Optimization of the structure of rolling stock of urban passenger transport

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Abstract. This article examines the problems related to the operation of urban passenger transportation system in the field of defining the structure of the rolling stock, the analysis of existing methods of identification of the number and capacity of the urban vehicles has been conducted. The paper focuses on the results of experimental research of passenger flows and roominess, volumetric capability of a variety of transport means (public transportation minibuses) in the district municipalities of the Russian Federation. Furthermore, taking into account these results, differences and variety of these vehicle makes and models, the measures and activities have been suggested, aimed at improving the methods of selection of urban passenger transport rolling stock.

1. Introduction
Current status and state of passenger transportation systems on the municipal routes can be described as a system of interaction between three parties: a customer, a consumer and a provider of services of passenger transportation. The administration of municipal unit («a city») is a customer. The consumer of services is «a passenger», and the provider of services is the municipal and individual passenger transport organization («a carrier»). Besides, each participant of the system sets a variety of individual goals and objectives (figure 1) [1, 2].

2. Material and methods
If there are individual goals and objectives, so passenger transportation system operates and functions in the context of the conflict of interests of its participants (members) [3]. The presence of conflict situations in the public transport system is closely connected with the market model (type) of urban passenger transportation. Three types of them can be singled out, such as: an administrative (monopoly) market, a regulated market and a free market [4].

The administrative market model of the passenger transportation in our country has deep roots, because it was the only possible model in the Soviet Union. Moreover, this model is characterized by a minimal number of conflict situations between the customer and the supplier of passenger transportation services, because the service provider is directly subordinate to the customer (obeys client's demands) [1]. However, there may be a conflict between consumers and service providers. The regulated market model is characterized by a strict customer's control, imposed upon the supplier, which influences the number of conflict situations between them [3]. The free market model implies a minimal customer's intrusion into the sphere of the provider's activities [3].
However, regardless of the market model of passenger transportation, adopted in this or that region of our country, all the regular municipal routes must be put up for open competitions, in which legal entities and individual entrepreneurs, who meet certain requirements, can participate.

In accordance with federal law No. 220-FS (FL) «About organizing regular carriage (transportation) of passengers and luggage by means of cars and urban electrical transport in the Russian Federation and about amendments to certain legislative acts of the Russian Federation», dated 13.07.2015, one of the demands of the competition, which the participants have to meet, is that he must have «vehicles (based on the right of ownership or other legal basis), which meet the requirements, specified in the registry route of regular carriages, and receive either a certificate of the right to perform transportation along the route of regular transportations, or a commitment to acquire these vehicles within the time frame of contest (competition) documentation» (art. 23, paragraph 1) [5]. In the context of the topic of this publication, the relevant and up-to-date issue is the identification of the type and size of rolling stock by local self-government bodies.

There are several methodologies and techniques of calculating the needs of buses, intended for municipal routes, which differ in approaches to the task. Let's take a look at some of them. So, Professor D.S. Samojlov has offered to choose rolling stock (RS) according to the following procedure: to get data, concerning passenger turnover on the transportation routes and to determine (with a help of calculation) the average roominess and volumetric capability of the RS. Graph of distribution of the transportation volume on the routes is combined with and connected to the scale of volumetric capability of the RS in such a way (manner) that the average estimated and calculated volumetric capability coincides with an average passenger flow on the route [6]. The criteria of required minimum and maximum route intervals constitute the basis. Then, taking into consideration the values of passenger flow on the route, the medium volumetric capability and the interval (the shaft), the boundaries of the passenger turnover of RS with this average estimated capacity and volumetric capability are defined. This technique is used in order to figure out the main RS type for cities with different amount of population (population rates) [7].

However, we are interested in methods of identification of the structure of the rolling stock on a particular route. In general terms, the essence and the main objective of all these methods are to identify the type of public transport, which should be applied on this route [8]. This decision is usually adopted on the basis of identification of transportation demand (identification of passenger flow is carried out by means of one of the well-known methods of passenger flows) [9]. Then, the need for rolling stock along the routes of transport network is calculated according to the criteria of equality of the transportation requests, their insurance and guarantee of providing passenger seats in rolling stock and obtaining of the defined, predetermined route intervals [10, 11].

Turning to the overall assessment of the existing methods of calculation of significant amount of buses on the routes of a city we should point out several peculiarities. All of the methods, mentioned above, are acceptable mostly for the situations, where a small number of the models and makes of rolling stock is used [12]. In modern conditions, when there are a lot of carriers of various

**Figure 1.** The diagram of interaction among the participants of the public transport system
organizational forms of ownership and different models and makes of rolling stock, the existing methods do not allow to calculate reasonably the number of required rolling stock on routes in the urban passenger transport system [13]. The feature characteristic of all these methodologies and techniques should also be noted and emphasized. The feature characteristic of all these methodologies and techniques should also be noted and emphasized. Basically, all of them are focused on the calculation of the number of the buses on the route, which possess similar and identical roominess and volumetric capability. This method is convenient for calculations according to economic and engineering reasons. In practice the situation on the municipal bus routes can differ significantly from the planned recommendations [14].

A vivid example of the application of the methodology for identification of the type and number of rolling stock regardless of differences in makes and models, as well as time fluctuations of passenger flow is route No. 2 (a railway station – a house of Soviets – Road maintenance department) of urban passenger transport network on the territory of «Klintsy, which is a district, situated on the territory of the Bryansk region».

Small class buses are widely used in accordance with the register of scheduled, regular transportations on the route, the number of rolling stock is the following: during a day-off five buses are used and six buses are applied on a weekday.

In accordance with methodological recommendations for conducting the survey and research, aimed at identification of the extent of the use of public transportation by different categories of citizens (transport mobility of citizens) [15], the study was conducted during one day-off and during one weekday.

3. Results and Discussion

In the framework of this research the dependences of passenger flow changes on time (on part of the day) on the day-off and on the weekday have been obtained (figure 2, 3).

The uneven nature of passenger exchange on the stopping points (bus stops) should also be mentioned. So, the greatest passenger exchange can be seen at the bus stop, called «The House of Soviets» (the number of passengers reaches the average rate (value), situated within the range from 75 to 115 pass/h), and the smallest is observed at the bus stops, under the title «Tank farm» (within the range from 2 to 12 pass/h).

According to the results of the study of passenger flow on route No. 2 (a railway station – a house of Soviets – Daewoo) of urban passenger transport network on the territory of «Klintsy, which is a district, situated on the territory of the Bryansk region» we have obtained average values of the application capacity (coefficient) roominess and volumetric capability of rolling stock (table 1).

![Figure 2](image_url)

**Figure 2.** The total (common) passenger flow on route No. 2 (a railway station – The House of Soviets (House of Councils, House of Representatives) – Road maintenance department) of urban passenger transport network on the territory of «Klintsy, which is a district, situated on the territory of the Bryansk region» on a day off.
Figure 3. The total (common) passenger flow on route No.2 (a railway station – The House of Soviets – Road maintenance department) of urban passenger transport network on the territory of «Klintsy, which is a district, situated on the territory of the Bryansk region» on a weekday

Table 1. Average values of the application of rolling stock volumetric capability utilization ratio on route No. 2 (a railway station – The House of Soviets – Daewoo)

| An examination day | Average values of the application of rolling stock volumetric capability utilization ratio (coefficient) |
|--------------------|--------------------------------------------------|
| A day off          | 0.186                                            |
| A weekday          | 0.174                                            |

Besides, average values of the application of rolling stock volumetric capability utilization ratio of every bus are not so significant (figure 4) not only on the day off, but also on the weekday.

Furthermore, despite fairly low average values of the application of passenger transport volumetric capability utilization ratio, maximum values are achieved during rush hours and on the busiest and congested stretches (table 2).

These experimental data, represented above, prove that the identification of the number of the buses in the process of creating the route registry has been conducted in accordance with the peak (maximum) value of passenger flow, excluding the coefficients of non-uniformity of passenger flow, as well as excluding the possibility of using the buses, which have different level of roominess and volumetric capability in the period, when the roads are not very congested and loaded.

4. Conclusions

The data, given above, indicate and emphasize the necessity of development of the refined method of choosing the buses with different levels of roominess and volumetric capability on the route in the city, taking into account the need for making quality of transport services higher and better (i.e. achieving minimum of time spent on passenger transportation, minimum travel time). This method provides us with the solutions to the following problems and tasks:
- to align demand and supply on the market of urban bus passenger services;
- to get rational result;
- to get the versatility of calculation, irrespective of the number of makes and models of rolling stock, for any urban route.
Several activities can be singled out and proposed.

1. It is preferable to use the rolling stock with the small degree and rate of volumetric capability on the routes with the large unevenness and irregularity of passenger flows at particular parts of the day, and vice versa, apply the rolling stock with the large degree of volumetric capability on the routes with even and regular passenger flow at certain hours of the day. This facilitates growth and increase of the capacity (coefficient) of roominess and volumetric capability.

2. In order to regulate the amount of places in public transport, occupied by passengers at particular hours of the day it is advisable to use two types of rolling stocks with different volumetric capability, but with close dynamic characteristics. The rolling stock with small degree and rate of volumetric capability is applied for providing transportation service during the whole period of the movement, and the rolling stock with large degree of volumetric capability is preferable during rush hours. During the load drop (fall) on the route the buses with higher level of volumetric capability can be replaced with the rolling stock with smaller volumetric capability, which are unnecessary and redundant on other routes.

Thus, despite the fact that this field has already been discussed and is being analyzed now in a number of studies, the task of making a proper choice of the buses, which would be able to improve
one of the main indicators of quality, i.e. reduction and saving of traveling time, continues to be a
great challenge and an up-to-date, relevant problem, which should be thoroughly analyzed.

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