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Optimization of City Passenger Transport Routes in the Regional Centers of Russia

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Abstract: The study is devoted to optimization of the route net of the public passenger transport. The researcher analyze the state transportation system in the Russian Federation and elicit common problems in the organization of public transport in regional centers. The study presents the scientific and methodological approaches allowing routes optimization based on minimizing the time which passengers spend on movement. The results of the research were implemented to the public passenger transport routes in Orel.

Key words: Route transport net, route, stopping point, route vehicle, passenger

INTRODUCTION

Many regional centers in Russia are facing the problem of optimal planning of city passenger transport routes. Currently, the city passenger transport is the main means of transport for the majority of the urban population, so finding an optimal variant of the route network for the regional centre is one of the most important strategic objectives. Over the decades, energy crisis is one of the most important concerns of human societies. This happens under conditions that consumption of fossil energy and the climatic pollutions and changes caused by it has been changed into a problem that buildings can be considered as one of the most effective factors in accelerating this issue (Ghasemi, 2017; Korchagin *et al*., 2016).

The issues of increasing the efficiency of the city passenger transport system functioning are reflected in the works of the leading Russian and foreign scientists: C. Brand, G.A. Currie, D. Habarda, K.R. Jacques, H.S. Levinson, L.B. Mirotin, A.V. Velmozhin, M.E. Antoshvili, B.L. Geronimus and others. The problems of the urban passenger transportation quality are stated in the works by J. Cibulka, V.A. Gudkov, I.V. Spirin (Novikov *et al*., 2012; Korchagin *et al*., 2016a, b; Novikov *et al*., 2015a, b).

The purpose of writing this study is to improve the scientific and methodological approaches in the field of optimization of the passenger transport route net in the regional centers. To achieve this goal, the following tasks were set and solved: to analyze the state of urban passenger transport in Russia.

To develop a step-by-step technological scheme of the transport process for the urban passenger transport, taking account of passenger's time expenditure; to work out scientific and methodological approaches that can help to find an optimal variant of the city passenger transport route net in regional centers which is based on minimizing passenger's time expenditure.

To test the developed scientific and methodological approaches to the passenger transport route net in Orel. To determine the economic effect of the transition to the optimal municipal passenger transport route net.

MATERIALS AND METHODS

The condition of the urban passenger transport system in Russia: Passenger transport in the Russian Federation belongs to the basic elements of public services and it has significant socio-economic importance which is reflected in the effectiveness of functioning of city enterprises and organizations. The share of the urban passenger transport accounts for 80-85% of the total number of all passenger's transportations in the country which is >45 million people a day (Novikov *et al*., 2015, 2013a-c; Tahmassebpour, 2016a). In this regard, the efficient development of the passenger traffic sector is of great social and economic importance for Russia.

The most common means of urban passenger transport in Russia are automobile means of transport which are represented by taxis and buses. Currently, passenger taxi service is available in 2195 localities of Russia and regular bus routes function in 1620 localities. Trolleybuses are less common (88 localities), so are trams (62 localities). There are subway lines in 7 Russian cities (Novikov *et al*., 2011, 2013; Seyedhosseini *et al*., 2016).

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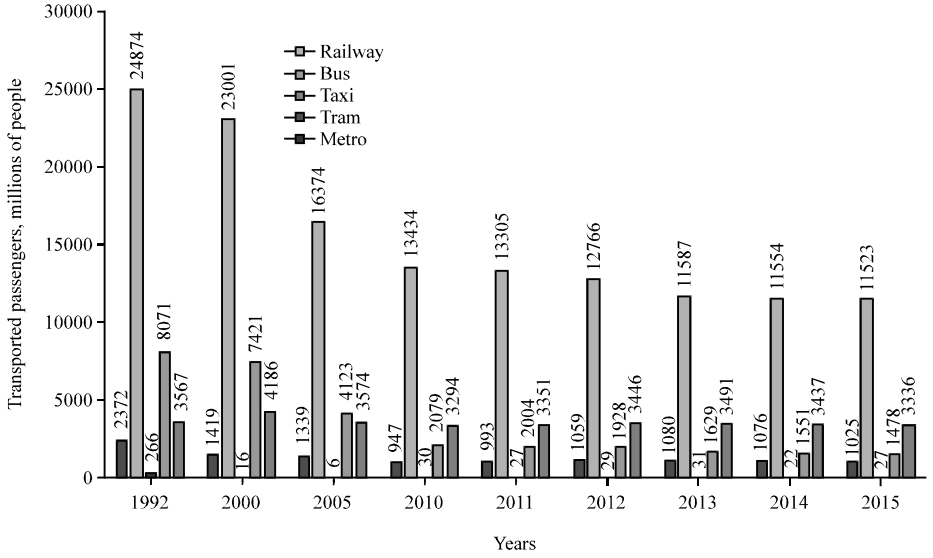

Fig. 1: The dynamics of the number of passenger transportations according to the means of transport in the Russian Federation

The tendencies which are observed currently in the field of passenger's transportation, indicate that the demand for this type of service is reducing each year (Fig. 1).

The main distinguishing feature of the urban passenger transport in Russia is that it is explicitly unattractive for the population. A number of common problems which are typical of the majority of the regional centers are the reason for this. An outdated moving vehicle is one of the decisive factors which influences the resident's preference to choose an individual transport but not a passenger one. The only limiting factor is the level of the population's income as the passenger transport is largely used by the citizens who are unable to purchase their own car for financial reasons. Another important factor which reduces the attractiveness of public transpor is its inefficient organization. In many regional centers of Russia, the route network does not meet the population's real needs for transportation services. Routes, for the most part have a historically formed character the city expansion and the emergence of new neighborhoods are not taken into account and this reduces the quality of transport services. Municipal budgets of the regional centers are not able to support the route transportation network which consists entirely of municipal carriers, so in majority of cities the mixed system which is characterized by the involvement of the private carriers is dominating. This fact stimulates the emergence of a number of negative consequences: as a result of competition between transport operators "in the struggle for passengers" the intervals of movement are not kept and the traffic regulations are violated. The moving vehicle of private carriers, for the most part, consists of fast-payback buses of small capacity category which increases the number of route vehicles and leads to additional load on the transport network in the regional centres.

The decline in demand and in quality indicators in the urban passenger transport of the regional centers in Russia is a serious problem which requires new scientific approaches to optimize the work of the route transportation network for the city passenger transport.

RESULTS AND DISCUSSION

Scientific and methodical approaches to optimization of the passenger transport route network in regional centres: Optimizing the route of transportation network of the city passenger transport was most efficiently carried out on the basis of total passenger's time expenses on the entire process of movement that can be represented in the form of the technological scheme (Fig. 2) (Eshutkin and Kulev, 2009; Tahmassebpour, 2016b; Novikov *et al*., 2011).

Passenger's time costs, when they use public transport include the time that is spent on approaching a stopping point, waiting for a vehicle, transferring from route to route and moving from the final stopping point to the destination (Novikov *et al*., 2011; Rassokha, 2010):

$$t_{passenger} = t_{appr} + t_{wait} + t_{move} + t_{change} + t_{depart} \quad (1)$$

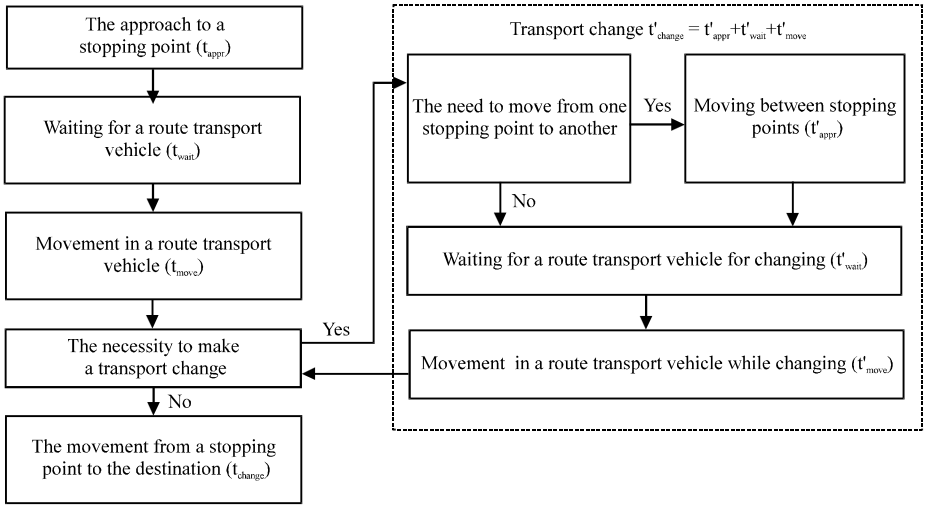

Fig. 2: The step-by-step technological scheme of the transport process in the urban passenger transport on the basis of passenger's time costs

Where:

t_{appr} = The time that a passenger spends on approaching a standing point (h)

t_{wait} = The time that a passenger spends on waiting for a transport vehicle (h)

t_{move} = The time that a passenger spends on moving in a vehicle (h)

t_{depart} = The time that a passenger spends on moving from the final stopping point to the destination (h)

t_{change} = The time that a passenger spends on transferring from route to route (h)

The time costs of transferring from route to route is the total time costs: moving between stopping points, waiting for a route means of transport, respectively and the trip itself (Novikov *et al*., 2012, 2013):

$$t_{change} = t'_{appr} + t'_{wait} + t'_{move} \quad (2)$$

Where:

t'_{appr} = The time that a passenger spends on moving between stopping points for transferring from route to route (h)

t'_{wait} = The time that a passenger spends on waiting for a transport vehicle to change (h)

t'_{move} = The time that a passenger spends on moving in a vehicle while changing (h)

The objective function to optimize the routing of the transport network is the total time costs for the entire transport process for all residents in the regional center (Tryastsin, 2013; Tryastsin *et al*., 2012):

$$E = \sum_{i=1}^{m}\sum_{j=1}^{m}(t_{move_{ij}} + t'_{move_{ij}})\cdot P_{ij} + \sum_{k=1}^{K}(t_{wait_k} + t'_{wait_k})\cdot P_k + \sum_{i_1=1}^{m_1}\sum_{i_2=1}^{m_1}(t'_{appri_1 i_2}\cdot P_{i_1 i_2} + P_{i_1}\cdot t_{appri_1} + P_{i_2}\cdot t_{departi_2}) \rightarrow \min \quad (3)$$

Where:

$i = 1, 2, ..., m$ = The micro-districts of the regional centre from which the passenger's movement starts (centers of the origin of the passenger traffic)

$j = 1, 2, ..., m$ = The micro-districts of the regional centre where the passenger's movement ends (centers of passenger's attraction)

$k = 1, 2, ..., K$ = Public passenger transport routes

$i_1 = 1, 2, ..., m_1$ = The stopping points from which the passenger's movement starts

$i_2 = 1, 2, ..., m_1$ = The stopping points where the passenger's movement ends

P_{ij} = The total number of passenger's trips between the micro-districts of the regional centre i and j

P_k = The total number of passengers who used the k route for a trip

P_{i1} = The total number of passengers who used the l initial stopping point

P_{i2} = The total number of passengers who used the r final stopping point

P_{i1i2} = The total number of passengers who made a transition between the l to r stopping points to transfer from route to route

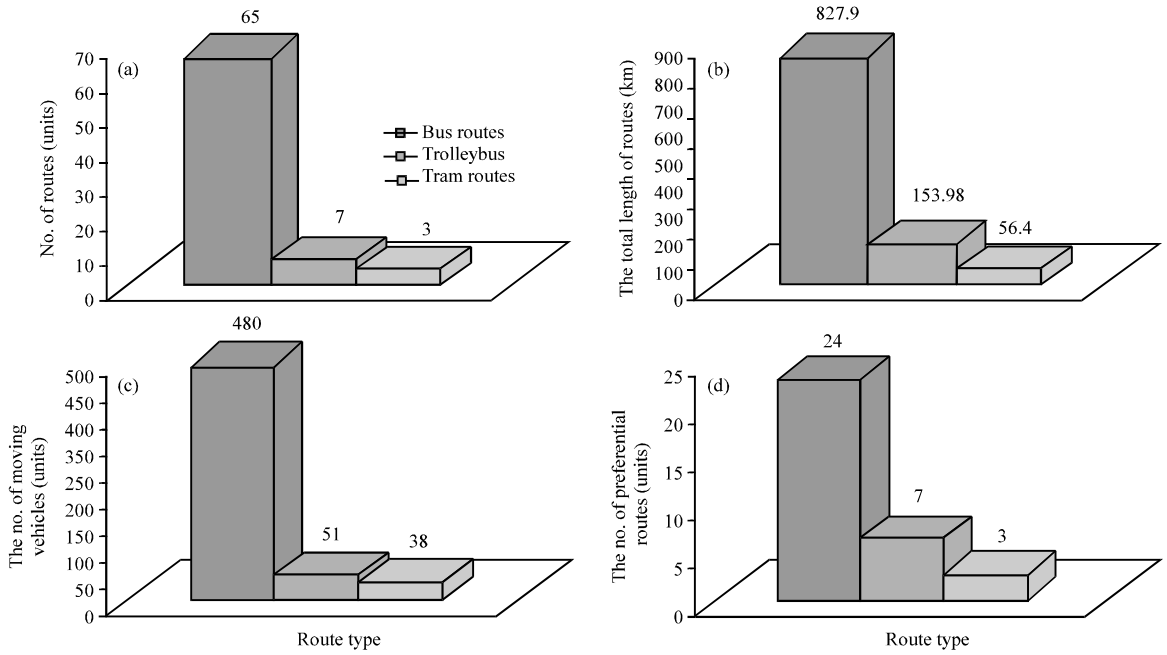

Fig. 3: Indicators of the optimized route transport network: a) The distribution of the number of routes according to route types; b) The distribution of the total length of routes according to route types; c) The distribution of the number of vehicles according to route types and d) The distribution of the number of preferential routes according to route types

The process of optimizing the route of transportation network in the regional center is characterized by the imposition of some restrictions which are related to the interests of passengers, transport operators and the administration of the municipality. These are the main requirements for the public transport route network for the administration municipality: the full population's satisfaction in passenger transport, trouble-free work of vehicles on routes, the decrease in the environmental damage from transportation, high level of safety for passenger's transportation, compliance with all regulatory requirements for passenger's transportation. Reducing operation costs and getting a maximal profit are the main requirements to the organization of work on public transport routes for transport operators. The following requirements should satisfy passengers: the minimum fare the maximum speed of communication, a high level of comfort, adherence to schedules and safety of the transport process.

Finding the optimal option of the route transport network is at the junction of the interests of these participants in the transport process.

Testing of the developed scientific and methodological approaches to the route transport network in Orel: The approbation of the scientific-methodical approaches was carried out on the route network of passenger transport in Orel. The main indicators of the passenger transport system in the city are presented in Table 1 (Rassokha, 2010; Novikov *et al*., 2012).

Table 1: Indicators of the passenger transport system in Orel

Means of passenger transport	The number of routes	The number of route vehicles
Bus	69	574
Trolley-bus	9	100
Tram	3	92

Initial information for optimizing the route transportation network in Orel was obtained from the surveys of the passenger flows. The study of the population's transport mobility was carried out in three stages the entire inspection of passenger flows of the public transport route network in Ore, 2011 (Novikov *et al*., 2011, 2013) (Fig. 3).

The partial inspection of passenger flows at the seasonal garden and suburban routes, 2013 (Korchagin *et al*., 2016). The partial inspection of passenger flows in micro-districts (Novikov *et al*., 2015).

In the result of passenger surveys, we obtained data on the population's mobility in Orel which were used for

the optimization of the passenger transport route network: interdistrict trips of different passenger categories, the passenger traffic on the routes, stopping points, hauls the vehicle filling ratio, movement interval compliance, passenger's preferences for vehicle choice, the number of performed changes and others. Technical and operating indicators for passenger routes before and after optimization helped to determine the effectiveness of these solutions. Optimization of public transport routes in Orel reduced the population's total time costs on moving from 286000-269000 h per day. Operating costs consist of (Seyedhosseini *et al*., 2016): reducing the number of moving vehicles, reducing the demand for fuels and lubricants, reducing the wear of components and parts of the vehicle and others.

The value of the total mileage of route vehicles at the initial route network in Orel for one working day "rush hour" is equal to 54363.64 km (Novikov *et al*., 2011). As a result of optimization, the value of the total mileage of route vehicles is equal to 48522.5 km, provided the same transport work is fulfilled for the same "rush hour" (Novikov *et al*., 2011).

The economic effect of implementing the optimized route network of public transport is 98651.35 rubles in a rush hour on weekdays in case the number of carried passengers remains the same (Rassokha, 2010). These values of efficiency indicators were achieved by the rational use of vehicles on routes in accordance with passenger's demand for transportation services.

In the course of optimization of the public transport route network in Orel, the total number of routes was reduced by 4 units without loss in the service quality. Here with, the number of tram and trolley bus routes remained unchanged. The total number of route vehicles was reduced due to the replacement of the vehicles of particular small capacity class to the vehicles of small and medium class (Fig. 3).

CONCLUSION

The proposed scientific and methodological approach of optimization of the passenger transport route network allows to determine the most effective regional centre routes which are based on minimizing the passenger's time costs on movement. The possibility of determining profitable routes allows in the optimization process to exclude unprofitable carriers routes from the registry.

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