Evaluating reliability of municipal public transport operation in the Russian Federation cities

A Yu Mikhailov¹, M I Sharov¹, A G Levashev¹, A B Butuzova¹ and N I Ovchinnikova²
¹Irkutsk National Research Technical University, 83, Lermontov Street, 664074 Irkutsk, Russia
²Irkutsk State Agrarian University, p. Molodezhnyy, 664038, Irkutskaya region, Russia
E-mail: alexa.kupriyanova@gmail.com

Abstract. The article presents the results of a study of municipal public passenger transport routes operation reliability. For the first time in Russian practice, a range of Travel Time and Buffer indices values is identified based on route networks of two different cities. A scale to evaluate route reliability levels is proposed.

1. Introduction
The growth of automobilization of the population and the intensity of traffic in Russian cities has created urgent urban planning, socio-economic and environmental problems. The adopted concept of transition of the Russian Federation to sustainable development involves sustainable development of cities and agglomerations of the country. The consequent requirement to establish sustainable municipal transport systems is associated primarily with the priority development of public passenger transport. So, the quantitative transport indicator was included in the comfort rating of Russian cities: annual quantity of trips of one person by public transport. Under the new conditions, the requirements for passenger transport are increasing constantly. First of all, it should be attractive and reliable from the point of view of a user and that is why appropriate criteria [1, 4-7] should be developed.

The main purpose of this article was to consider indicators for assessing the reliability of the urban passenger transport system, which has not yet been used in Russian practice. The peculiarity of these indicators is that the initial information can be obtained on the basis of modern equipment of buses (GLONASS / GPS).

2. Methods and Materials
Evaluation of public transport reliability has a long history. As early as 1987, the RSFSR Ministry of Automobile Transport issued the Order “On Introduction of Temporary Instructions and Recommendations to Ensure Implementation of Bus Route Tours”. In accordance with it, the regularity of bus routes was evaluated as follows (Table 1).
In modern Russian operation experience, the quality of functioning (i.e. the quality of service) of public passenger transport is proposed to be evaluated by an integral indicator:

\[ S = \sum_{i=1}^{6} c_i k_i, \]

where \( S \) traffic reliability in exact compliance with schedule (travel time); \( S_2 \) public transport frequency; \( S_3 \) security; \( S_4 \) comfort (trip quality); \( S_5 \) cost indicator (transportation rate amount); \( S_6 \) information service indicator (level of information support); \( k_i \) exponents, weighing coefficients that characterize the significance of the corresponding service level indicator.

Some of the indicators, included in the formula (1), are measured quantitatively, and some are qualitative and are measured in points. Accordingly, when calculating the integral criterion to evaluate public passenger transport quality \( S \), it was proposed to evaluate the reliability by regularity of vehicle movement indicator \( R \):

\[ R = \frac{N_{sh}}{N_r} k_r = \left( \frac{N_{sh}}{N_r} \right) \left( \frac{N_s}{N_p} \right) = \frac{N_{sh}}{N_p}, \]

where \( N_{sh} \) – number of vehicle trips that kept the route schedule; \( N_r \) – number of all actually completed vehicle trips; \( k_r \) – accomplishment quotient of scheduled trips; \( N_p \) – number of scheduled trips.

The development of geo-information technologies and vehicle-borne equipment provide new opportunities in evaluating public passenger transport reliability, either on the basis of track archives or in real time conditions. In this case, tracks of rolling stock are permanently generated data; therefore, the processing of such data is of great interest in terms of theory and practice.

In the current practice of evaluation of any transportation systems operation reliability, the following based on the travel time indicators are used [2, 3, 11, 12]:

- **Travel Time Index \( TTI \)**
  \[ TTI = \frac{T_{90\%(95\%)}}{T_{FF}}, \]  

- **Buffer Time \( BT \)**
  \[ BT = T_{95\%} - \bar{T}, \]  

- **Buffer index \( BI \)**
  \[ BI = \frac{T_{90\%(95\%)}}{\bar{T}} \times 100\%, \]  

- **Planning Time Index \( PTI \)**
  \[ PTI = \frac{T_{95\%}}{T_{FF}}, \]  

where \( T_{90\%(95\%)} \): 90th or 95th percentile travel times, minutes; \( T_{FF} \): travel time at free-flow speeds (5th, 10th or 15th percentile travel times), minutes; \( \bar{T} \): average travel time, minutes.

Nowadays, Irkutsk Scientific Research Technical University Transport Laboratory is conducting a research in the field of evaluation of the reliability of operation of both road networks and public passenger transport networks [8-10]. From the point of view of formation of a sustainable (i.e. reliable and attractive) public passenger transport system, Buffer Time is an important indicator, since it represents the additional time to be spent by a user to choose an appropriate route taking into account public transport reliability.

Consequently, Buffer Index and Planning Time Index, including Buffer Time, can be used to evaluate transport system reliability taking into consideration a user.
The reason that we consider street-road network and route network separately is peculiar calculations of weighted indicators $TTI_{net}$, $BI_{net}$ for the network. Traffic flows are taken into account to consider road networks, and in the case of route network, passenger flows are taken into account:

$$TTI_{net} = \frac{\sum_{i=1}^{n} TTI_i V_i}{\sum_{i=1}^{n} V_i},$$

$$BI_{net} = \frac{\sum_{i=1}^{n} BI_i V_i}{\sum_{i=1}^{n} V_i},$$

where $TTI_i$, $BI_i$ – Travel Time Index or Buffer Index values per segment of street-road or route network $i$; $V_i$: traffic flow value (vehicle per hour) or passenger flow (passengers per hour) per segment $i$.

3. Results and discussion

In the Russian Federation up to nowadays, the statistical data of TTI, BI and PTI indicators have not been accumulated and systematized. Therefore, the following objects were formulated in the performed studies:

- to determine the range of variety of TTI, BI values in relation to municipal public passenger transport routes;
- to suggest a scale to evaluate the reliability of public transport routes.

The routes of public passenger transport in the cities of Irkutsk and Angarsk were studied as fundamentally different transport systems. Irkutsk is one of the Russian Federation historical cities; that is why the street-road network does not meet the requirements of town-planning standards. The city is characterized by a high level of transport congestion. Unlike Irkutsk, Angarsk was founded in early 1950s and is one of new cities. The street grid is regular; no transport congestion is observed within it.

The study was performed during several months at different periods of the year. The onboard equipment Omnicomm LLS was used. The GLONASS / GPS tracks were collected and the data were processed using Wialon Pro software. On the basis of the collected data (Figure 1), the statistical data, presented in Table 2 and Figure 3, were calculated for each route.

![Figure 1](image_url). Trip duration (min) of Angarsk route No.11 (02/03/2017- 08/03/2017).
Table 2. Statistics of the trip duration and reliability of Angarsk route No. 27

| Trip duration and values of indicators | 3/11/17 | 4/11/17 | 5/11/17 | 6/11/17 |
|---------------------------------------|--------|--------|--------|--------|
| Tracks number                         | 62     | 65     | 57     | 67     |
| Average duration, min                 | 79.02  | 76.37  | 78.60  | 78.47  |
| Minimum duration, min                 | 74.75  | 70.28  | 70.75  | 67.00  |
| Maximum duration, min                 | 87.15  | 82.25  | 91.50  | 87.43  |
| 5% duration percentile                | 75.25  | 71.88  | 71.98  | 73.75  |
| 15% duration percentile               | 76.00  | 73.50  | 76.22  | 76.00  |
| 85% duration percentile               | 81.87  | 79.17  | 81.40  | 80.75  |
| 95% duration percentile               | 84.78  | 80.22  | 86.58  | 82.00  |
| Standard deviation                    | 3.02   | 2.53   | 3.82   | 2.78   |
| Buffer Time, min                      | 5.76   | 3.85   | 7.98   | 3.53   |
| Buffer Index                          | 7.29%  | 5.03%  | 10.15% | 4.50%  |
| Travel Time Index                     | 1.15   | 1.09   | 1.17   | 1.11   |

The choice of routes appeared to be appropriate, since all the routes are characterized by completely different characteristics and reliability indicators.

Thus, there are 40 and 60 stopping points along routes No.27 and No.11 respectively in Angarsk, and traffic speed 17.8 and 17.85 km/h. While peak periods, there is no deviation from the bus table; and calculated for the routes traffic speed is observed.

There are 20-70 stopping points along the studied routes No. 18, No. 27, No. 37 and No. 67 in Irkutsk, traffic speed is 18.98; 16.08; 23.06 and 17.47 km/h, respectively. Completely different indicators were obtained if to compare with Angarsk. The routes show low level of reliability and large values of the variation range of the travel duration (Table 3).

![Figure 2](image-url)  
Figure 2. Trip duration (minimum, maximum and mean values, 5%, 15%, 85% and 95% percentiles of trip duration) of Angarsk Route No.27 (02/11/2017-11/11/2017).
Table 3. Irkutsk routes characteristics

| Route No. | Maximum delay, min | Maximum schedule advance, min | Variation range of travel time, min |
|-----------|--------------------|------------------------------|-----------------------------------|
| No. 18    | 10                 | 15                           | 30                                |
| No. 27    | 10                 | 10                           | 18                                |
| No. 37    | 20                 | 12                           | 30                                |
| No. 67    | 15                 | 12                           | 40                                |

The final results of study of all considered routes are presented in table 4.

Table 4. Results of municipal passenger transport routes reliability study

| City route No. | Travel Time Index | Buffer Index |
|----------------|-------------------|--------------|
|                | Direct route TTI  | Direct route BI | Return rout TTI | Return rout BI  |
| No.11 Angarsk  | 1.07              | 6.65%         | 4.02%           | 6.30%          |
|                | November – 1.11   |               |                 |                |
|                | January – 1.08    |               |                 |                |
| No.27 Angarsk  | 2.05              | 4.58%         | 2.97%           | 4.47%          |
|                | March-April – 1.05|               |                 |                |
|                | July 1.06         |               |                 |                |
| No.18 Irkutsk  | 1.52              | 17.66%        | 39.19%          | 13.97%         |
| No.27 Irkutsk  | 1.64              | 37.90%        | 19.90%          |                |
| No.37 Irkutsk  | 1.56              | 26.27%        | 39.87%          |                |
| No.67 Irkutsk  | 1.56              | 26.27%        | 39.87%          |                |

4. Conclusion
The results of the study have proved the idea that Travel Time Index of urban passenger transport networks can vary in the range of 1.05-1.70 in the conditions of the Russian Federation. Accordingly, the range of Buffer Index values is as much as 3-40%.
Comparing the results of the study and published statistics of different countries [3], at this preliminary stage, we can suggest the following scale of evaluation of routes and public transport networks reliability:
  - High Reliability Network / Route – $TTI < 1.10$
  - Reliable Network / Route – $1.10 < TTI < 1.20$
  - Moderate Reliability Network / Route – $1.20 < TTI < 1.40$
  - Low Reliability Network / Route - $TTI > 1.40$

The proposed above scale will be specified by the accumulation of statistical representative samples, including weighted calculated for the network values. It seems that the most objective scale can be developed on the basis of distribution quantiles of statistically representative samples of TTI values and this is the aim of our ongoing research.

References
[1] Bates J, Polak J, Jones P, Cook A 2001 Evaluation of reliability for personal travel. Transportation Research Part E: Logistics and Transportation Review 37(2-3) 191–229
[2] Defining and Measuring Urban Congestion, available at: https://www.tactc.ca/sites/default/files/site/doc/Bookstore/defining-measuring-congestion.pdf
[3] Travel Time Index, available at: https://www.bts.gov/content/travel-time-index
[4] König A and Axhausen Kay W 2002 Reliability of the transportation system and its influence on the choice behaviour. Presentation at STRC 2002. Proc. of the 2nd Swiss Transport Research
Litman T Evaluating Public Transit Benefits and Costs. Best Practices Guidebook, available at: Evaluating Public Transit Benefits and Costs at: http://www.vtpi.org/tranben.pdf

Lyman K and Bertini R L 2008 Using Travel Time Reliability Measures to Improve Regional Transportation Planning and Operations. Transportation Research Record 2046 1–10

Polus A 1978 Modeling and Measurements of Bus Service Reliability. Transportation Research 12(4) 253–256

Rumyantsev Ye and Mikhailov A 2010 On efficiency of criteria for assessment of movement conditions of traffic flows Proc. 9th Int. Conf. on Traffic Safety Organization (Saint Petersburg) pp 121–123

Sharov M and Mikhailov A 2017 Urban transportation system reliability indicators. Transportation Research Procedia 20 591–595

Sharov M and Mikhailov A 2014 On issue of development of modern system of evaluation criteria for public passenger transport functioning quality. Volgograd State Technical University Reports 9(19) 64–66

Taylor M A P 2013 Travel through time: the story of research on travel time reliability. Transportmetrica B, Transport Dynamics 1(3) 174–194

Travel Time Reliability: Making It There On Time, All the Time, available at: www.ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm.