Method for assessing the level of transport accessibility in the largest cities of Russia

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Method for Assessing the Level of Transport Accessibility in The Largest Cities of Russia

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Abstract. The article presents an approach to research methods and key performance indicators for assessing accessibility in smart cities. This approach is based on the strategy of a sustainable urban transport system. A methodological basis was proposed for assessing the level of transport accessibility in the service of the population of cities. As an example, data on the features of the development of transport systems in cities with high quality of transport services for the population and mobility are given. The analyzed examples confirmed the validity of the idea of sustainable development of the transport system. Achieving the strategic goals of sustainable transport services and mobility of the population is impossible without the use of modern technologies of intelligent transport systems. This article shows the importance of an intelligent transport system in the policy of public transport services. This article also formulates indicators for assessing accessibility in the urban transport system of the largest cities of Russia. The developed method of assessing the level of transport accessibility will allow us to study the dynamics of changes in indicators and plan measures to improve the quality of transport services. The implementation of the proposed method will allow analyzing routes, as well as planning measures to increase the level of transport accessibility and attractiveness of public transport when transporting passengers.

INTRODUCTION

Currently, one of the most important trends in urban development is the transition to the formation of sustainable transport systems. This is due to the fact that traditional approaches to solving problems of congestion of the road network, which only increase the network capacity, are ineffective [1].

The transport networks of most cities of the world remain insufficiently developed and do not correspond to the growth of demand. The demand for movement arises not for the sake of movement itself, but to meet certain needs (for work, rest, health) and to carry out various types of activities in certain places.

The lack of a systematic approach to the problem of transport planning of an urban agglomeration is expressed in the fact that different types of transport are considered only separately. Such an approach to planning in the future does not exclude the fact that many important relationships of transport infrastructure elements remain out of sight of decision makers, and, as a result, lead to incorrect conclusions.

The scientific works of E. M. Lobanov, V. V. Cherepanov, V. V. Zyryanov [2], A. E. Gorev [3], S. V. Zhankaziev [4], M. Ya. Blinkin, M. R. Yakimov [5] and R. R. Zagidullin [6, 7] and others are devoted to research in the field of transport planning and development of transport systems.

Ensuring mobility for modern society has become an integral part of it. Mobility in the broadest sense is usually understood as the possibility of spatial, intellectual, social, and professional exchange. Transport mobility is the possibility of spatial movement of people. At the same time, increasing mobility is always in contradiction with the capabilities of the corresponding infrastructure.

Cities with a mixed transport system provide mobility to all citizens, not just car owners. In such cities, all citizens are offered alternative travel options, including options that do not depend on the load of the road network. And, finally, mobility (usually extremely high in cities focused on the use of cars) is an indicator much less important than accessibility, i.e. the ability to move between different points of life of the population [8].

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Most people strive for privacy, but this desire should not be absolutized. Complete immunity means no contact with other people. But people are social beings, and they move to cities mostly in order to interact with their own kind. In agglomerations focused on the almost complete predominance of automobile travel, public life is much more limited than in cities where different types of transport coexist. On the contrary, the use of a mixed model of land use, humanitarian-oriented planning solutions for residential and business development, the creation of pedestrian zones stimulate the activation of public life.

Increasing mobility through the purchase of cars leads to a dead end, because it is impossible to build an adequate transport network even in the absence of financial restrictions due to a shortage of available space and environmental consequences. In this regard, the transport policy of large and large cities of the world, which have passed the level of motorization exceeding 300 cars per 1000 inhabitants, has taken a course for the development of public transport with a high level of service quality and demotivation of the use of personal (individual) transport.

A new development strategy is needed, and it includes a strategy of smart cities and cities with a sustainable transport system. There are various definitions of a sustainable transport system. One of them is devoted to the economic side of the problem. L. Schipper used the following term: "Sustainable transport is transport in which beneficiaries fully pay for their social expenses, including those that will be paid for by future generations" [9]. There is also a definition of sustainable mobility. For example, as " the ability to meet the needs of society for free movement, access, communication, trade and establishing relationships without compromising other basic human or environmental values today or in the future" [10].

Thus, sustainable mobility allows you to move from one place to another using a multimodal approach with the highest safety standards, offers a choice of transport mode, provides access to cargo and passenger transportation, reducing emissions and minimizing the use of energy resources and territories. To create an efficient and sustainable transport system, the city must change its transport policy from the movement of vehicles to the movement of people and goods. This includes accounting for a multimodal trip from the place of departure to the destination, carried out, as a rule, using various modes of transport.

Congestion and traffic accidents in the urban transport system are one of the important problems of modern society. A new quality of mobility can be achieved through the application of the "smart city" strategy and the transition to a sustainable urban transport system. The main conditions for creating a sustainable transport system are the development of an integrated public transport network that provides efficient multimodal travel, the development of a non-motorized mode with minimal consumption of energy resources, the development of cargo distribution and urban logistics, and the improvement of an intelligent transport system. An important topic for smart city projects is the definition of key performance indicators for various types of urban transport services and population mobility.

The issues of organizing passenger transportation and ensuring traffic safety are considered in a number of scientific works by V. V. Silyanov [11], A. B. Velmozhin, E. P. Volodin, P. P. Volodkin, A. E. Gorev, V. A. Gudkov, V. V. Zyryanov [12], B. A. Korchagin, L. B. Mirotin, A. N. Novikov [13], I. V. Spirin, C. A. Shiryaev, H. H. Yakunin [14], N. V. Yakunina [15], R. R. Zagidullin [16] and others.

The assessment of the work of urban public transport in achieving effective mobility of the population is changing. Various types of transport are used in an integrated manner to achieve the most effective mobility of the population, allowing to reduce the total travel time of passengers.

To conduct research on the level of transport accessibility, an updated classification by the number of cities is proposed in table 1. Further research concerns the class of the largest cities in Russia with a population of more than 1000 thousand people.

TABLE 1. Classification of cities by population.

Class	Population, thousand inhabitants
Super large	over 5000
Giant	1000 to 5000
Large	500 to 1000
Big	250 to 500
Medium	100 to 250
Towns	50 to 100
Villages	10 to 50
Settlements	up to 10

We will calculate the assessment of transport accessibility of the largest cities of Russia, which include urban settlements with a population of more than 1 million people, according to the developed author's method.

MATERIALS AND METHODS

Method For Assessing The Level Of Transport Accessibility

When forming a transport policy and evaluating urban transport systems, the problem of comparative evaluation of the indicators of the functioning of public transport and the transport system as a whole in different cities inevitably arises. There are many criteria for assessing the level of transport accessibility.

One of the most important indicators for assessing the level of transport accessibility is the accessibility index (the ratio of the length of the lines of separate (priority) movement of public route transport, including the metro, to the length of the general street and road network). Next, we will investigate the length of the lines of separate (priority) movement of public route transport in the largest cities of Russia.

According to the length of bus lanes (BL) for the movement of public route transport, including the tram network, the cities of Russia were distributed as follows according to the data of 2021 (Table. 2) [17, 18].

TABLE 2. The length of dedicated lanes and tram networks of Russian cities.

Seq. No.	City	Population, (thousand people)	Area, (km^2)	Length of bus lanes, (km)	Length of the tram network, (km)
1	Moscow	12 678	2551,9	734,80	166,00
2	Saint-Petersburg	5 398	1439	75,80	222,00
3	Novosibirsk	1 625	506,67	20,30	62,00
4	Ekaterinburg	1 493	468	9,80	78,00
5	Kazan	1 257	614,16	182,70	59,00
6	Nizhny Novgorod	1 252	466,5	5,40	75,00
7	Chelyabinsk	1 196	501,57	15,40	64,00
8	Samara	1 156	541,38	9,60	68,00
9	Omsk	1 154	566,9	6,80	31,00
10	Rostov-on-Don	1 137	348,5	29,30	26,00
11	Ufa	1 128	707,93	16,60	33,00
12	Krasnoyarsk	1 093	353,9	57,10	23,00
13	Voronezh	1 058	596,51	24,20	
14	Perm	1 055	801,44	11,20	46,00
15	Volgograd	1 008	859,35	16,90	58,00

The list of subways and high-speed electric transport in Russian cities is presented in Table 3.

TABLE 3. The length of the metro and high-speed tram in Russian cities.

Seq. No.	Metro system	Network length (km)	Lines	Stations
1	Moscow (with MCC and overhead monorail conveyors)	408.1 (466,8)	15 (17)	238 (275)
2	St. Petersburg	124.8	5	72
3	Nizhny Novgorod	21.82	2	15
4	Volgograd (high-speed tram)	17.3	1	22
5	Kazan	16.77	1	11

TABLE 3. Continued

Seq. No.	Metro system	Network length (km)	Lines	Stations
6	Novosibirsk	15.9	2	13
7	Yekaterinburg	12.7	1	9
8	Samara	12.6	1	10

The index of transport accessibility of public services (ITA) – is the ratio of the length of the lines of separate (priority) movement of public route transport (PRT), including the metro l_P, to the length of the general street and road network (SRN) l_I:

$$l_P = l_A + l_T + l_M, \text{км}. \quad (1)$$

$$I_A = \frac{l_P}{l_I}, \quad (2)$$

The transport system is evaluated by the level of transport accessibility of public services (LTA) based on the following values of the transport mobility index (Table 4).

TABLE 4. Level of transport accessibility.

Level of transport accessibility (LTA)	Index of transport accessibility (ITA)
A	more than 1,001
B	0,801 – 1,000
C	0,601 – 0,800
D	0,401 – 0,600
E	0,201 – 0,400
F	less than 0,200

The transport accessibility index can also be determined for other road users (cyclists, pedestrians) when assessing the conditions for the functioning of the transport system, as an additional parameter.

RESULTS AND DISCUSSION

We will calculate the length of the lines of separate (priority) traffic of the route PRT of the largest cities of Russia (Table 5).

TABLE 5. Summary table calculate the length of the lines of separate (priority) traffic of the route PRT of the largest cities of Russia.

Seq. No.	City	Length of bus lanes, (km)	Length of the tram network, (km)	Length of the metro, (km)	Sum total, (km)
1	Moscow	734,80	166,00	466,8	1367,60
2	Saint-Petersburg	75,80	222,00	124.8	422,60
3	Novosibirsk	20,30	62,00	15.9	98,20
4	Ekaterinburg	9,80	78,00	12.7	100,50
5	Kazan	182,70	59,00	16.77	258,47
6	Nizhny Novgorod	5,40	75,00	21.82	102,22
7	Chelyabinsk	15,40	64,00		79,40
8	Samara	9,60	68,00	12.6	90,20
9	Omsk	6,80	31,00		37,80
10	Rostov-on-Don	29,30	26,00		55,30
11	Ufa	16,60	33,00		49,60

TABLE 5. Continued

Seq. No.	City	Length of bus lanes, (km)	Length of the tram network, (km)	Length of the metro, (km)	Sum total, (km)
12	Krasnoyarsk	57,10	23,00		80,10
13	Voronezh	24,20			24,20
14	Perm	11,20	46,00		57,20
15	Volgograd	16,90	58,00	17.3	92,20

We get the following levels of transport accessibility of the largest cities of Russia (Table 6).

TABLE 6. Indexes and levels of transport accessibility of the largest cities of Russia.

Seq. No.	City	length of the general street and road network, (km)	length of the lines of separate (priority) traffic of the route PRT (km)	Index of transport accessibility (ITA)	Level of transport accessibility (LTA)
1	Moscow	3600,00	1367,6	0,380	E
2	Kazan	1750,00	258,47	0,148	F
3	Saint-Petersburg	3461,80	422,6	0,122	F
4	Nizhny Novgorod	1143,88	102,22	0,089	F
5	Samara	1022,70	90,2	0,088	F
6	Ekaterinburg	1327,00	100,5	0,076	F
7	Volgograd	1284,95	92,2	0,072	F
8	Chelyabinsk	1109,40	79,4	0,072	F
9	Novosibirsk	1425,60	98,2	0,069	F
10	Krasnoyarsk	1200,80	80,1	0,067	F
11	Perm	868,00	57,2	0,066	F
12	Rostov-on-Don	1367,88	55,3	0,040	F
13	Ufa	1563,00	49,6	0,032	F
14	Omsk	1257,20	37,8	0,030	F
15	Voronezh	1088,40	24,2	0,022	F

The highest index of transport accessibility in the city of Moscow (0.380) with the highest length of lines of separate (priority) route traffic (1367.6 km), which also confirms the results of studies of cities in the world, in which Moscow occupies a leading position in the world [19]. The second place was taken by Kazan with the result of the transport accessibility index of 0.148, which is more than 5 times inferior in terms of the length of the lines of separate (priority) traffic of the route TOP. St. Petersburg took the third place (0.122), despite its level of well-being and the presence of a well-developed metro network. Next, with a significant gap, are N. Novgorod (0.089), Samara (0.088), Yekaterinburg (0.076), Volgograd (0.072), Chelyabinsk (0.072), Novosibirsk (0.069), Krasnoyarsk (0.067), Perm (0.066), Rostov-on-Don (0.040), Ufa (0.032), Omsk (0.030) and Voronezh closes the rating with the transport accessibility index 0.022, with the lowest length of dedicated lanes (24.2 km).

SIMETRA company analyzed the operation of transport systems in 60 major cities of Russia and compiled a rating of the quality of public transport. Moscow and St. Petersburg were excluded from the study due to their significant differences from other cities. The company's experts analyzed five groups of parameters: physical and price accessibility for the population, efficiency of the transport network, comfort and safety. Yekaterinburg (73.5) became the leader of the rating, then Izhevsk (70.6) Samara (69.3), Kazan (68.8), Volgograd (65.1), N. Novgorod (64,9), Novosibirsk (64,0), Kirov (64,0), Perm (63,4), Chelyabinsk (62,3) is in 11th place, Omsk (59,6) is in 16th

place, Rostov-on-Don (57,6) is in 21st place, Krasnoyarsk (56,6) is in 25th place, Ufa (55,5) is in 32nd place, Voronezh (46,9) is in 58th place [20].

Many European cities have implemented a strategy of sustainable mobility [9, 12, 21, 22, 23]. The example of London is very attractive [24]. London demonstrates an effective transport policy – investment in public transport, priority for buses and cyclists, a local freight transport strategy and charging for traffic jams. From 2000 to 2006, the number of trips by public transport increased by 42%. More trips are made by bike and on foot, the average speed in central and inner London has increased since 2003 (reversing a long-term trend), and the number of road fatalities in London has decreased faster than in the rest of the country. The traffic congestion pricing scheme in the city reduced the number of vehicles entering the city by 25 percent, and the volume of circulating traffic decreased by 15 percent.

In Amsterdam, the creation of sustainable mobility is carried out in accordance with the intellectual mobility program [25]. The goals of this Smart Mobility action program contribute to achieving the goals of the executive agenda "Mobility and Sustainability Agenda": improving the security, accessibility, quality of life and attractiveness of Amsterdam.

In Vienna, one of the most popular types of urban public transport, the share of public transport, pedestrian and bicycle traffic in the division of modes of transport is 69%. The annual volume of transportation by all types of public transport is about 870 million passengers. The daily mileage of Vienna's public transport is 180,000 km. The average travel time to work in Vienna is 28 minutes, and this is a very good result for a large city. In Vienna, there is a very high level of satisfaction with public transport, so more than 450 thousand people own an annual ticket. The Vienna Program for the Development of the Public Transport System includes innovative approaches to ensuring the environmental, economic and social sustainability of transport. Vienna's public transport strives for efficient and environmentally friendly mobility [26].

The Stockholm Urban Mobility Strategy defines the city policy regarding priorities in the development of the transport system to promote the creation of a more efficient, safe, attractive, environmentally friendly and healthy city [27]. Stockholm is implementing smart choice measures that help residents and encourage urban travelers to plan their trips in a more reasonable way in order to reduce congestion and environmental impact.

Examples of observations confirm the validity of the idea of sustainable mobility based on the master plans of smart cities; public transport is less harmful to the environment; sufficient infrastructure and convenient access; advanced technologies of intelligent transport systems.

In the future, it will be possible to develop a set of models of transport services and population mobility for cities with different levels of development of the urban transport system.

CONCLUSION

The results of the calculations showed that the presence of a developed metro network (more than 1 line) in cities provides a transport mobility index above 0.5.

A relatively high transport accessibility index of more than 0.1 can be ensured by the optimal organization of public transport in the city even without the presence of a developed metro network, following the example of Kazan.

The presence of a large length of dedicated lanes for public transport guarantees a relatively high index of transport accessibility of the city, following the example of Kazan. The organization of dedicated lanes allows relatively small financial investments in transport infrastructure to increase the level of transport services for the population and provide remote territories and the whole city with a high level of transport mobility. For many cities with insufficient financial resources, the organization of dedicated lanes may be the only solution to the problem of poor quality of public services.

Ensuring mobility is one of the most difficult systemic tasks for cities. With all the variety of solutions and models, few were able to quickly integrate them and unlock their potential. Interaction and consideration of the interests of all participants in the process of improving urban transport will help the emergence and integration of innovative solutions. Moreover, many cities do not have a clear concept and strategy for the development of their transport networks aimed at increasing the level of transport mobility that contributes to the growth of the attractiveness of public transport.

The obtained new results of assessing the level of transport accessibility and the developed method make a significant contribution to the theory and practice of transport services and public transport planning.

The implementation of the proposed method will make it possible to create optimal routes, as well as plan measures to increase the level of transport accessibility and attractiveness of public transport when transporting passengers.

The conducted studies allow us to assess the level of transport services and mobility, taking into account the structure of the transport systems of the largest cities. The obtained results of transport accessibility levels allow us to conduct a comparative analysis to assess the efficiency of urban public transport systems and determine promising directions for its development in further research.

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