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Urban Transport System Reliability Indicators

Maxim Sharov, Alexander Mikhailov*

Irkutsk National Research Technical University, 83 Lermontov St., Irkutsk, 664074, Russia

Abstract

In 2014–2015, the Transport Laboratory of the National Research Irkutsk State Technical University (TL-ISTU) participated in development of the Federal Methodological Guidelines "Quality Evaluation of Traffic Management". This article represents a number of suggestions in the framework of the document in development. As follows from the analysis of special periodicals and literature as well as considering the onrush of geoinformation technology, the following quantitative criteria have been chosen to assess reliability: time index, Herman–Prigogine criterion; buffer time. In this context, time index is offered to be used for comparative analysis of functioning reliability of transport systems in different cities. Based on these inspections (about 600 tracks in Irkutsk), rating scales of the chosen criteria have been offered.

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Keywords: functioning reliability of urban transport system; time index; buffer time; Herman-Prigogine criterion; level of service; GPS; GLONASS

The Transport Laboratory of the National Research Irkutsk State Technical University (TL-ISTU) has been participating in development of the Federal Manual “Quality Evaluation of Traffic Management” since 2014. This article considers a part of the criteria offered in these guidelines.

In conditions of high level of saturation of the street and road network (SRN), quality evaluation of SRN projects surely has to include evaluation of conditions of traffic fow movement. Therefore, both projects of SRN sites and traffic management projects being evaluated on the basis of modeling have to get a uniform system of evaluation criteria (i.e. it is necessary to form something that got the name Traffic Analysis Tools in the international practice).

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: mikhaylov@gmail.com

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Consequently, SRN functioning is characterized by two parameters — reliability and quality of traffic conditions provided to a user. It should be noted at once that the second indicator got an unambiguous definition as a level of service long ago.

The approaches to reliability evaluation are much more various. One of the most widespread approaches to reliability determination is assessment of transport system behavior in conditions of congestion. In this context, we interpret congestion as a state (of both SRN and a route system of the public passenger transport, etc.) at which transport demand begins to exceed transport supply.

As follows from the analysis of the international practice, special periodicals and literature [Bakhirev and Mikhailov (2015), Rumyantsev and Mikhailov (2010), Rumyantsev (2012), Sharov and Mikhailov (2014), Susilawati and Taylor (2010)] as well as considering the onrush of geoinformation technology, the following quantitative criteria have been chosen to assess reliability:

- Time index
- Herman–Prigogine criterion
- Buffer time and buffer index

In conditions of high loading levels of SRN and influence of random factors, time expenditures for trip begin to vary in a wide range of values and have to be considered as a random variable. Consequently, the time index *TT1* is a ratio of time spent for passing the site in conditions of a rush hour to way time in conditions of a free flow.

$$TTI = \frac{T_{PP}}{T_{FF}}, \tag{1}$$

where *TPP* — time spent for passing the site in conditions of a peak period, min; *TFF* — time spent for passing the site in conditions of a free flow, min.

According to the results of the own investigations and data of other authors, the following gradation of reliability levels presented in Table 1 is offered for urban SRN.

Table 1. Assessment of traffic conditions at sites of main streets and roads.

Reliability level	Extent of a site, km		Traffic conditions
A	< 5	25	Deterioration in traffic conditions is not observed in peak periods
B	<1.2	<1.2	Insignificant deterioration in traffic conditions is observed in peak periods
C	1.3–1.5	1.3–1.45	Deterioration in traffic conditions is observed in peak periods
D	1.5–2	1.45–1.6	Considerable deterioration in traffic conditions is observed in peak periods
E	>2	>1.6	The road functions unreliably in peak

	periods. Traffic jams are possible

Time index is offered to be used for comparative analysis of functioning reliability of transport systems in different cities.

Herman–Prigogine criterion is another offered indicator which is recommended to be applied at the level of the city to assess both all SRN and its separate sites. In this context, the indicator of trip time per unit diatance T (min/km) is used, which is considered as a sum of the running time per unit distanse T_r (min/km) and the stop time per unit distanse T_s (min/km)

$$T = T_r + T_s \tag{2}$$

Using the values T, T_r and T_s, two other parameters are determined:

T_m — a minimum trip time per unit distanse, which is possible at this site of the street and road network (min/km) in free conditions when there is no interaction between vehicles in the flow;

n — Herman–Prigogine criterion evaluating the influence of saturation of the street and road network with traffic flow on the communication speed.

According to the results of the investigations (more than 600 tracks — SRN of the city of Irkutsk), the following estimating gradation is offered (Table 2).

Table 2. Classification of sites of the street and road network based on degree of influence of traffic saturation.

Sites of the street and road network	Value of Herman–Prigogine criterion n
Poorly reacting to increase in loading of SRN	<1.20
Reacting to increase in loading of SRN	1.20–2.50
Having a strong reaction to increase in loading of SRN	2.50–5.50
Having a strong reaction to increase in loading of SRN	>5.50

One more chosen indicator is “buffer time” *Tb*, characterizing additional time expenditures necessary to achieve the purpose of movement with the desired reliability (for example, with reliability of 90% or 95%). Consequently, *Tb* is determined as a difference

$$T_b = T_{90\%(95\%)} - \overline{T}, \tag{3}$$

where $T_{90\%(95\%)}$ — 90% or 95% persentile of trip duration; $\overline{T}$ — average trip duration.

The relative indicator conjugated to *Ib* — “buffer index” is determined as

$$I_b = \frac{T_b}{\overline{T}} 100\%, \tag{4}$$

The given above indicators *Tb* and *Ib* characterize functioning reliability of the urban SRN or the route network of the public passenger transport. In this context, “buffer time” *Tb* can be applied (using the cost of a passenger-hour, machine-hour, etc.) to assess economic costs which shall be incurred by a user (driver or passenger) in the form of additional time expenditures as a result of unreliability of the transport system.

The representative statistics of the buffer index values is not yet collected in the Russian Federation. Therefore, it is offered to use temporarily the rating scale of reliability of sites of the street and road network and traffic routes obtained on the basis of inspections of bus routes (inspections of NR ISTU: Irkutsk, Angarsk, Biysk).

Ib <0.1 — high reliability;

Ib =0.1–0.3 — acceptable reliability;

Ib =0.3–0.5 — low reliability;

Ib >0.5 — very low reliability.

Given that regular transport inspections are quite uncommon, it is crucially important to determine the minimum quantity of GPS tracks necessary to apply each of the listed above criteria.

It is offered to assess the time index on the basis of two tracks recorded in conditions of free flow (i.e. at the level of loading with traffic of a segment or a site of no more than 10%, for example, at night) and in the peak period when the peak traffic flow is observed. Tracks are recorded on weekdays, cases of extreme road conditions (stormy wind, fog, heavy rain, intensive snowfall, etc.) as well as cases of road works being excluded from the consideration.

To determine Herman–Prigogine criterion, it is offered that four tracks are necessary as the minimum quantity recorded in specific periods of a day:

- In the morning rush hour
- In the interpeak period (usually 12 p.m.–2 p.m.)
- In the evening rush hour
- In conditions of a free flow (i. e. at the low loading level of less than 10–20%, for example, at night time)

The conditions of track recording are the same as in case of determination of the time index.

When determining buffer time and index, all available tracks executed at the evaluated site are accepted for consideration. The minimum quantity of tracks is -20…25, at the same time a part of them (2–3 tracks) have to be surely recorded in conditions of free flow.

It is offered to execute a detailed assessment of movement conditions quality of traffic streams using a level of service criterion that became traditional in the foreign practice [Mikhailov and Golovnykh (2004), Rumyantsev and Mikhailov (2010), Rumyantsev (2012), Sharov and Mikhailov (2014), (1999), (2000), (2010), US Department of Transport, Federal Highway Administration (2013)]. The offered set of indicators of the level of service for different SRN elements is presented in Table 3.

Table 3. Service level indicators.

SRN element	Service level indicator
Multilane highways	Ratio of the driving speed to the speed in free conditions
Dual highways and streets	Time share of movement in the mode of following the leader
Segments of urban streets and roads	Ratio of the driving speed to the speed in free conditions
Regulated, unregulated and roundabouts	Average delay

It should be specially noted that the service level indicators are chosen on the basis of the essential condition, they have to:

- Be determined in the field
- Be calculated on the basis of standard procedures
- Be determined by means of modeling

Everything in total will make it possible to unify the quality evaluation of projects and traffic management.

It is also important to note a new tendency in investigations of recent years — making connections between reliability indicators and a level of service [Friedrich and Lohmiller (2012), Friedrich et al. (2011)]. In many respects it is conditioned by more and more expanding use of geoinformation technology.

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