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

A Yu Mikhailov[1], M I Sharov[1], A G Levashev[1], A B Butuzova[1] and N I Ovchinnikova[2]

[1]Irkutsk National Research Technical University, 83, Lermontov Street, 664074 Irkutsk, Russia
[2]Irkutsk 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).

Table1. Maximum permissible deviation from the schedule

Route type	Permissible advance schedule, min	Acceptable delay, min
Urban	2	2
Suburban	2-5	5
Inter-city	Over 5	20

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:

$$S = \sum_{i=1}^{i=6} S_i^{k_i} = , \quad (1)$$

where S_1 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_1 ... k_6 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:

$$R = \frac{N_{sh}}{N_r} k_r = \left(\frac{N_{sh}}{N_r}\right)\left(\frac{N_r}{N_p}\right) = \frac{N_{sh}}{N_p}, \quad (2)$$

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*

$$TTI = \frac{T_{90\%(95\%)}}{T_{FF}}, \quad (3)$$

Buffer Time *BT*

$$BT = T_{95\%} - \bar{T},$$

Buffer index *BI*

$$BI = \frac{T_{90\%(95\%)} - \bar{T}}{\bar{T}} 100\%, \quad (4)$$

Planning Time Index *PTI*

$$PTI = \frac{T_{95\%}}{T_{FF}}, \quad (5)$$

where $T90_{\%(95\%)}$: 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:

$$TTI_{net} = \frac{\sum_{i=n}^{n} TTI_i V_i}{\sum_{i=n}^{n} V_i}, \quad (6)$$

$$BI_{net} = \frac{\sum_{i=n}^{n} BI_i V_i}{\sum_{i=n}^{n} V_i}, \quad (7)$$

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.

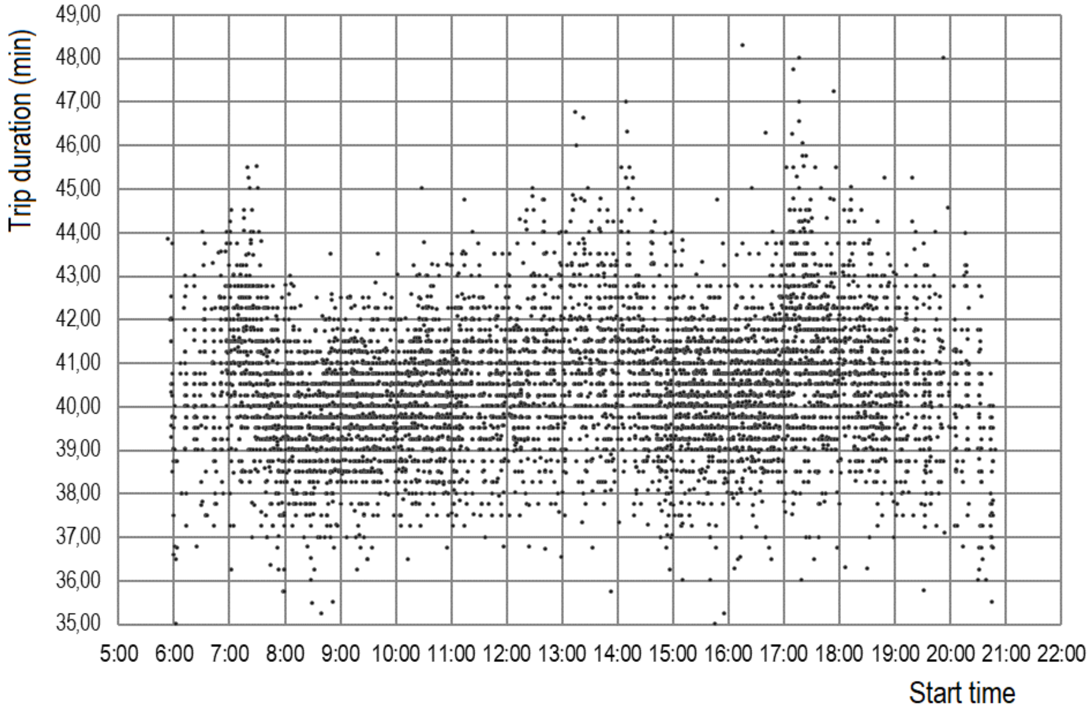

Figure 1. Trip duration (min) of Angarsk route No.11 (02/03/2017- 08/03/2017).

Table 2. Statistics of the trip duration and reliability of Angarsk route No. 27

Trip duration and values of indicators statistics	Data receipt date			
	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).

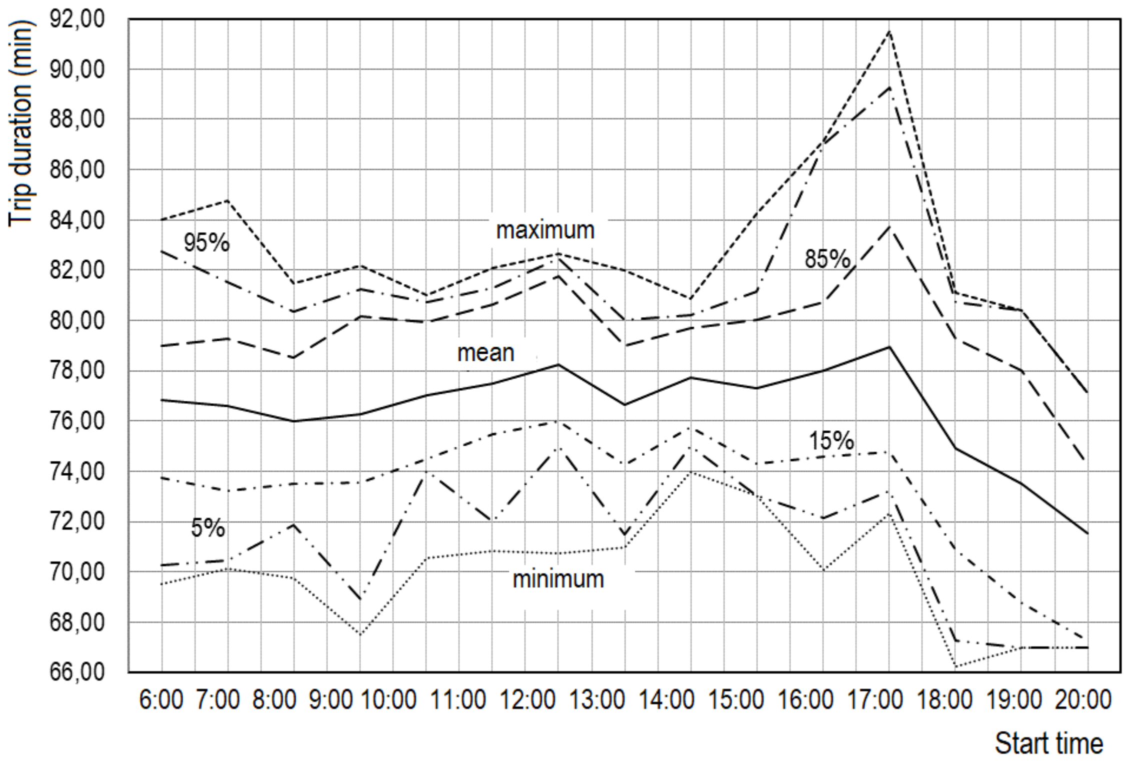

Figure 2. Trip duration (minimum, maximum and mean values, 5%, 15%, 85% and 95% percentiles of trip duration) of Angarsk Route No.27 (02/11/2017-11/11/2017).

Table 3. Irkutsk routes characteristics

Route	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 TTI		Buffer Index BI	
	Direct route	Return rout	Direct route	Return rout
No.11 Angarsk	1.07	1.10	4.02%	6.30%
No.27 Angarsk	November – 1.11		6.65%	
	January – 1.08		4.58%	
	March-April – 1.05		2.97%	
	July 1.06		4.47%	
No.18 Irkutsk	1.52	1.35	17.66%	13.97%
No.27 Irkutsk	2.05	1.28	39.19%	16.08%
No.37 Irkutsk	1.64	1.34	37.90%	19.90%
No.67 Irkutsk	1.56	1.64	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.

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