Trolleybuses and trams in the urban public transport network of Russian regions: problems and prospects

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Abstract. This study covers the problems and prospects of integrating trolleybuses and trams into the public urban transport network of the Russian regions, to the analysis of the relevant experience of individual cities of the world. As part of the implementation of the national project "Safe High-Quality Roads", the regions are financed to modernize the rolling stock of trolleybuses and trams, expand the network of routes, and create modern infrastructure. The study identified the problems of transition to electric public transport, typical for Russian regions and individual foreign cities. In most cities of Russia, the fleet of trolleybuses and trams has drastically decreased compared to the Soviet period, tram lines often interfered with traffic due to increased urban traffic and were dismantled, the infrastructure and rolling stock are worn out and do not meet safety requirements. Abroad, city authorities face other problems: equipping trolleybuses and trams with security systems that allow them to avoid collisions with pedestrians and collisions with other city transport, equipping rolling stock with on-board batteries with recharging while driving, creating low-floor models of trams and trolleybuses. Thus, the task of switching to electric public transport is common on a global scale, but the problems that the city authorities of Russian and foreign regions need to solve differ significantly.

1 Introduction

Russia follows global trends in improving the environmental situation in cities by reducing greenhouse gas emissions from transport and industrial enterprises. One of the ways to achieve this goal is the transition to environmentally friendly urban transport. In a number of Russian cities, programs are being implemented that stimulate the development of a network of electric buses, free parking for electric vehicles, rental of bicycles and electric scooters, etc. However, in most cities of the Russian regions, along with buses, trolleybuses and trams are traditionally used to transport the population. In addition to zero emissions, public electric transport with high passenger flows can reduce operating costs and reduce damage from traffic accidents.

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The development of urban public electric transport in the regions is in the field of view not only of transport industry organizations and professional associations, but also of the Russian legislator. According to the Ministry of Transport of Russia, public land transport (bus, tram, trolleybus) accounts for 72% of passenger traffic in the country, in cities it is used by at least half of the inhabitants. In total every year, urban public transport in Russia carries over 12 billion passengers, including trams and trolleybuses - 1.8 billion passengers. More than 162 thousand buses, almost 8 thousand trolleybuses and 7.5 thousand tram cars are involved in urban and suburban transportation (https://mintrans.gov.ru/press-center/news/10401?ysclid=l95nosz5ll151375252).

In some Russian regions, measures are being taken to modernize the tram infrastructure, reconstruct tram tracks, traction substations, depots, replace the contact network, and renew the rolling stock. In 2022, the first intercity tram line with a length of about 17 km was launched in the city of Yekaterinburg. However, the situation with the development of urban electric transport is still far from ideal. In most Russian cities, the fleet of trolleybuses and trams has been drastically reduced compared to the Soviet period, tram lines often interfered with traffic due to increased urban traffic and were dismantled, the infrastructure and rolling stock are worn out and do not meet safety requirements. Ways to solve the problems of development of trolleybuses and trams in the urban public transport network in Russian and foreign cities are analyzed in this article.

2 Materials and methods

The study is based on a comprehensive data analysis using a set of scientific methods. The use of the historical method made it possible to show the history of the development of electric public transport in Russia. The main factor that historically determined the popularity of trolleybuses and trams in Russia was the cost of fuel. With the fall in fuel prices, buses came to the fore in the public transport system. And vice versa. Rising fuel prices determined the popularity of trams and trolleybuses. The use of the comparative method in the research process made it possible to substantiate the conclusion that this trend is also characteristic of the development of public transport systems in the cities of other countries.

In the 21st century, the development of electric urban transport is stimulated by the struggle to improve the ecology of cities and reduce emissions. Analyzed data on the state of the rolling stock of trams and trolleybuses, the relevant infrastructure in the cities of Russian regions, as well as individual foreign cities. In the course of the study, publications of authors from Russia, Italy, Austria, India, Poland and some other countries devoted to the problems of updating public electric transport, modernizing tram and trolleybus networks were studied.

The traditional leading positions of Russia among the cities of the world in terms of the number and length of tram and trolleybus routes, the number of rolling stock are noted. At the same time, problems were identified that impede the development of electric public transport in the Russian regions. In Russia, there is a tendency to reduce the number of trolleybus and tram routes due to the depreciation of the infrastructure (contact networks, cable and rail facilities, traction substations, repair depots) and rolling stock. In many cities, the state of electric transport does not allow providing safe working conditions for workers and a modern level of passenger service. In the cities of the Russian regions, the authorities are actively introducing gas-powered buses to transport the population. Due to their high cost, electric buses are relevant only for individual megacities, whose authorities do not experience problems in investments.

Based on the study of publications of foreign authors, radically different problems have been identified in the development of trams and trolleybuses in the public transport systems of cities around the world. The general trend for them is the modernization of electric urban transport in accordance with modern environmental requirements. Important areas of

modernization are equipping trolleybuses with on-board batteries that can be charged while driving; equipping rolling stock with security systems to avoid collisions with pedestrians, collisions with other urban transport, which are successfully used in passenger cars; inclusion of trams and trolleybuses in the "smart city" system.

3 Development of electric urban transport in Russia

Trolleybuses have been operating in Russian cities for almost 90 years. The first trolleybus line was built in Moscow in 1933. For the transportation of the population, trolleybuses have always been a priority, since the tram tracks interfered with traffic in historical centers, buses had low-power engines, and electricity was low-cost. In the Soviet Union, trolleybuses were widespread. Cities were equipped with domestic models of trolleybuses. Compared to trolleybuses, trams have a longer history. As you know, the first trams were horse-drawn. By the end of the 19th century, trams were first equipped with a steam engine, then with electrical traction.

The first city in Russia, where a tram line was launched, was Nizhny Novgorod. It happened in 1896. Nizhny Novgorod was the trading capital of Russia thanks to the annual trade and industrial fair.

Fig. 1. Tram model from the 1920s.

Fig. 2. The interior of this tram car.

The most active tram network in Soviet cities developed until the 1940s. Later came the trolley bus boom. Trolleybuses were more economical and more maneuverable than trams.

In the 1980s, the development trend of urban electric transport changed. Rising oil prices have shifted interest away from city buses in favor of trams.

Fig. 3. Tram model of the 1930s, made in the USSR.

Fig. 4. Tram model of the 1970s, made in the USSR.

One of the principles for the development of modern transport systems in Russian cities is the availability and completeness of information on quality indicators and costs for urban public transport. In addition to travel speed, comfort, safety, environmental pollution indicators, costs for the development and operation of transport, the time spent by the population on movement and other factors are taken into account.

In 2019-24 Russia is implementing the national project "Safe High-Quality Roads" (https://bkdrf.ru). As part of the project, a unified comprehensive program for the modernization of public transport in the regions has been formed. According to the Minister of Transport of Russia, special attention in the federal project is paid to the development of electric transport - and not only in terms of the purchase of rolling stock, but also in terms of infrastructure upgrades. The result of the implementation of a unified program for the development of public transport until 2024 will be the renewal of up to 1.5 thousand units of electric transport rolling stock. This is about 21% of the need to upgrade trams and trolleybuses. In addition, by 2027, 645 km of tram lines will be reconstructed and built, which is more than 10% of their length. (https://mintrans.gov.ru/press-center/news/10401?ysclid=l95nosz5ll151375252). Subject to proper transport planning, the regions are financed from the federal budget.

Strategy Partners experts note that in recent years, passenger traffic on electric transport has continued to decline in Russia. In their opinion, compared with the level that was in

the USSR, the volume of traffic has decreased significantly, by about 5-10 times. Let's take the situation in the city of Belgorod as an example. According to the Ministry of Roads and Transport of the Belgorod Region, there were 124 trolleybus routes in the city earlier. Currently, only 2 routes operate, which carry less than 5% of all passengers. Trolleybus infrastructure (contact network, cable facilities, traction substations, repair depot) and rolling stock of electric transport in the city do not allow ensuring safe working conditions for workers and a modern level of passenger service (http://mapget.ru/ministerstvo-avtomobilnyx-dorog-i-transporta-belgorodskoj-oblasti-soobshhaet-o-neokonchatelnom-otkaze-ot-trollejbusa/).

We believe that a similar situation with public electric transport is typical for most Russian cities. Under these conditions, the transition to city buses is a necessary measure. For the modernization, and in some cities for the restoration of the most environmentally friendly and economical urban transport - trolleybuses and trams, significant financial investments are required.

The modern needs of the transport systems of Russian cities with a population of 100,000 people in the restoration of electric transport are justified by a reduction in public and budget spending on public transport by 10-20%. Thanks to the development of urban electric transport, the time spent on moving citizens will decrease by 10-15%. Damage from traffic accidents will be reduced by 2-3 times, and damage from environmental pollution - by 30-40%. It is also noted that, in comparison with the bus, trolleybus transport in the field of its most efficient use is more economical on average by 15% of other modes of transport (https://rg.ru/2022/10/11/vziatsia-za-delo-s-energiej.html?ysclid=l95npqxrcf378813042).

The positive aspects of the development of tram and trolleybus networks in Russian cities are obvious. However, when planning routes, it is necessary to take into account the historical development of cities, high traffic in the central and business districts. We believe that it is advisable to lay public electric transport routes to connect remote residential and industrial areas. A full-fledged city development strategy is needed to introduce new trolleybus or tram routes.

Russia is the leader among the cities of the world in which trolleybus and tram routes operate. In many cities, trolleybuses are the main form of public transport. One of the goals of the development of urban transport is the phased replacement of buses with electric transport. Achieving this goal will reduce the authorities' costs for servicing public transport, improve the environmental situation in cities, and provide the population with fast and comfortable movement. The introduction of electric buses on city routes has shown the high cost of this type of transport, a significant increase in the cost of creating infrastructure for their service. Therefore, trolleybuses and trams remain a priority for most Russian cities. The development of an electric bus network is a priority for Russian megacities, where there are no problems with financing the development of this type of electric urban transport.

At the same time, the development of a network of trams and trolleybuses in the regions of Russia is currently running counter to the global trend. The International Association of Urban Electric Transport Enterprises notes that over the past 30 years, the length of tram and trolleybus lines in the cities of the world has increased significantly. At the same time, in the Russian regions, the trend is opposite due to the deterioration of the infrastructure and rolling stock of trolleybuses and trams. With proper planning and management of transport in cities, there is a gradual replacement of bus transport with trolleybuses, trolleybus transport with trams. (http://mapget.ru/115-let-peterburgskomu-tramvayu/).

4 Development of electric public transport in the cities of the world

The trends in integrating trolleybuses into the urban public transport system of European countries are generally identical to those in Russia. Just like in Russia (formerly in the Soviet Union), in Europe trolleybus transport is one of the classic types of public transport. Also, its popularity in cities is connected with the fuel market conditions. During periods of falling fuel prices, electric vehicles lost popularity. During fuel crises, trolleybuses gained popularity [1].

In modern Europe, the development of alternative energy technology makes trolleybus transport partially independent of the contact network, which is its great advantage. Thus, it is possible to develop trolleybus communication in areas where the construction of overhead wiring is impractical. The authors note the trend of closing trolleybus transport due to the strong competition of electric buses that do not require a contact network, which allows the dynamic development of this transport industry. The solution to the problem is seen in providing trolleybuses with on-board batteries [2].

The equipping of trolleybuses with on-board batteries, the use of recharging while driving is also considered a promising technological solution by authors from Italy. This conclusion is substantiated by them on the basis of calculations for each trolleybus route of the Bologna trolleybus system, based on the characteristics of the power consumption of conventional trolleybuses and IMC trolleybuses [3].

It should be noted that such technological innovations are practically not discussed by Russian researchers, since the smart city system is still far from being introduced and implemented in the vast majority of Russian regions.

The importance of the electrification of public vehicles in terms of the transition to a more sustainable transport system is noted by authors from various continents.

In addition to cars, trams and metro are noted as priority areas for the development of electric mobility in Austrian cities. This approach could be a potential solution to air pollution and greenhouse gas emissions. [4].

On the example of the Philippines, economic and technological factors are noted as the main barriers to the introduction of public transport on electricity. This includes high investment and operating costs, lack of charging infrastructure, problems of use in different areas, availability of spare parts and repair stations. For the development of a zero-emission public electric transport system, the authors recommend government investment in this area, a mass information campaign to educate the public about its benefits. [5]

Factors influencing the development of the trolleybus system of individual cities in Poland have been studied by Polish economists.Results indicate that after including external costs into the economic calculation, trolleybus transport is economically efficient, although the energy mix is an important factor. In-motion charging trolleybus can be seen as a compromise solution between capital costs and battery capacity and is recommended for cities already operating this system [6].

Trams are still popular in the modern transport systems of the world's cities. An analysis of the publications of foreign authors allows us to state that the most actively discussed problems are the inclusion of trams in the "smart city" system, the inclusion of trams in the overall system of urban rail transport. Topical issues of equipping trams with innovative equipment to avoid collisions with pedestrians, collisions with other urban transport, which is successfully used in cars. The modernization of the rolling stock of trams is being discussed. Researchers from the Florence Department of Industrial Engineering note the following approach. Tram manufacturers have different ways of approaching the design of low-floor trams with compact and reliable running gears, and therefore several tram architectures can still be found. A complete standardization of trams is nearly impossible, and technical

innovations can be more easily introduced if compared to conventional railway vehicles, but the trend towards large-scale standardization based on vehicle "platforms" can be seen in recent years. Even if the complete low floor is still one of the main requested features, several solutions combining pivoting and non-pivoting bogies are commercially available, showing a tendency to give more relevance to running quality performance with respect to the recent past [7].

The relevance of using trams to transport the population of cities around the world is also due to unprecedented climate change, which requires the adoption of environmentally friendly solutions. The fight for the ecology of cities is the most important task of the authorities of megacities, including in India. The energy sector in India significantly contributes to global warming through emissions of 142 million tonnes of carbon dioxide emissions annually where the transport sector alone accounts for 123 million tonnes of emissions. Such commitments focus on to the need for electric mobility with Kolkata's century old trams providing a viable option in the public transport mode sector. Trams have a higher carrying capacity than buses, have lower operation and maintenance costs which make them a sustainable mode of transport. On the down side, weaknesses plaguing the growth of tramways include congestion on roads, poor network, passenger safety while boarding and alighting and the visual displeasure due to overhead wires. A developed tramway system will enrich urban environment, recreational activity and tourism industry of Kolkata and help in growing interest among citizens to use tramways. One of the solutions to the problem is the allocation of lanes for urban traffic [8].

Thus, the expansion and modernization of trams and trolleybuses in the urban transport systems of the world's cities is of particular relevance on the path to zero emissions and improving the ecology of the world's cities.

5 Conclusions

In the modern world, urbanization processes are proceeding at a rapid pace. One of the side effects of urbanization is the deterioration of air quality in cities, which invariably leads to an increase in morbidity and a reduction in the life expectancy of the population. As you know, the main causes of air pollution in cities are transport emissions, which account for approximately 70%, emissions from industrial enterprises (approximately 20%), emissions from thermal power plants, decay products of garbage dumps, dust, etc. Outdated transport routes and interchanges, an increase in personal and commercial vehicles in cities lead to "traffic jams", which lead to a sharp concentration of emissions. One of the ways to solve the problem of reducing transport emissions in cities has traditionally been the expansion of the network of electric public transport. To this end, the authorities are stimulating a reduction in the use of personal vehicles, actively replacing buses with internal combustion engines with electric buses, and expanding the network of trolleybus and tram routes. Electric public transport is characterized by zero emissions, due to which it is the only acceptable for the transportation of the population in the struggle for clean air in cities.

The high cost of electric buses and their infrastructure brought to the fore the traditional public transport for cities in the world - trams and trolleybuses. The study showed that for Russian cities, the problems boil down to replacing outdated and unsafe rolling stock of trolleybuses and trams, restoring and modernizing the infrastructure for their service, and incorporating new routes into the already established transport system of cities, which is often overloaded. The analysis of foreign literature revealed problems of a different order: equipping trolleybuses and trams with security systems that allow avoiding collisions with pedestrians and collisions with other urban transport, equipping rolling stock with onboard batteries with recharging while driving, creating low-floor models of trams and trolleybuses.

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