Automated technologies of urban electric transport as the basis for ensuring the mobility of residents of a modern city

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Abstract. The article presents the advantages of using a tram for transporting passengers in a modern city over other means of transportation. These are speed, profitability, environmental friendliness, large capacity, safety. The main task is the fast, safe and mass transportation of passengers. The article presents the current problems of the tram economy of most modern cities. Both the creation of new bodies and the introduction of modern automated systems such as unmanned control systems and automatic traffic control systems (ATCS) can help solve existing problems. The influence of ATCS on driving time is studied on the example of a designed tram line on the section of Dzerzhinsky Avenue from the Birch Grove stop platform to the intersection of Dzerzhinsky Ave. with Trikotazhnaya Street in Novosibirsk. When writing abstracts, articles of authors on this topic from Italy, England, Belgium, China and others were used and analyzed. They offer some solutions to existing problems in the most modern ways and technical solutions. ATCS is already tested and begins to be used in real conditions.

1. Introduction

In modern megacities in the 21st century, the problem of mobility of citizens makes very serious demands on the development of urban transport infrastructure. It is often impossible to reach remote areas of the city by public transport, it either does not exist, or the intervals of existing vehicles do not satisfy the desired speed. Personal transportation or an individual taxi is not affordable for everyone.

The task posed by a rational transport system consisting of buses, trolleybuses, trams, taxis and, for the largest cities, the metro is to transport a large volume of passengers from one part of the city to another as quickly and cheaply as possible [1, 2].

Urban planning structure changes in the process of evolution of transport systems. If in the past the cities had a clear centralization of jobs, today production, offices, transport and logistics centers are located in suburban areas due to the low cost of construction and rent, and the same thing happens with the construction of new housing. Therefore, modern cities are moving to a polycentric structure. Transport systems must adapt to a changing structure.

Another important task is the maximum automation and tracking of technological processes that occur during the transportation of passengers, and after analysis of the information received. This will allow abandoning human labor (conductors, drivers) and exclude the human error factor in emergency situations. The rolling stock includes terminals for contactless fare payment, webcams, Wi-Fi routers, navigators. Unmanned electric vehicle control systems are also being developed and tested, and smart traffic lights that provide benefits to public transport are installed to avoid congestion on complex sections of the road network.
2. Survey on the problem

2.1. Advantages of the tram over other vehicles for movement in cities

The tram is able to provide mass and speedy transportation of passengers to the busiest destinations. Therefore, this particular type of urban passenger transport is able to solve the transport problem of modern cities in the highest quality. Consequently, it will unload the existing flows of rail vehicles. The solution to the transport problem without a tram for a large city is problematic.

The carrying capacity of the tram can reach 20-25 thousand passengers per hour. The capacity of one car varies from 150 to 350-700 passengers. The possibility of coupling cars allows increasing this value by a factor. Tram capacity can be compared with the capacity of 2-3 buses (trolleybuses) and up to 100 cars.

When isolated from traffic, the tram has advantages in terms of speed. The speed of the tram is 21-30 km / h, under certain conditions this value can reach 45 km / h [3].

Efficiency is a special advantage of the tram. Operating costs are less than trolleybuses, the use of electricity is cheaper than the fuel of buses, and the construction of rail tracks is much cheaper than the construction of the subway.

Modern wagons, together with new ways when moving, do not create noise [4]. This makes it possible to create tram and pedestrian tourist streets where there is no noise and emissions, but the possibility of fast movement remains.

2.2. Current state of the transport infrastructure of most modern cities in Russia

The current state of the urban transport infrastructure is the result of the peculiarities of its formation, which occurred under the influence of natural-geographical, territorial, economic and planning-urban factors and conditions.

The current state of the network of tram lines, the level of their equipment, in many respects does not correspond to urban planning requirements and traffic safety requirements. Not all tram lines have dedicated lanes for traffic, so motor vehicle flows often impede the movement of trams.

The main problems associated with the use of trams in the built-up areas of cities are:

- placement of tram lines on a significant part of city streets (in many cases in the middle of their carriageway) in violation of regulatory requirements for the allocation and arrangement of tram lanes separated from other modes of transport, as a result of which, in the event of a technical malfunction of the rolling stock or accident, traffic and the transportation process are blocked at passengers stops;
- lack of a sufficient number of equipped stopping points that would satisfy the conditions of accessibility and safety;
- lack of access to public transport for people with limited mobility;
- placement of final and intermediate rings of tram routes on valuable land plots.

In this regard, a phased modernization of the city tram system is required, including through appropriate measures to reconstruct part of the tram lines in the built-up areas of the cities, taking into account the optimization of tram routes, the construction of new tram lines that meet modern urban planning, technical requirements and the development of tram track infrastructure.

2.3. Rolling stock in Russia

In the field of rolling stock in Russia, active improvement began to take place in preparation for the 2018 World Cup. To ensure stable passenger traffic, several modern models of tram cars equipped with automated systems were proposed. The discussed tram models are shown on figure 1.

Special attention is given to the prototype of the Russia One (R1) tram created at Uraltransmash in Yekaterinburg. He was presented at the INNOPROM exhibition in 2014.
Tram developers compare it with a crystal - a gem in the frame. The tram is equipped with video surveillance systems, GLONASS, GPS, Wi-Fi. Orders for this tram immediately came from Russia, Morocco, the UAE. The cost of one tram is about 50 million rubles.

At the INNOPROM-2015, the Vityaz tram was presented, the main advantage of which is 100% low floor and long length - 27.4 meters. To date, this tram is operated in Moscow, St. Petersburg, Krasnodar. The cost of one tram is about 100 million rubles.

The evaluation and improvement of tram capabilities is actively taking place in Asian countries. In October 2017, a trackless tram was launched along the streets of Zhuzhou in the Chinese province of Hunan, which moved along virtual lines.

This development belongs to the Chinese CRRC Corporation Limited. The “smart” tram is capable of accelerating to 70 km/h, has a capacity of 300 passengers, the track width required for movement is 3.75 m.

According to the developers, the construction of such a transport system is much cheaper than the traditional one. The construction of 1 km of track is estimated at 50-100 million yuan, which is 2 times cheaper than conventional tram tracks.

3. Implementation of transport automation

3.1. Wireless technologies in trams

The tasks set by the developers of modern technologies for transport correspond to current problems.

The main task is to reduce the time of correspondence. Specialists from France, Germany, USA, Japan, Russia and other countries are working on this problem [5, 6]. In cases where it is impossible to ensure complete isolation, and the traffic situation does not allow satisfying the desired time of correspondence, automatic traffic control systems can come to the rescue. The wireless technologies and Wi-Fi in particular is an appropriate technological basement for this solution.

Currently, the Wi-Fi network is popular. It can be installed on any transport. The router communicates with the base station, and the signal is sent to the identification platform. A more detailed diagram is shown in Figure 2. In Saint Petersburg, Enterprise-level Wi-Fi routers are used for connection. This router is powered by 220, 48 and 12 V, so they are easily integrated into transport.
At the same time, the technologies of unmanned transport are developing [9]. In 2020–2022, Moscow may see a fully unmanned tram. The tests took place in 2019 and showed that the system copes with the tasks set. The tram control system recognizes vehicles, traffic lights, pedestrians, stops, arrows, and other obstacles, including stopping in front of them and resuming traffic after the obstacle disappears. Sensors are up to 20 video cameras and up to 10 radars. In the future, it is planned to introduce unmanned rolling stock on metro trains, test the system on buses and electric buses.

3.2. Traffic control system

The greatest safety for passengers can be achieved with the maximum isolation of transport systems, the transition to unmanned control systems and automation of other technological processes, which will eliminate the human factor in emergency situations.

ATCS is a system that consists of many components, both software and hardware. In real time, traffic information is collected and analyzed.

The main tasks of ATCS:

- Forecasting and traffic management;
- Information transfer to the operator at the checkpoint and simultaneous downloading of this data to remote servers or cloud storages;
- The automatic traffic light control system, also included with ATCS, reduces the waiting time for the enable signal and increases the throughput of the road section. The system automatically controls the duration of one phase of the traffic light or the entire cycle using a transport detector. According to existing algorithms, based on the traffic situation at the moment, the system itself changes the traffic light conditions and thereby improves traffic.

At the traffic control center are employees responsible for managing the ATCS and the state of its components. For quick response to emergency situations in such points police stations, the Ministry of Emergencies, repair crews are often located.

As a proof of the viability of this system, a study was made of the time taken by a tram to move along a section of a designed tram line on the section of Dzerzhinsky Ave. from the station Berezovaya roshcha to the intersection of Dzerzhinsky Ave. with Trikotazhnaya St. in Novosibirsk. There are three intersections with adjacent streets on the site (Krasina St., Koroleva St., Industrialnaya St.).

The source data are:

- The total length of the plot is 2,258 m;
- Projected speed of movement - \( v = 30 \, \text{km} / \text{h} \);
- The number of stopping platforms - 5 units;
- Stop Time - \( t_{\text{stop}} = 40 \, \text{s} \);

The capacity of the first intersection and haul is determined by the formulas

Figure 2. Mobile Wi-Fi network connection diagram
\[ N_{\text{crossroads}} = N_{\text{driving}} \cdot \frac{t_g - t_c}{t_{ac}} \]

where \( N_{\text{driving}} \) is the capacity of the stage;
\( t_g \) - time of the green traffic light;
\( t_c \) - traffic light cycle time;
\( t_{ac} \) - acceleration time (12 s).

\[ N_{\text{driving}} = \kappa \cdot \frac{3600 \cdot V}{L_s} \]

where \( \kappa \) is the band coefficient (1);
\( L_s \) - safety distance (120 m).

\[ N_{\text{driving}} = 1 \cdot \frac{3600 \cdot 8.3}{12} = 250 \text{ tram/hour}. \]
\[ N_{\text{crossroads}} = 250 \cdot \frac{34 - 12}{100} = 55 \text{ tram/hour}. \]

Driving time:
\[ t_1 = \frac{S}{V} + t_{\text{stop}} = \frac{785}{8.33} + 2 \cdot 40 = 2.9 \text{ minutes}. \]

When using ATCS, it was assumed that when a tram approaches the intersection of carriageways, a green traffic signal lights up for it, thereby reducing travel time.

The results of the calculation of other intersections of carriageways are shown in table 1.

| Intersection | Driving length, m | Driving capacity, tram/hour | Intersection capacity, tram/hour | Quantity of stops, units | Time without using ATCS, min | Time using ATCS, min |
|--------------|-------------------|-----------------------------|---------------------------------|--------------------------|-----------------------------|---------------------|
| «Berezovaya roshcha » - Krasina St. | 785 | 250 | - | 2 | 2.9 | 2.9 |
| Krasina St. - Koroleva St. | 544 | 250 | 55 | 1 | 2.75 | 1.75 |
| Koroleva St. - Industrialnaya St. | 355 | 250 | 132 | - | 1.2 | 0.72 |
| Industrialnaya St. – Trikotazhnaya St. | 574 | 250 | 83 | 2 | 3.13 | 2.48 |

The total time to move around the site was reduced from 9.48 minutes to 7.85 minutes, which indicates the effectiveness of the use of ATCS. However, at the intersection of major highways, such technology can not be used, and the movement of the tram must be organized in accordance with the general flow.

4. Conclusion
Having examined the trends in the development of transport needs of modern cities and the development of transport systems, we can conclude that the emphasis is placed on tram services. Properly organized infrastructure, the complete isolation of tram tracks will increase the speed of communication, increase passenger flow due to the greater capacity of the rolling stock. In order to improve tram services in modern cities, first of all it is necessary to replace existing obsolete tram models with new ones, repair and restoration of rail tracks, build new lines and introduce modern technologies such as ATCS, which will reduce the time of correspondence by 20% or more. Based on existing passenger flow indicators, the tram is popular. Improving the system will increase this figure and provide the greatest comfort for passengers. In order for the tram to become a modern form of urban public transport, it is necessary to modernize the
infrastructure of existing lines to ensure priority tram travel on the street-road network, as well as the infrastructure of stopping points.

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