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Analysis of Influence of Number of Station Stops on Punctuality of Passenger and Suburban Trains

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ABSTRACT

One of the main tasks of railway employees is to ensure 100 % punctuality of passenger and suburban trains. However, this is impossible due to the action of various reasons, comprising actual reliability of technical equipment and vehicles, natural and other factors. Various companies have different standards and practices of setting and monitoring relevant indicators.

The objective of the study was to find out the degree of influence of the e factor formulated as «the number of station stops on the route» on the rate of punctuality of passenger and suburban trains.

Calculations and approbation of the suggested model were performed using the example of the JSC Russian Railways.

Russian Railways standardise punctuality indicators based on the past performance principle. This does not guarantee that the objective conditions for organising operational work on various railways are fully considered. Besides, it is suggested to consider as main conditions: the level of the use of transit capacity, the technical condition of the infrastructure and rolling stock, etc. However, the factor of the number of station stops of passenger or suburban trains en route envisaged by the traffic schedule is not considered. The greater is the number of station stops, the greater impact, in the absence of a possibility to recover the delay and catch up the traffic schedule, this factor has on the level of traffic punctuality. In turn, the chance to get back on traffic schedule in passenger long distance traffic is higher than in suburban traffic with short routes.

The number of station stops varies significantly across the railways, which indicates the unequal conditions of their operation according to this factor.

The numerical value of the e factor, as well as of the values of the share of delayed trains (calculated separately for passenger and suburban trains) were determined: by delay in departure – α_{dep}*; by delay in arrival at intermediate points of the route –* α_{int}*; by delay in arrival at the destination –* α_{ar}*. Based on these data, parameters have been established that have allowed to determine the relationship between the number of station stops (e) and the change in the share of delayed trains. Using the methods of mathematical statistics, the insignificant influence of the e parameter on the values of* α_{dep}*,* α_{int} *and* α_{ar} *has been established. It is shown that the punctuality of passenger and suburban trains is significantly influenced by the traffic conditions after departure from the initial station and especially by the possibility to come back on the traffic schedule after possible delays along the route. In this case, one should consider the combined organisation of passenger and freight traffic on most lines of the considered network. It is proposed to optimise the number of standardised indicators in view of their reduction.*

Keywords: transport, railway, train schedule, passenger, suburban and commuter trains, standardisation, accounting and analysis of punctuality, factors affecting the punctuality.

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For the original Russian text of the article please see p. 136.

INTRODUCTION

Punctuality of passenger and suburban[1] trains is one of the most important criteria of assessment of the quality of services provided by railway transport in all the countries where the rail traffic exists (in some countries, e.g., in Great Britain train punctuality analysis is open access for public[2]). That is entirely true as well regarding railway system in the Russian Federation that has one of the longest networks.

Hence, issues of punctuality attract sufficiently significant attention in science literature, master's, and doctoral theses. The task of this study has not comprised comparative analysis of parameters and methods used on different railways, but diversity of on-going research should certainly be mentioned. Along with system studies on the issue [1–4], the detailed analysis focuses on various dedicated problems, e.g., of the impact of multiplatform stations [5], infrastructure maintenance [6–8]. The approach towards studying impact of total route length on punctuality should not be neglected (i.e., the author of [4, p. 77] suggests that punctuality is negatively correlated with the length of the journey, on average dropping is by about 3 % per 100 km). Particular attention in the context of the topic under the study should be paid to the works that examine different aspects of the punctuality within the framework of the national rail networks (e.g., [1; 9–10].

In Russia the traffic schedule[3] compliance is regulated by legal acts[4]. This issue is part of curricula intended for training railway employees (e.g., [11]).

[1] The term «passenger trains» used by the author in original Russian text refers to all types of passenger trains, the term «suburban train» refers to both suburban and commuter trains. – *Editorial note*.

[2] The Rail Delivery Group (RDG). [Electronic resource]: https://www.raildeliverygroup.com/punctuality.html. Last accessed 15.01.2021.

[3] The author in the original Russian text based on national perspective differentiates the notions of a timetable as of information, e.g. public timetable, on train times and of railway companies' train traffic schedule (e.g., chart) intended for operations of traffic control centres translated in the article for simpicity as traffic schedule or schedule.The approach to punctuality regarding the time of train arrival at stations in both cases mostly coincide. – *Editorial note*.

[4] Rules for technical operation of the railways of the Russian Federation, approved by Order of the Ministry of Transport of Russia dated December 21, 2010, No. 286. [Electronic resource]: https://base.garant.ru/55170488/. Last accessed 15.01.2021.

Lack of punctuality of passenger and suburban trains is often critical for passengers[5], for example, when travelling to workplace or to the place of a business meeting, when changing to another mode of transport and in other cases. Almost all delays cause a feeling of dissatisfaction among passengers, affecting the passenger index of satisfaction with the quality of railway transportation services[6].

Railway employees should strive to comply the established traffic schedule of passenger and suburban trains at 100 %. However, for a number of objective reasons, it is not possible to achieve this over a long period and for all the trains. Such reasons comprise actual reliability of technical equipment, locomotives, cars, tracks, control devices; natural factors (weather conditions, natural anomalies); technogenic anomalies; special technological need (embarkation and disembarkation at intermediate stations of medical staff, patients); passage of priority trains (fire, engineering trains); human factor. Therefore, when standardising, accounting and analysing traffic schedule of passenger and suburban trains, it is necessary to correctly assess deviations from timetable.

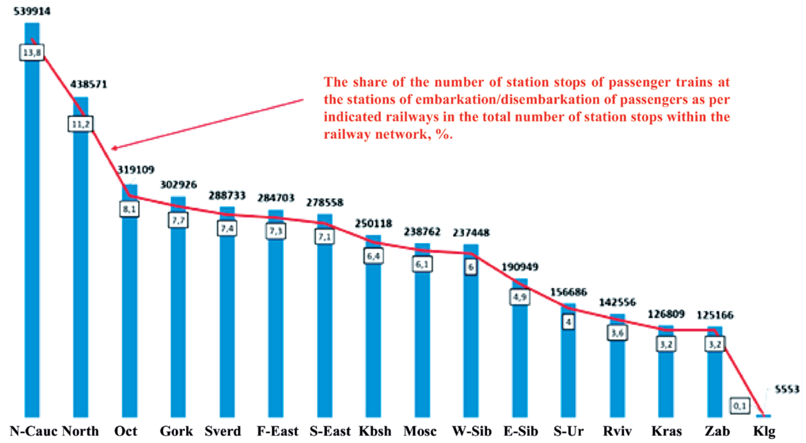
Russian Railways for accounting and standardising timetable compliance in passenger traffic use, among others, indicators that reflect possible deviations from timetable of passenger and suburban trains while they are moving between terminal stations of departure and arrival:

- Degree of punctuality of passenger trains at stations of embarkation (disembarkation) of passengers along the route: γ_{ed}^{pass} .
- Degree of punctuality of suburban trains at intermediate stations: γ_{ed}^{sub} .

Those and other indicators are currently standardised based on past performance principle which does not allow considering the

[5] The program for improving quality of transport services for passengers in 2017–2019, approved by the order of JSC Russian Railways dated March 24, 2017, No. 543r. [Electronic resource]: https://docs.cntd.ru/document/456076255?marker=6560IO. Last accessed 15.01.2021.

[6] A unified methodology for assessing the level of passenger satisfaction with quality of railway transport services, approved by the order of JSC Russian Railways dated February 7, 2018, No. 227/r. [Electronic resource]: https://urizdat.ru/books/zheleznodorozhnyy-transport/infrastruktura-obschie-polozheniya-cdi/edinaya-metodika-ocenki-urovnya-udovletvorennosti-passazhirov-kachestvom-uslug-zheleznodorozhnogo-transporta.-utverzhdena-rasporyazheniem-oao-rzhd-ot-07.02.2018-227-r.html. Last accessed 15.01.2021.



Pic. 1. Annual number of station stops as per stations of embarkation/disembarkation of passengers along the network (2018 year) and their shares as per number of station stops on each railway (compiled based on the statistical reports of DO-13VTs, DO-11 forms of JSC Russian Railways on punctuality of passenger trains at the stations of embarkation (disembarkation) of passengers).
Here and further-on the abbreviations mean: N-Cauc – Northern Caucasian railway; North – Northern (Severnaya) railway; Oct – Octyabrskaya (October) railway; Gork – Gorkovskaya (Gorky) railway; Sverd – Sverdlovskaya (Sverdlovsk) railway; F-East – Far Eastern railway; S-East – South-Eastern railway; Kbsh – Kuybyshevskaya (Kuybyshev) railway; Mosc – Moscow railway; W-Sib- West Siberian railway; E-Sib – East Siberian railway; S-Ur – South Urals railway; Priv – Privolzhskaya (Volga coastal) railway; Kras – Krasnoyarskaya (Krasnoyarsk) railway; Zab – Zabaikalskaya (Baikal) railway; Klg – Kaliningradskaya (Kaliningrad) railway.

objective conditions of operations on the railways when standardising tasks for the future periods. A methodology was developed [12] for accounting and standardising the punctuality indicators for passenger and suburban traffic through separate railways and the whole network based on the action of several factors that objectively affect the train traffic along their routes.

Such factors, according to [12], are:

• The level of use of available transit capacity of the sections (except for low-activity sections), as well as the degree of concentration of train flows.

• Technical condition of infrastructure and rolling stock, determined by the share of failures of technical equipment and rolling stock (affecting the punctuality) per 1 million train-km performed on a separate railway.

• The total duration of the daily time budget allocated for planned repair and construction works[7], ratioed to the operational length of the railways.

• The degree of respect of the technology standards assumed to be the same for all the railways.

At the same time, it can be assumed that for quantitative assessment of indicators γ_{ed}^{pass} and γ_{ed}^{sub}, the factor of the actual number of station stops along the route may be of great importance.

The *objective* of the study was to reveal the degree of influence of the factor of the number of station stops along the route on the rate of punctuality of passenger and suburban trains using *mathematical statistics*.

RESULTS

Let us examine the case when, for example, a passenger train has seven station stops along the route. If the delay occurred at the first station stop, and there is no possibility to get back on the schedule along the rest of the route, then seven cases of deviations from the schedule will be recorded in the statistical reporting data for the indicator γ_{ed}^{pass}. If the train has one station stop while moving from the departure station to the destination station, then one delay along the route will not increase the number of statistical cases of deviations from the timetable.

The condition of a possibility to recover the delay of passenger and suburban trains is also important[8]. Passenger trains have a much

[7] Instructions for calculating available transit capacity of railways. Moscow, Techinform publ., 2010, 289 p.

[8] The method of accounting for the time of late arrival of high-speed, speed, passenger and suburban trains, approved by the order of JSC Russian Railways dated June 10, 2019 No. 1142/r. [Electronic resource]: https://promarket.shop/metodika-ucheta-vremeni-nagona-opozdaniya-vysokoskorostnykh-skorostnykh-passazhirskikh-i-prigorodnykh-poezdov-utverzhdena-rasporyazheniem-o-ao-rzhd-ot-10-06-2019-1142-r/. Last accessed 15.01.2021.

longer route than suburban trains. Consequently, the chances to come back to the planned timetable are much higher. Therefore, it is possible to expect a lesser effect of delays in passenger traffic on the level of performance of the indicator under consideration than in suburban traffic. Accordingly, these two types of traffic (passenger and suburban traffic) should be considered separately when studying statistical data.

The analysis has shown that the number of station stops of passenger trains for embarking and disembarking passengers differ significantly as per railways. Of course, the value of this indicator is influenced by the length of the railways, the number of passenger trains and other conditions. But in general, it reflects the unevenness of the conditions for calculating the value of the indicator γ_{ed}^{pass} as per railways, as shown in Pic. 1, that presents the annual number of station stops of passenger trains at stations of embarkation (disembarkation) on various railways of JSC Russian Railways (2018) and their share by the number of station stops.

To consider the effect of the number of station stops of passenger (suburban) trains for embarking/disembarking passengers as an additional factor for standardisation of indicators γ_{ed}^{pass} and γ_{ed}^{sub}, it is necessary to perform a statistical analysis of the dependencies:

$$\gamma_{ed}^{pass} = F(K_{stop}^{pass}), \quad (1)$$

where K_{stop}^{pass} – the number of station stops of passenger trains.

$$\gamma_{ed}^{sub} = F(K_{stop}^{sub}), \quad (2)$$

where K_{stop}^{sub} – the number of station stops of suburban trains.

The influence of the number of scheduled station stops on punctuality of passenger and suburban trains should be assessed not by the absolute, but by the specific number of station stops per a single departed train.

The more stops dispatched trains have on the route, the greater the influence of the single case of delay on the indicators γ_{ed}^{pass} and γ_{ed}^{sub} should be. Let us call this dependence a *e* factor, the numerical value of which for railways is:

- For passenger trains:

$$e^{pass} = \frac{K_{stop}^{pass}}{n_{dep}^{pass}}, \quad (3)$$

where n_{dep}^{pass} is the number of passenger trains that departed along this railway from departure stations or arrived from neighbouring railways;

K_{stop}^{pass} is the number of stops of passenger trains.

- For suburban trains:

$$e^{sub} = \frac{K_{stop}^{sub}}{n_{dep}^{sub}}, \quad (4)$$

where n_{dep}^{sub} is the number of suburban trains that departed along the railway from departure stations or arrived from neighbouring railways;

K_{stop}^{sub} is the number of station stops of suburban trains.

The number of station stops of passenger ($K_{\text{stop}}^{\text{pass}}$) and suburban ($K_{\text{stop}}^{\text{sub}}$) trains is equal to the number of events available in the reporting forms: arrivals at the embarkation (disembarkation) station for passenger trains and arrival at intermediate stations for suburban trains.

Table 1 shows the reported data on punctuality of passenger trains in 2019, and Table 2 – on punctuality of suburban trains for all accounting indicators adopted by Russian Railways for these types of traffic:

In passenger traffic: departure – γ_{dep}^{pass}; passed stations, i.e., stations of embarkation and disembarkation of passengers – γ_{ed}^{pass}; arrival at the terminal station – γ_{ar}^{pass}.

In suburban traffic: departure of trains from points of departure – γ_{dep}^{sub}; arrival of trains at intermediate points – γ_{ed}^{sub}, arrival of trains at destinations – γ_{ar}^{sub}.

In accordance with the current reporting, the numerical value of e^{pass} factor, i.e., the number of station stops of passenger trains at embarkation and disembarkation stations per a dispatched passenger train is determined by the formula:

$$e^{pass} = \frac{n_{ed}^{pass}}{n_{dep}^{pass}}, \quad (5)$$

where $n_{\text{ed}}^{\text{pass}}$ is number of events of arrival of passenger trains at the station of embarkation (disembarkation) of passengers along the train route;

$n_{\text{dep}}^{\text{pass}}$ is number of events of departure of passenger trains.

For the factor e^{sub}:

$$e^{sub} = \frac{n_{ed}^{sub}}{n_{dep}^{sub}}, \quad (6)$$

where $n_{\text{ed}}^{\text{sub}}$ is number of events of arrival of suburban trains at intermediate points;

Table 1

Punctuality of passenger trains as per railways*

Railways	Departure of passenger trains		Arrival of passenger trains at the station of embarkation/disembarkation		Arrival of passenger trains at the destination station	
	number of departure events	incl. with delays	number of ed. Arrival events	incl. with delays	number of arrival events	incl. with delays
	n_{dep}^{pass}	$n_{dep}^{pass\ del}$	n_{ed}^{pass}	$n_{ed}^{pass\ del}$	n_{ar}^{pass}	$n_{ar}^{pass\ del}$
Oct.	47 980	440	349 053	5 437	47 976	652
Klg	824	–	6 051	17	823	2
Mosc.	63 675	409	255 526	4 595	63 661	1 645
Gork.	13 979	49	311 192	3 465	13 956	91
North.	14 562	72	442 595	6 011	14 560	398
N-Cauc.	27 577	98	568 152	8 314	27 580	328
S-East.	6 244	33	284 530	3 426	6 243	48
Priv.	6 528	91	137 980	2 518	6 538	161
Kbsh	8 498	29	260 699	3 285	8 490	116
Sverd.	9 876	27	288 156	7 131	9 903	136
S-Ur.	6 395	36	162 868	1 702	6 459	41
W-Sib.	11 770	36	251 143	2 178	11 706	79
Kras.	3 282	18	137 016	4 461	3 288	63
E-Sib.	3 905	29	198 649	9 640	3 908	244
Zab.	4 025	54	127 258	13 417	4 014	240
F-East.	8 557	56	284 008	5 430	8 553	241
Network	237 677	1 477	4 064 876	81 027	237 658	4 485

*Compiled based on statistical reports of DO-13VTs, DO-11 forms (report on punctuality of passenger trains at the stations of embarkation (disembarkation) of passengers).

Table 2

Punctuality of suburban trains as per railways**

Railways	Departure of suburban trains		Arrival of suburban trains at intermediate points		Arrival of suburban trains at destination points	
	number of departure events	incl. with delays	number of arrival events	incl. with delay	number of arrival events	incl. with delay
	n_{sent}^{sub}	$n_{sent}^{sub\ del}$	n_{ed}^{sub}	$n_{ed}^{sub\ del}$	n_{ar}^{sub}	$n_{ar}^{sub\ del}$
Oct.	347 983	1 521	2 058 112	18 316	347 985	3 458
Klg	26 582	14	83 952	70	26 582	35
Mosc.	996 070	12 898	6 071 131	121 486	996 286	24 930
Gork.	165 204	494	988 571	5 333	165 209	1 094
North.	56 478	337	454 682	4 963	56 114	623
N-Cauc.	129 780	549	758 919	4 990	129 780	1 128
S-East.	64 725	206	318 364	1 459	64 725	355
Priv.	38 972	157	301 465	2 129	38 972	357
Kbsh	55 787	200	487 972	3 132	55 894	468
Sverd.	120 203	964	921 782	10 002	120 567	2 204
S-Ur.	39 904	129	275 180	1 545	39 539	306
W-Sib.	106 554	151	640 268	1 545	106 554	372
Kras.	36 187	241	148 692	1 991	36 187	650
E-Sib.	41 491	323	311 784	5 963	41 492	1 346
Zab.	19 114	348	120 598	9 918	19 115	2 722
F-East.	40 208	209	250 616	3 259	40 209	608
Network	2 285 242	18 741	14 192 088	196 101	2 285 210	40 656

** Compiled based on statistical reports of DO-13VTs, DO-11 forms (report on punctuality of suburban trains at the stations of embarkation (disembarkation) of passengers).

Table 3

Results of calculation of values of e^{pass}, α_{dep}, α_{ed}, α_{ar}, $z_{ed/dep}$, $z_{ar/ed}$ for passenger traffic

Railways	Calculated values					
	e^{pass}	α_{dep}, %	α_{ed}, %	α_{ar}, %	$z_{ed/dep}$	$z_{ar/ed}$
Oct.	7,275	0,92	1,56	1,36	1,70	0,87
Klg	7,343	0,00	0,28	0,24	0,00	0,86
Mosc.	4,013	0,64	1,80	2,58	2,80	1,44
Gork.	22,261	0,35	1,11	0,65	3,18	0,59
North.	30,394	0,49	1,36	2,73	2,75	2,01
N-Cauc.	20,602	0,36	1,46	1,19	4,12	0,81
S-East.	45,569	0,53	1,20	0,77	2,28	0,64
Priv.	21,137	1,39	1,82	2,46	1,31	1,35
Kbsh	30,678	0,34	1,26	1,37	3,69	1,08
Sverd.	29,177	0,27	2,47	1,37	9,05	0,55
S-Ur.	25,468	0,56	1,05	0,63	1,86	0,61
W-Sib.	21,338	0,31	0,87	0,67	2,84	0,78
Kras.	41,748	0,55	3,26	1,92	5,94	0,59
E-Sib.	50,870	0,74	4,85	6,24	6,53	1,29
Zab.	31,617	1,34	10,54	5,98	7,86	0,57
F-East.	33,190	0,65	1,91	2,82	2,92	1,47
Network	17,103	0,62	1,99	1,89	3,21	0,95

n^{sub}_{dep} is number of facts of departure of suburban trains.

The share of delayed trains for each type of train (passenger or suburban) is equal to:

• as per departure of trains:

$$\alpha_{dep} = \frac{n^{del}_{dep}}{n_{dep}} 100 \text{ , \%,} \quad (7)$$

where n^{del}_{dep} is the number of delayed trains (passenger and suburban) at departure;

n_{dep} is the number of events of departure of (passenger or suburban) trains.

• upon arrival at the station of embarkation (disembarkation) or upon arrival at intermediate points:

$$\alpha_{ed} = \frac{n^{del}_{ed}}{n_{ed}} 100 \text{ , \%} \quad (8)$$

where n^{del}_{ed} is the number of delayed passenger trains upon arrival at the station of embarkation (disembarkation) of passenger trains or suburban trains upon arrival at intermediate points;

n_{ed} is the number of events of arrival at the station of embarkation (disembarkation) of passenger trains or at intermediate points of suburban trains.

• upon arrival at the destination station or at terminal points:

$$\alpha_{ar} = \frac{n^{del}_{ar}}{n_{ar}} 100 \text{ , \%} \quad (9)$$

where n^{del}_{ar} is the number of delayed passenger trains upon arrival at the destination station or suburban trains upon arrival at terminal points;

n_{ar} is the number of events of arrival of passenger trains at the destination station or suburban trains at terminal points.

The change in the share of delayed trains for the accounting line «arrival at the station of embarkation (disembarkation)» in comparison with the share for the accounting line «train departure» is determined by the formula (also for suburban trains upon arrival at intermediate points):

$$z_{ed/sent} = \frac{\alpha_{ed}}{\alpha_{sent}} . \quad (10)$$

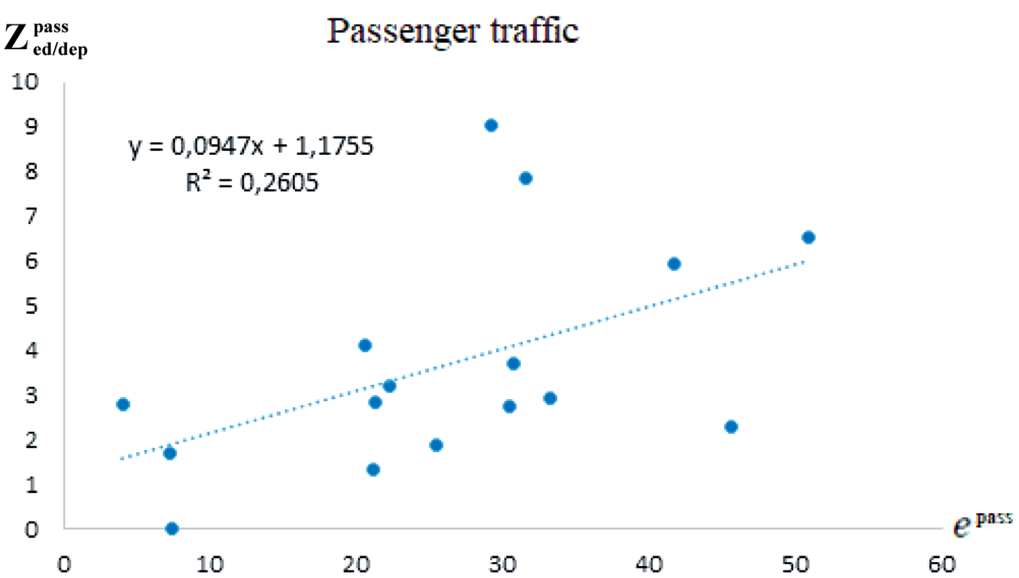
Of interest is also the effect of the share of arrivals at stations of embarkation (disembarkation) on the share of delays on arrival:

$$z_{\frac{ar}{ed}} = \frac{\alpha_{ar}}{\alpha_{ed}} . \quad (11)$$

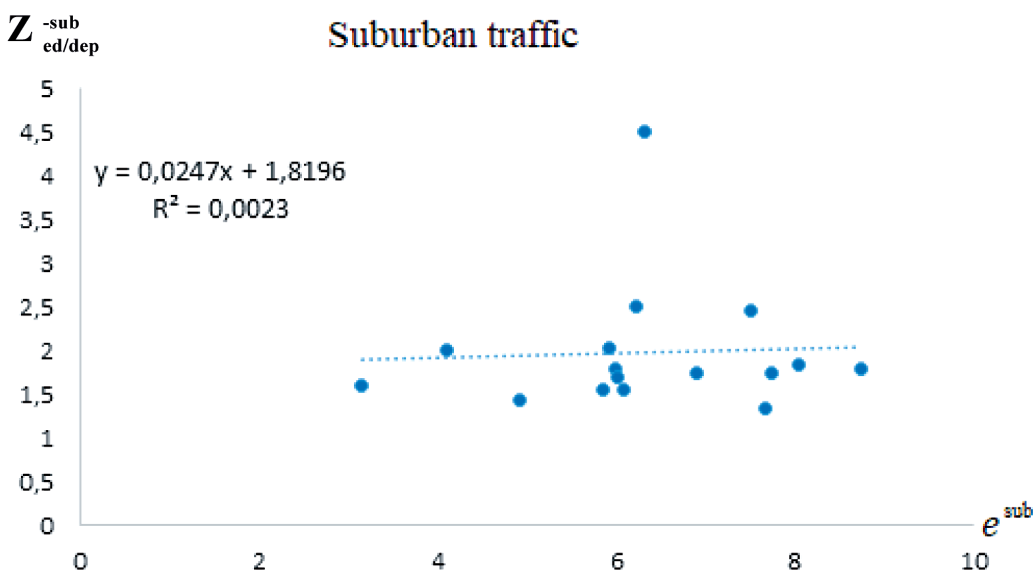
Table 4

Results of calculation of values of e^{sub}, α_{dep}, α_{ed}, α_{ar}, $z_{ed/dep}$, $z_{ar/ed}$ for suburban traffic

Railways	Calculated values					
	e^{sub}	α_{dep}, %	α_{ed}, %	α_{ar}, %	$z_{ed/dep}$	$z_{ar/ed}$
Oct.	5,914	0,44	0,89	0,99	2,02	1,12
Klg	3,158	0,05	0,08	0,13	1,6	1,58
Mosc.	6,095	1,29	2,00	2,50	1,55	1,25
Gork.	5,984	0,30	0,54	0,66	1,80	1,23
North.	8,051	0,60	1,09	1,11	1,83	1,02
N-Cauc.	5,848	0,42	0,66	0,87	1,55	1,32
S-East.	4,919	0,32	0,46	0,55	1,44	1,20
Priv.	7,735	0,40	0,71	0,92	1,75	1,30
Kbsh	8,747	0,36	0,64	0,84	1,79	1,30
Sverd.	7,669	0,80	1,09	1,83	1,35	1,68
S-Ur.	6,896	0,32	0,56	0,77	1,74	1,38
W-Sib.	6,009	0,14	0,24	0,35	1,70	1,45
Kras.	4,109	0,67	1,34	1,80	2,01	1,34
E-Sib.	7,514	0,78	1,91	3,24	2,46	1,70
Zab.	6,309	1,82	8,22	14,24	4,52	1,73
F-East.	6,233	0,52	1,30	1,51	2,50	1,16
Network	6,210	0,82	1,38	1,78	1,68	1,29



Pic. 2. Linear regression of the dependence of the number of delays of passenger trains, moving with station stops along the route, on the number of station stops on the route.



Pic. 3. Linear regression of the dependence of the number of delays for suburban trains, traveling with stops along the route, on the number of stops on the route.

All calculations using formulas (3–11) based on statistical data for 2019 for passenger traffic are summarised in Table 3, and for suburban are shown in Table 4.

The relationship between the number of station stops and the change in the share of delayed trains was verified based on calculation of the determination coefficient (agreement criterion) – R^2 [13], i.e., of variability of $z_{ed/dep}$ (the share of delayed trains in relation to the proportion of trains' departures) in relation to the *e* factor (the ratio of the number of stations stops to the number of departure events). Complete data for all railways for $z_{ed/dep} = f(e)$ in passenger and suburban traffic are shown in Pics. 2 and 3, respectively.

According to the Chaddock scale [13], the value of the coefficient of determination (R^2) in the range from 0 to 0,3 is interpreted as a very weak dependence.

Thus, the number of scheduled station stops along the route has been found to have an insignificant effect on the punctuality of passenger and suburban trains. Consequently, the *e* factor should not be considered when standardising traffic schedule compliance indicators.

For standardising and analysing of the achievement of indicators, the relationship of indicators for departure, transiting and arrival of passenger and suburban trains, which can be established from the statistical data of Tables 1–4, is of interest.

It is worth mentioning high level of punctuality (in %) regarding departures at the integral network level for passenger traffic (99,38 %) and for suburban traffic (99,18 %). Execution of transit punctuality (at intermediate station stops) is reduced, respectively, to 98,01 % and 98,62 %. Punctuality on arrival is close to transit punctuality: 98,22 % and 98,11 %, respectively.

Comparison of these results, achieved on JSC Russian Railways network, with published foreign data, indicates the steady work of domestic railways to comply with the traffic schedule regarding passenger traffic. For example, in the UK in the first half of 2010s [14], according to 23 operators of passenger transportation, the maximum level reached 96,7 %, and 11 operators reached 90 % level, with an average value for all the operators attaining 89,1 %. In 2019 the methodology of assessing punctuality changed. If previously the delay at the destination within 5–10 minutes was only considered, then since 2019 all delays of more than 1 minute and at all the stations are considered[9]. For example, according to data regarding second quarter of the 2020–2021 financial year 2,2 % of scheduled departures (2645696) were cancelled, and the cancellation score moving annual average was of 3 %. Based on data on 17792303 station stops en route, 79,3 % of them were on time (within 1 minute), and on time moving annual average was of 71, 2 %. 92, 5 % of station stops en route were within 3 minutes delay, so moving annual average was of 87, 2 %. 99,3 % of station stops were within 15 minutes delay interval, so moving annual average was of 98,7 %[10].

The situation in EU countries was different at the beginning and through first half of 2010s. According to the data [15], on some sectors of French railways, passenger trains deviated for more than 10 % from the timetable, but only 29 % of such delays were related to external reasons and problems of infrastructure maintenance. In suburban traffic of Hamburg (Germany), the timetable compliance was 94 % [16], while the transport contract with the company acting as operator of passenger transportation provided for a timetable compliance accuracy of 94,7 %. When assessing the achieved level, the factor of an increase in the volume of traffic in comparison with that provided for in the contract is considered. It became especially difficult to comply with the timetable when the situation complicated due to climatic conditions. It was noted, for example, that on the railways of Germany [17] in the winter months the punctuality could decrease to 77,2 %, and on some days even to 20,5 %.

EU adopted in 2007 (entered into force in 2009) the Regulation (EC) No 1371/2007 of the European Parliament and of the Council of 23 October 2007 on rail passengers' rights and obligations, providing particularly compensation [reimbursement, re-routing, etc.] for delay exceeding an hour depending on the type of travel [18, p. 21, Fig. 7]. Since 2017 its revision has been discussed since its goals have not been fully achieved particularly due to exceptions made by most countries regarding part of not-binding obligations [18, p. 5]. The report highlights substantial differences regarding regularity, collected and published data on punctuality in regional and long-distance traffic in EU countries in 2016 [18, p. 24], as well as correlation of satisfaction of passenger with service provided with punctuality.

The highest level of timetable compliance was achieved on the high-speed railways of Japan [19], where the average delay of trains does not exceed one minute. This is achieved through creation of highly reliable infrastructure and rolling stock and constant measures for their current maintenance and repair.

CONCLUSIONS

Based on the analysis using the example of JSC Russian Railways and on the suggested calculation formulas it is possible to draw a conclusion that the relationship between different passenger traffic indicators can be estimated by the value of z values in formulas (10) and (11). For passenger traffic, these values are equal to 3,2 and 0,95; and for suburban traffic they are 1,7 and 1,3.

It follows from this that punctuality is significantly influenced by the conditions of trains running after their departure from the original point.

The main delays within the Russian rail network are associated with failures of technical means of 1–2 categories [according to classification of failures] which cause train delays. The analysis of failures shows that in the absence of control actions on passenger and suburban trains' traffic after the failure, the level of punctuality would have decreased by about 6–7 %, i.e., to the level of 93–94 %, which would adversely affect the image of JSC Russian Railways in the field of passenger transportation. Indeed, this probable significant reduction in punctuality does not occur due to the control actions of the dispatching staff aimed at making the trains get back on the traffic schedule.

Consequently, in modern conditions, it is extremely important to ensure that the dispatching staff performs traffic control operations at sections and, in general, on railways to allow delayed passenger and suburban trains to come back on the traffic schedule. On the Russian railway network, passenger and freight transport is carried out mainly on the same tracks, often with a high level of the transit capacity use. In these conditions, schedules' delays are recovered due to a shift in the schedule of dedicated schedule slots of freight trains, causing deviations from their schedules.

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[9] [Electronic resource]: https://media.raildeliverygroup.com/news/every-second-counts-as-rail-firms-use-new-punctuality-measures-to-help-improve-performance. Last accessed 15.01.2021.

[10] [Electronic resource]: https://dataportal.orr.gov.uk/popular-statistics/how-many-trains-arrive-on-time/. Lasst accessed 15.01.2021.

This factor should be considered when standardising the performance indicators of freight train traffic schedules.

The proximity of the values of α_{ed} and α_{ar} indicates the possibility of reducing the number of standardised indicators in passenger traffic. It is advisable to maintain two indicators, for example, the punctuality of departure and of arrival, since the value of γ_{ar} essentially includes the indicator γ_{ed}.

The proposals developed in the article seem expedient to be considered to improve the system of standardisation of punctuality indicators.

REFERENCES

1. Abdul Sukor, Nur Sabahiah; Subramaniam, Moganraj; Masirin, Mohd Idrus Mohd. Punctuality of Intercity Trains and Passengers' Perspective towards Arrival Time Delay. *Research Journal of Applied Sciences, Engineering and Technology*, 2013, Vol. 5, Iss. 6, pp. 1998–2002. DOI: 10.19026/rjaset.5.4741 Last accessed 15.01.2021.

2. Goverde, R. M. P. Punctuality of Railway Operations and Timetable Stability Analysis. PhD thesis. TRAIL Thesis Series no. T2005/10. The Netherlands TRAIL Research School [Netherlands Research School on Transport, Infrastructure and Logistics], 2005, 293 p. [Electronic resource]: http://resolver.tudelft.nl/uuid:a40ae4f1-1732-4bf3-bbf5-fdb8dfd635e7. Last accessed 15.01.2021.

3. Grechi, D., Maggi, E. The importance of punctuality in rail transport investigation on the delay determinants. *European Transport/Trasporti Europei, Eur. Transp. Trasp. Eur.*, 2018, Iss. 70, pp. 1–23. [Electronic resource]: http://www.istiee.unict.it/europeantransport/papers/N70/P02_70_2018.pdf. Last accessed 15.01.2021.

4. Palmqvist, C.-W. Delays and Timetabling for Passenger Trains. Doctoral Dissertation. Lund University, Faculty of Engineering, Department of Technology and Society. Bulletin 317, 2019, 104 p. and annexed papers. [Electronic resource]: https://www.trafikverket.se/contentassets/27b69216a6b845efb48ec7dd2bf049ce/carl-william_palmqvist_komplett.pdf. Last accessed 15.01.2021.

5. Garrisi, G., Cervelló-Pastor, C. Train-Scheduling Optimization Model for Railway Networks with Multiplatform Stations. *Sustainability*, 2020, Vol. 12, Iss. 257. DOI:10.3390/su12010257.

6. Olsson, N. O. E. Train punctuality analysis in a rolling stock perspective. *Transportation Research Procedia*, Vol. 47, pp. 641–647. DOI: 10.1016/j.trpro.2020.03.142. Last accessed 15.01.2021.

7. Nyström, B. Aspects of Improving Punctuality. From Data to Decision in Railway Maintenance. Doctoral thesis. Luleå University of Technology, Department of Civil, Mining and Environmental Engineering, Division of Operation and Maintenance Engineering, 2008, 101 p., appendixes. [Electronic resource]: http://ltu.diva-portal.org/smash/get/diva2:999787/FULLTEXT01.pdf. Last accessed 15.01.2021.

8. Soltani, S. Investigating the Effect of Trackwork on Punctuality of Swedish Railways. Master's thesis in Project Management (Supervisor N. Ollson). Norwegian University of Science and Technology, Faculty of Economics and Management, Department of Industrial Economics and Technology Management, June 2019. [Electronic resource]: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2632047/no.ntnu%3Ainspera%3A2523332.pdf?sequence=1&isAllowed=y. Last accessed 15.01.2021.

9. Økland, A., Olsson, N. O. E. Punctuality development and delay explanation factors on Norwegian railways in the period 2005–2014. *Public Transport*, 2021, Vol. 13, pp. 127–161. Published online 9 June 2020. DOI: https://doi.org/10.1007/s12469-020-00236-y.pdf. Last accessed 15.01.2021.

10. Palmqvist, C.-W., Olsson, N. O. E., Winslott-Hiselius, L. Some influencing factors for passenger train punctuality in Sweden. *International Journal of Prognostics and Health Management* (IJPHM Special Issue on Railway Systems & Mass Transportation), 2017, Vol. 8, Iss. 3. DOI: https://doi.org/10.36001/ijphm.2017.v8i3.2649. Last accessed 15.01.2021.

11. Avdovsky, A. A., Badaev, A. S. [*et al*]. Organisation of railway passenger transportation: a textbook [*Organizatsiya zheleznodorozhnykh passazhirskikh perevozok: Uchebnoe posobie*]. 5th ed. Moscow, Publishing Center «Academy», 2013, 256 p. [Electronic resource]: https://fileskachat.com/download/44528_5b63ab34eae0c771c15f4b269a94a5f8.html. Last accessed 15.01.2021.

12. Mekhedov, M. I., Sotnikov, E. A., Mekhedova, E. A. Development of a system of indicators of punctuality of passenger and suburban trains for railways and the network as a whole [*Razvitie sistemy pokazatelei vypolneniya raspisaniya dvizheniya passazhirskikh i prigorodnykh poezdov dlya zheleznykh dorog i seti v tselom*]. *VNIIZhT Bulletin*, 2020, Iss. 4, pp. 183–190. DOI: https://doi.org/10.21780/2223-9731-2020-79-4-183-190. Last accessed 15.01.2021.

13. Ishkhanyan, M. V., Karpenko, N. V. Econometrics. Pairwise regression: Study guide [*Ekonometrika. Parnaya regressiya: Ucheb. posobie. Chast' I*]. Moscow, MIIT, 2016, 117 p. [Electronic resource]: https://docplayer.ru/45933548-Kafedra-matematika-m-v-ishhanyan-n-v-karpenko-ekonometrika-chast-i-parnaya-regressiya-uchebnoe-posobie.html. Last accessed 15.01.2021.

14. Sherrat, Ph., Mikes, T. Steady performance decline. *Modern Railways*, 2016, Vol. 73, No. 813, p. 13.

15. Mauvais jours pour la ponctualite des trains. *La Vie du Rail hebdo*, 2017, No. 3621, p. 9. [Electronic resource]: https://www.laviedurail.com/magazines-archives/la-vie-du-rail-hebdomadaire/3621_LVDR/. Last accessed 15.01.2021.

16. Hamburg's S-bahn sets a precision record. *Zheleznye dorogi mira*, 2011, Iss. 2, p. 5. [Electronic resource: https://www.elibrary.ru/download/elibrary_16365723_51685922.pdf. Last accessed 15.01.2021.

17. Winter Train Delays in Germany. *Zheleznye dorogi mira*, 2011, Iss. 2, p. 2. [Electronic resource]: https://www.elibrary.ru/download/elibrary_16365723_51685922.pdf. Last accessed 15.01.2021.

18. Le suivi de la qualité de service et des droits des passagers dans le transport ferroviaire de vouageurs en Europe et en France. [Electronic resource]: http://autorite-transports.fr/wp-content/uploads/2018/12/le_suivi_de_la_qualite_de_service_et_des_droits_des_passagers_dans_le_transport_ferroviaire_de_voyageurs_en_europe_et_en_france_novembre_2018.pdf. Last accessed 15.01.2021.

19. Punctuality Tokyo style: Modern Railways, February 2019, pp. 76–79. [Electronic resource]: https://www.keymodernrailways.com/article/punctuality-tokyo-style. Last accessed 15.01.2021. ●