in the passenger traffic between settlements *a* and *b*.

In this case, the share of the mode of transport T is determined as a function of distance (based on the information prepared at stage 3) (**Formula 8**):

$$k_a{}^T{}_{\text{-в}} = f\,(L_{a\text{-}в}\,), \qquad\qquad (8)$$

Where: $k_a{}^T{}_{\text{-в}}$ – share of transport mode T in passenger traffic between settlements *a* and *b*, %; $f\,(L_{a\text{-}в}\,)$ – function of the distance between settlements *a* and *b*.

When using only one mode of transport, direct transport costs are determined as the average annual actual cost of travel for each mode of transport.

Mode-weighted indirect costs are calculated using the formula presented in Step 4.

4.Conclusions

The study showed that transport accessibility is a complex indicator that should take into account not only cost parameters, but also the parameters of passenger traffic, the throughput of roads, railways, air transport, as well as geographic location, i.e. the ability to quickly get to as far as possible. More settlements, and the size of nearby settlements (population), travel time to which is minimal. At the same time, proposing to measure transport accessibility by cost characteristics (the share of transport costs in the average annual income of the population), we do not take into account the influence of a number of other factors. Nevertheless, the proposed indicator makes it possible to objectively compare the transport accessibility of various settlements to the regional center.

Summarizing the above, we can conclude that the transport system is one of the important factors in the development of industrial complexes and the regional economy, since it serves as the basis for interdistrict and intersectoral interaction, creating conditions for the economic independence of regions.

The results obtained will create the basis for the development of scientific directions related to the formation and development of the transport system of individual territories and will expand the possibilities for the practical application of scientific results.

5.Acknowledgement

References

1. MV Ivanov. On the theory of transport accessibility Organizational and economic problems of development of transport industry enterprises. Materials of the Seventh Prokhorov readings. N.Novgorod: Litera, 2011.
2. VN Bugromenko. Transport in territorial systems. Moscow: Nauka, 1987.
3. VN Bugromenko. Modern geography of transport and transport accessibility Izvestiya RAN Geographical series. 2010; 4, 7-28.
4. AB Bardal. Change in Accessibility of Transport Services for the Population of the Far East of Russia IOP Conf. Series: Materials Science and Engineering. 2018; 463 (4), 042079. DOI:10.1088/1757-899X/463/4/042079
5. EV Belyakova, LV Erygina and TE Akbulatov. Regional transport system as a key transport accessibility factor for social services Economics and entrepreneurship. 2019; 13 (7), 404-408.
6. WG Hansen. How Accessibility Shapes Land Use. Journal of the American Institute of Planners. 1959; 25, 73-76. DOI: 10.1080/01944365908978307
7. RG Mugion, M Toni, H Raharjo, Di Pietro and SP Sebathu. Does the service quality of urban public transport enhance sustainable mobility? J. Clean. Prod. 2018; 174, 1566–87.
8. MA Saif, MM Zefreh, and A Torok. Public Transport Accessibility: A Literature Review. Periodica Polytechnica Transportation Engineering. 2018; 47 (1), 36-43.

9. K Fransen, T Neutens, S Farber, P De Maeyer, G Deruyter and F Witlox. Identifying public transport gaps using time-dependent accessibility levels. J. Transp. Geogr. 2015; 48, 176-187. DOI: 10.1016/j.jtrangeo.2015.09.008

10. R Kujala, C Weckström, MN Mladenović and J Saramäki. Travel times and transfers in public transport: Comprehensive accessibility analysis based on Pareto-optimal journeys. COMPUT ENVIRON URBAN. 2018; 67, 41-54. DOI: 10.1016/j.compenvurbsys.2017.08.012

11. F Rajé. The Lived Experience of Transport Structure: An Exploration of Transport's Role in People's Lives. Mobilities. 2007; 2 (1), 51-74.

12. PA Lavrinenko, AA Romashina, PS Stepanov and PA Chistyakov. Transport accessibility as an indicator of regional development Problems of forecasting. 2019; 6, 136-146.