Optimizing the route network of the city

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Abstract. Improving the quality of passenger service by public transport is a priority in major cities of the Russian Federation. One of the important indicators of the quality of transport services in passenger transport is the regularity of transportation, which, in addition to the planned traffic intervals, also depends on factors related to the conditions of public transport in the settlement (the intensity and composition of the traffic flow, the structure of passenger traffic, the mode of traffic lights, atmospheric conditions). The article analyzes the regularity of urban public passenger transport in the conditions of the city of Ryazan, by studying the intervals of arrival of vehicles at stops along a given route. According to the results of the study, serious problems were identified in the existing route network, and measures were outlined to eliminate shortcomings in the operation of urban transport by optimizing the city route network.

1. Introduction

The vast majority of the population of Russia (more than 74%) lives in cities, and this percentage is growing steadily. Cities are increasing in size and territory. Migration to cities is caused by better working conditions, as well as material motives associated with high wages, and the fact that cities provide more opportunities for education, spiritual and cultural development, etc. The growth of the urban population has led to serious difficulties in traffic and speed, including public transport, as well as parking difficulties [1]. Transport problems experienced by many cities in our country are similar to those faced by European countries at the beginning of mass motorization:

- the population buys cars at an accelerated pace;
- slower public transportation makes even more people buy cars;
- uncontrolled parking;
- disregard of pedestrians.

All this leads to a deterioration in the quality of life in cities. The speed of movement is significantly reduced, causing frequent congestion and traffic accidents, making it difficult for both individual vehicles and vehicles serving urban public passenger transport lines (UPPT). One of the most important conditions for the quality service of passengers is safety and regularity of movement, as well as a significant improvement in the reliability of the transport process [2].

2. Analysis of the existing urban route network of the city

According to a detailed study of traffic in the city of Ryazan, the distribution by mode of transport in the city is shown in Figure 1.
UPPT is one of the most important branches of the city’s life support. The quality of life of the population, Ryazan’s economy and the possibility of using its urban planning and socio-economic potential depend on it. The location of the places of generation / absorption of passenger flows forms the demand for traffic, its volumes and directions. There is a functional separation of correspondence depending on the purpose of generating and absorbing objects. The classic daily flow pattern contains two peak periods: morning and evening. As a rule, during these periods the vast majority of workers (Home-Work, Work-Home) and educational (Home-Study, Study-Home) correspondence are realized. The most pronounced locations of passenger-forming stopping points are presented mainly in the central part of the city in the directions of Moskovskoye Highway, Pervomaiskiy Prospect, Dzerzhinskiy Str. and Gagarin Str. Microdistricts of Dashkovo-Pesochnya, Semchino, Nedostoevo and Priokskiy should be distinguished separately as the main passenger-generating transport areas.

For this study, 10 busiest UPPT stops in Ryazan were selected (Figure 2). The main highways of the radial and latitudinal directions of the city of Ryazan are (Kuibyshevskoye Highway - Tsiolkovskiy Str., Novaya Str. and Kasimovskoye Highway, Moskovskoye Highway, Kashirina Str., Chernovitskaya Str. - Gagarin Str., Lenin Str., Pervomaiskiy Prospect, Mikhailovskoye Highway, Tsiolkovskiy Str., Griboedov Str., Yesenin Str., Northern District Road), which ensure the
interconnection of all functional areas: residential, industrial, social centers and access to external destinations. Significant flows of passenger and freight transport are concentrated in these streets, which then inevitably fall into the central part of the city, where they are redistributed. This is a clear sign that the city’s transport system is malfunctioning. The idea that the congestion problem can be solved by further expanding the road network has always had its supporters, but it requires serious investments and, ultimately, will make the city less comfortable for life [3,4].

Figure 2. Passenger traffic at stopping points.

One of the measures to reduce the travel of cars is to increase the attractiveness of public transport and to take measures to stimulate its use. In this sense, research in the field of maintaining and improving the quality of passenger transport services is important to support the processes of increasing the use of public transport. Assessment of the regularity of UPPT is an important condition for improving operational transport management.

Improving the quality of passenger transportation can be understood as a set of measures aimed at reducing the travel time of passengers and improving the convenience of their movement. One of the main criteria for the quality of transport services is the total travel time of the passenger from the point of departure to destination. These criteria, directly or indirectly, include such characteristics as communication speed, getting on / off the vehicle, moving in the vehicle and walking to the initial boarding and destination [5,6].

Ensuring the quality of passenger transportation today is one of the highest priorities in servicing the population. Various authors [7] consider the quality of urban passenger transport, highlighting a number of criteria: passenger travel time; regularity of movement along routes; fill factor of rolling stock; traffic accidents. The following indicators for assessing the quality of trips are decisive: reliability, convenience, safety, politeness, availability, understanding, sociability.

Many authors propose measuring and evaluating the quality indicator, as well as minimizing the gaps between the planned and actual quality indicators. The intensification of the transport process of the UPPT service depends on the use of a complex of factors affecting the travel time, travel comfort, reliability of service and traffic safety, as well as transportation costs in cash. As a criterion for the quality of transport services, the regularity of vehicles is used, which affects the waiting time of passengers at stops.

The location of passenger-forming stopping points in the current environment of functioning of public transport determined the number of routes serving passenger-generating transport areas [8].
It is quite natural that the main concentration of routes per stop falls on the same location as passenger-generating stops, namely stops in directions of Moskovskoye Highway, Pervomaiskiy Prospect, Dzerzhinskiy Str., Gagarin Str. and micro districts of Dashkovo-Pesochnya, Semchino, Nedostoevo, Priokskiy.

The map (Figure 3) presents information in the context of the number of routes serving each stopping point.

3. Analysis of the problems of urban public transport

Analysis of the state of regular bus transport on municipal routes in the city of Ryazan shows that the existing route network of the city has accumulated a number of problems that require some solution.

**Route network:**
- There is a high proportion of route network duplication, leading to inefficient use of the road network, the concentration of a large number of vehicles in one direction and a decrease in transportation safety;
- The spontaneity and non-optimality of the historically developed city public transport exist;
- There is significant growth in unregulated tariff routes;
- A uniform fare system is absent;
- Popularization of personal vehicles (high level of motorization of Ryazan residents: over 360 units of vehicles per 1,000 inhabitants);
- Most of the end points of the routes do not have equipped places for inter-trip terminus, which in turn negatively affects transport safety and the environmental situation [9,10].

**Rolling stock:**
- Poor technical condition of the vehicle fleet;
- The dominance of small buses on the city route network, incompatibility with actual passenger flows;
- Low environmental class vehicles;
- The predominant work of high-floor rolling stock, which creates difficulties in landing and transportation of elderly people and people with disabilities [11].

**Carriers.** Reduction of passenger flows on municipal bus and trolleybus routes, which leads to a significant loss of revenue, a deterioration in the financial condition of the municipal unitary enterprise and an increase in the budget load.
Walking distance. Analysis of the walking accessibility of stopping points showed that all stops located in the city are located in a 5-minute walking distance, which corresponds to the standards of remoteness of 500 meters from residential areas. The city will not need additional stopping points in the medium term, because existing infrastructure is sufficient.

Affordability. The current fare for a one-time transfer (23 rubles) is in the upper price range compared with the tariffs in cities that are comparable in terms of population. Despite this, this tariff restrains development and prevents the attraction of long-term investments in the industry (for example, targeted purchase of vehicles with a low floor location). It is advisable to consider the possibility of a revolving tariff increase in the short-term both with the aim of reducing the budget load and creating conditions for the development of RSR (rolling stock renewal, introduction of electronic payment systems, unified traffic control service).

Accessibility for people with limited mobility. Current urban transport provides practically no ability for low-mobility groups to move. The entire city accounts for only 16 units of large-class buses with a low floor level. It is necessary in the medium term to bring the rolling stock with low floor onto the routes and these can be both medium and large class buses and trolleybuses.

Route network duplication. Almost all municipal routes operating with a regulated tariff are duplicated by commercial (unregulated tariff) by more than 60%. As a rule, there are 2 commercial routes duplicating 1 social route. Routes operating outside the regulated tariff also duplicate each other not only on the main city highways, but also within the boundaries of urban areas (micro districts). Total duplication reduces the overall economic efficiency of the route network, leads to irrational use of vehicles and excessive load on the road network. To do this, it is necessary to develop an improved (optimal) version of the route network of urban public transport in Ryazan, providing for the optimal construction of routes taking into account passenger traffic and the optimal share of duplication on average throughout the network [12].

Efficient use of the vehicle capacity. The coefficient of utilization of the bus capacity is an indicator of the optimal occupancy of the passenger compartment of the bus in terms of comfort and economic efficiency. If the coefficient value is below 0.53, it indicates that the route is either not claimed (low passenger flow), or there is an oversupply of vehicles involved in the transportation of passengers. If the indicator exceeds 1, it means that the number of cars serving the route is not enough. With rare exceptions, exceeding the indicator above 1 can mean a high turnover of the vehicle cabin on the hauls between stopping points.

Based on the data from a comprehensive study of passenger flows:
- only 20 routes are within acceptable capacity utilization;
- 27 routes have a clear lack of the rolling stock and insignificant passenger traffic per 1 vehicle.
- 25 routes have a shortage of the rolling stock, when passenger flows exceed the rated carrying capacity of the vehicle.

For efficient use, it is necessary to form an optimal route network, built according to the balanced parameters of the optimal vehicle capacity, traffic intervals and the number of the vehicles in connection with passenger flows. Traffic regularity (intervals) is a key parameter of the public transport performance. Actual traffic intervals on routes where small-class vehicles operate on average throughout the network is 13 minutes, for the middle class it is 25 minutes and for the large class it is 54 minutes. The total average interval value for all types of capacity is currently 42 minutes.

Taking into account the fact that about 76% of the urban rolling stock falls on small-class vehicles. Given the minimum traffic intervals and a high degree of network duplication, the main share of daily passenger traffic (71%) is transported by small-class vehicles. The high concentration of small-class vehicles on city routes will never contribute to the emergence of high-capacity buses, especially to vehicles with a low floor location (more expensive vehicles compared to low-cost analogs of a small class).

Therefore, priority should be given to vehicles of mainly the middle and large classes, which provide for the possibility of transporting people with limited mobility. Buses of this type should work on the main busy city highways, while the average traffic interval (throughout the network) for middle-
class buses should not exceed 15 minutes and not more than 25 minutes for a large class (both buses and trolleybuses are taken into account). Small-class buses should be assigned the role of transporting to the main highways, while their average traffic interval should be in the range of 11-15 minutes [13].

4. Prerequisites for optimizing the urban route network

Optimization goals:
1. Improving the quality of public transport services and the safety of passenger traffic;
2. Meeting the needs of the city population in passenger traffic;
3. Reducing travel time in urban passenger public transport;
4. Reducing excessive duplication of the route network, excessive amount of the worn-out rolling stock, reducing the load on the urban street-road network;
5. Improving transport and environmental safety;
6. Maintaining the most popular routes, providing a convenient transition to a new route network.

The main task of optimizing the city route network is to integrate all types of public transport into a single synchronized network [14].

The main load for the carriage of passengers should be distributed on the so-called basic (main) route network connecting passenger-loaded transport micro districts. These are trunk routes connecting several districts of the city and providing mainly direct traffic between the points of passengers' attraction.

The coverage density of the core (main) route network should cover all city highways with the rolling stock of medium and large capacity to ensure the maximum transfer of passengers at rush hour. At the same time, minibuses are assigned the role of an auxiliary (pick-up) network to the main city highways.

When forming an optimized route network, the pendulum intraday migration of the population was primarily taken into account. When optimizing the route network, the operating mode of bus transport changes. Electric transport, by virtue of its link to utilities, is involved as a major participant in the implementation of transport work. The diagram below also shows some of the key parameters when designing an optimized network (Figure 4) [15].

![Figure 4. Initial route network simulation parameters.](image-url)
5. Conclusion

Based on the analysis of passenger flow survey data for the entire city route network of the city of Ryazan, including the routes of municipal buses, trolleybuses and route taxis (buses operating at unregulated tariffs), it seems possible to confirm working hypotheses about the need to optimize the existing route city public transport network.

The data confirm the fact that the route network is overloaded with an excessive amount of low-capacity buses operating on commercial routes (unregulated tariff), inefficient use of vehicle capacity, redistribution coefficients of passenger flows and almost full duplication of social municipal routes with a commercial network (unregulated tariff).

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