Regional Information and Technology Aspects of Increase Quality of Passenger Transportation

O Shirokorad1, S Arkhipov1, P Volodkin2

1Far Eastern Federal University (FEFU), Engineering school, v. Ayaks, 10, Russian island, Vladivostok 690922, Russia
2Pacific National University (PNU), Transport and Energy faculty, Tikhookeanskaya st., 136, Khabarovsk 680035, Russia

E-mail: zyba250@mail.ru

Abstract. At the present stage of the formation of innovative passenger transport systems in major cities, the problem of improving the quality of passenger transport is becoming one of the key factors in the intensification of transport services. The article deals with key performance indicators (KPI’s) of improving the quality of transport services using modern information systems. The main reasons for the influence of ergonomics, speed of communication and transport infrastructure on increasing the competitiveness of passenger motor transport are singled out. In addition, one of the main directions of the study is to describe the impact of traffic quality indicators, which include comfort, accessibility, safety and information level, on the demand of passengers for public transport services. Also, the description of the information and analytical model of the program for selecting the required vehicle, taking into account passenger flows, capacity, and comfort indicators for passengers and operational performance of buses, is described. As a result of research the algorithm of work of the information program for passenger transport which can be applied by the organizations for increase of satisfaction of passengers by transport services is offered.

1. Introduction
Urban public transport plays an important role in ensuring sustainable development of cities and agglomerations, which directly affects the development of infrastructure. As the economic competencies and the transport services market develop, the requirement of consumers, including passengers, to the quality of services is increased. However, the integration of quality indicators into the stabilization system of the transport market has not yet received engineering solutions [1].

The Vladivostok transport market currently has a large number of small and medium-sized enterprises of various forms of ownership, and new types of rolling stock have appeared on city routes with different characteristics of dynamism, capacity and quality of passenger service, etc.

All this contributes to increasing traffic flows, their complexity and interdependence. The uncertainty of the quantitative and qualitative characteristics of the emerging passenger traffic in the course of urban dynamics entails the problem of unmet demand for the services of urban passenger transport. These circumstances indicate that the adoption of extensive solutions (for example, the acquisition of rolling stock) is not enough - an intensive approach is required that is associated with the rational placement of passenger vehicles on urban routes in accordance with the demand for its services, improving the quality of the provided transport services[2, 3].
This situation requires a more reasonable approach to the planning and organization of rolling stock of various types of transport on urban routes, taking into account the security and the level of quality of services provided, which makes research in this direction relevant.

The purpose of this work is to study the quality of passenger transportation by public passenger vehicles [4, 5, 6].

To achieve this goal, the following tasks were set:
- Identification of priority indicators of the quality of transport services and drawing up a plan of corrective actions aimed at improving the level of service of urban passenger transport;
- designing a program (workstation) for planning the production of passenger rolling stock with a specific capacity per line;
- approbation of design results (sociological survey of passengers' satisfaction with the quality of transport services) after the introduction of changes on certain routes.

The object of the study is the process of interaction between passengers and means of urban public transport within the street-road network of a large city.

The subject of the study is the relationship between the quality of service indicator on urban public transport and the parameters of the passenger flow.

2. Quality criteria for passenger traffic in Russia

In Russia there is the following classification of passenger transport quality indicators [7, 8, 9, 10]:
1. Information service indicator.
2. Indicators of comfort.
3. Indicators of speed.
4. Timeliness indicators.
5. Indicators of luggage safety
6. Indicators of transport services safety.

According to the Federal State Statistics Service of Russia, in 2017, 14,134 million people were transported by city land passenger transport which is 6% less than in 2016 [11].

|          | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|----------|------|------|------|------|------|------|
| Buses    | 13434| 13305| 12766| 11587| 11554| 10939|
| Trams    | 2079 | 2004 | 1928 | 1629 | 1551 | 1483 |
| Trolleybuses | 2206 | 2152 | 2051 | 1735 | 1803 | 1712 |

The decrease in traffic volume is due to the fact that an increasing number of people prefer personal transport to the public.

3. Analysis of the route network of the city of Vladivostok

The growth of the urban population and the intensification of its business activity have made it necessary to improve passenger transport and road and transport infrastructure. For Vladivostok (is one of the largest in the Far Eastern Federal District) the transport problem is particularly acute [12, 13, 14, 15]

Regular passenger transportation in the city of Vladivostok is carried out by road, land electric (tram, trolleybus) and public maritime transport (table 2).

As of 01/01/2018, the market of passenger road transport in Vladivostok is being operated by intra-urban transport by buses of 14 companies: 1 municipal and 13 commercial trucking enterprises [16].

The total number of buses on the city routes is growing every year, so in January 2016 there were 776 units on the line of them 68 municipal and 708 commercial buses, and in January 2017 their number was 812 units, including about 200 municipal and 600 buses of commercial enterprises (Figure 2.2 with a linear trend [16].
On the routes in 2011, mainly Korean buses 82% (Hyundai AEROCITY, DAEWOO, ASIA COSMOS, Hyundai GRACE) were mainly used, and only 18% fell on Japanese (Toyota Hiace) and Russian (GAZ-322132) manufacturers.

**Table 2.** Number of routes of public urban land transport in the city of Vladivostok [16].

| Transport type      | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---------------------|------|------|------|------|------|------|------|------|
| Bus                 | 90   | 87   | 83   | 85   | 85   | 91   | 91   | 91   |
| Trolleybus          | 4    | 3    | 2    | 2    | 2    | 2    | 2    | 2    |
| Tram                | 3    | 2    | 1    | 1    | 1    | 1    | 1    | 1    |
| Passenger ships     | 4    | 4    | 4    | 4    | 1    | 1    | 1    | 1    |
| Total               | 101  | 96   | 90   | 92   | 91   | 97   | 97   | 97   |

On the routes of Vladivostok, Korean buses are also currently used (53.6%), but the number of Russian buses has increased from 13% to 26.6%, which is a positive factor. Also in the city in the period from 2011 - 2016, 50 buses of MAN brand were purchased and launched on the line and equipped with mechanical ramps for loading wheelchair users with wide doorways and a wide storage area with fasteners for wheelchairs and other special equipment [16].

The rolling stock in Vladivostok consists of only four classes, excluding the class of especially large buses. This is due to the fact that Vladivostok is one of the few cities in Russia that combines many unfavorable natural and geographical conditions that complicate transport services in the city. The ratio of buses of different classes in the city park is shown in Figure 1.

![Figure 1](image)

**Figure 1.** Classification of buses in Vladivostok by passenger capacity.

It can be seen from the figure that buses of especially small and medium capacity prevail in the transport services market.

When considering the busiest routes of the city public transport in Vladivostok, the parameters of the distribution of passenger traffic were studied, which formed the basis for the development of specialized software [17].

The algorithm of the application is based on the normal law of distribution of passenger traffic, as on the experimental routes there are system changes in the number of passengers using transport services.

So, if we consider most of Vladivostok's routes as a closed system, then the probability density of passenger traffic distribution can be represented by the Gaussian distribution law, expressed as [18, 19]:

\[
f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-m)^2}{2\sigma^2}}.
\]  

The distribution curve of passenger traffic on such routes depends on the parameters: the mathematical expectation \( m \) and the standard deviation. The maximum value of passenger traffic (fixed by "peak hours") is:
Achieved at \( x = m = Q_{\text{max}} \).

Let's find, at what values of the coefficient of the ratio of actual passenger traffic on the routes to the nominal, it will be necessary to change the capacity of the vehicle, and as a consequence – to improve the quality of passenger transportation

If the probability density of the distribution function of the passenger traffic \( f(x) \), then the probability of hit on the segment \([Q_{\text{min}}, Q_{\text{max}}]\) (in the formulas further we will take \( Q_{\text{min}} = \alpha \) and \( Q_{\text{max}} = \beta \)) is determined by the formula:

\[
p(\alpha \leq x \leq \beta) = \frac{1}{\sigma} \int_{\alpha}^{\beta} f(x) \, dx
\]

(3)

Since the passenger traffic on the routes is distributed according to the normal law, which was established above, the probability of getting the ratio of the ratio of actual and nominal passenger traffic will be expressed by the ratio:

\[
p(\alpha \leq x \leq \beta) = \frac{1}{\sigma} \int_{\alpha}^{\beta} \frac{1}{\sqrt{2\pi}} e^{-\frac{(x-m)^2}{2\sigma^2}} \, dx
\]

(4)

\[
\frac{x}{\sigma} \cdot \frac{\alpha}{\sigma} = \frac{\beta}{\sigma} \]

\[
= \int_{\alpha}^{\beta} e^{-\frac{(x-m)^2}{2\sigma^2}} \, dx
\]

(5)

To calculate the integral obtained, we use the Laplace function [20], we obtain

\[
p(\alpha \leq x \leq \beta) = \frac{1}{\sqrt{2\pi}} \int_{\alpha}^{\beta} e^{-\frac{\beta^2}{2\sigma^2}} \, dt = \frac{1}{2} \left[ \frac{\beta}{\sqrt{2\pi}} e^{-\frac{\beta^2}{2\sigma^2}} - \frac{\alpha}{\sqrt{2\pi}} e^{-\frac{\alpha^2}{2\sigma^2}} \right]
\]

What is equal

\[
p(\alpha \leq x \leq \beta) = \frac{1}{2} \left[ \Phi\left(\frac{\beta}{\sigma}\right) - \Phi\left(\frac{\alpha}{\sigma}\right) \right]
\]

(6)

To calculate the maximum and minimum values of passenger traffic, we calculate the mean square deviation from the ratio

\[
f_{\text{max}}(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}
\]

(7)

where \( F_{\text{max}} = Q_{\text{paxon}} = m \).

and geometric deviation, which is calculated from the expression of the normal law:

\[
\sigma = \frac{E}{\rho \sqrt{2}}
\]

(8)

where \( \rho = 0.477 \), then the geometric expectation

\[
E = \sigma \rho \sqrt{2}
\]

(9)

Then the values of \( Q_{\text{min}} \) and \( Q_{\text{max}} \) will lie in the intervals of geometric deviation, as shown in Fig. 2.
Figure 2. Distribution scheme $Q_{\text{min}}$ and $Q_{\text{max}}$ in the area of geometric deviation of passenger traffic $Q_{\text{fact}}$.

The projected passenger traffic is in the range of geometrical deviation $E$, characterizing the limiting (maximum and minimum permissible values) of the projected passenger traffic $Q$ (shown in Figure 3).

Figure 3. Distribution of passenger traffic values on the explored routes of Vladivostok.

As a result of the mathematical analysis, the required criteria for increasing the capacity of vehicles as one of the key factors affecting the quality of passenger traffic were established and a special program was developed to determine the recommended passenger capacity parameters for the Vladivostok route network.

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