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Comparative analysis of the degree of influence of factors on the speed of trains (using the example of Uzbek railways)

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Abstract: The main objective of the work is to conduct a comparative analysis of the impact of the main factors on train speeds on the normative and implemented train traffic schedule indicators. This was done using systematic, analytical, factor and tabular analyses. The train traffic speeds on the railway sections of the regional railway nodes of “UTY” JSC were systematically analyzed for the period 2011-2022, and as a result, the main factors that significantly negatively affect the actual implementation of the established normative speed values (replacement of train locomotives, the number of seasonal freight trains, stopping times at stations along the route, the number of seasonal passenger trains) were identified. The shares of the degree of influence of the identified main factors on the speed of freight trains on the railway sections were determined according to the criteria of weak, medium and strong. It was determined that the share of the main factors influencing the speed of freight trains on the railway sections under the jurisdiction of “UTY” JSC is weak - 32%, medium - 44% and strong - 24%. The method of systematic analysis of factors makes it possible to reasonably establish the values of train speeds in the production process and predict them on a daily, quarterly and annual basis.

Keywords: Train speed, factor, systematic analysis, comparative analysis, railway section

1. Introduction

One of the important tasks of the railway transport management system is the delivery of cargo and passengers in accordance with the established technical standards of the train traffic schedule (TTS) based on the daily planned performance indicators [1-4]. In this regard, the level of actual implementation of such indicators as technical equipment, movement speeds, type of traction supply, transportation and throughput capacity of railway sections attached to railway enterprises (regional railway nodes (RRN)) is of great importance [5, 6].

When standardizing the values of train speeds, the existing capacity of railway sections, the standard interval time, and the flow of freight and passenger trains are taken into account. However, the share of constant factors affecting the speed of movement during train movement is not taken into account. In particular, the number of high-speed passenger trains on railway sections, the traction force of locomotives, the variability of seasonal train flows, inefficient waiting of trains at stations, etc [1, 4, 7-9].

It is advisable to assess the values of train speeds for the next day, quarter and year by comparing the share of factors with the level of influence of established technical standards and the indicators actually achieved.

2. Research methodology

For comparative analysis of the speed indicators in the train movement graph, the following analytical methods are used: ((1)÷(3)- expressions) [1, 7]:

running speed

$$\vartheta_{run} = \frac{L_{sec}}{t_{run}} \qquad (1)$$

technical speed

$$\vartheta_{tech} = \frac{L_{sec}}{t_{run}+\sum t_{ac/sl}} \qquad (2)$$

section speed

$$\vartheta \frac{L_{sec}}{t_{run}+\sum t_{ac/sl}+\sum t_{in.st}}_{sec} \qquad (3)$$

here L_{uch} – length of specific railway sections, km;

t_{yur} – the time spent on trains moving at the set speed on the sections, hours;

$\sum t_{or.st}$ – time spent by freight trains on technological operations at intermediate stations and passing trains in the opposite direction, hours;

$\sum t_{t/s}$ – time spent by trains on acceleration and deceleration, hours;

These analytical expressions ((1)÷(3)) allow for the assessment of daily operational indicators on railway sections and planning for future periods. In particular, they allow for the comparison of daily operational indicators of the normative and implemented TTS, the determination of the reserve carrying capacity of sections, and the analysis of factors that negatively affect the established technical standards of movement speeds.

To stabilize transportation processes on the railway network, automated information systems have been developed and put into practice instead of information systems. These systems create opportunities for operational management of train movements on railway sections and assessment of their technical and economic efficiency [3]. For a comprehensive assessment of the TTS, a mathematical method has been developed for calculating the capacity of freight trains during periods when railway sections are devoid of passenger trains [8]

$$N_{fr}^{max\,min\left(\sum_{i=1}^{n\Sigma}\frac{\Delta t_{zon}^{i}}{T_{int}}()\right)} \qquad (4)$$

there

N_{fr}^{max} – The TTG has a maximum number of freight train movements during the period when the passenger is free of the train zone;

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Δt_{zon}^{i} – Time in the TMG in the freight train running zone, minutes.

T_{int} – interval time between trains, minutes;

1 – Extra train for fast TMG conversion.

In [9], a method for estimating the speed of a section was developed, taking into account factors that indicate the daily movement of freight trains.

$$\vartheta\left(1-A\frac{T}{1440}\right)_{run_{sec}} \quad (5)$$

here

A – correlation coefficient of factors affecting the movement of freight trains;

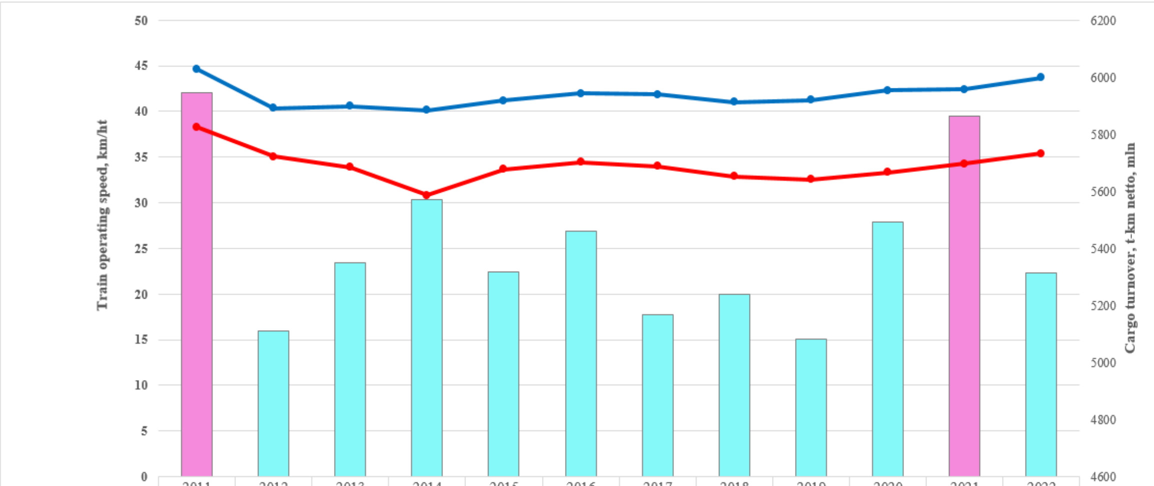
T – total travel time of freight trains on railway sections, minutes;

ϑ_{run} – speed of freight trains, km/h;

The author developed a method for analyzing and estimating section speed, taking into account random factors *(A)* affecting the movement of freight trains on railway sections, the speed of travel on sections, and the total time spent on the movement of freight trains during the day *(T)*.

3. Result and discussion

The impact of freight turnover on train speeds on railway sections within the regional railway hubs of "UTY" JSC was analyzed for the period 2011-2022 (Figure 1).



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
cargo turnover	5945,177	5110,539	5348,995	5572,463	5316,148	5461,527	5167,718	5240,92	5081,737	5492,225	5865,642	5313,071
plot speed	38,27	35,07	33,9	30,81	33,66	34,46	33,99	32,9	32,55	33,34	34,28	35,4
technical speed	44,64	40,35	40,58	40,14	41,18	41,98	41,84	41,05	41,28	42,31	42,42	43,7

Fig. 1. Dynamics of the degree of influence of the amount of cargo turnover on train speeds on railway sections within the regional railway nodes of JSC "UTY"

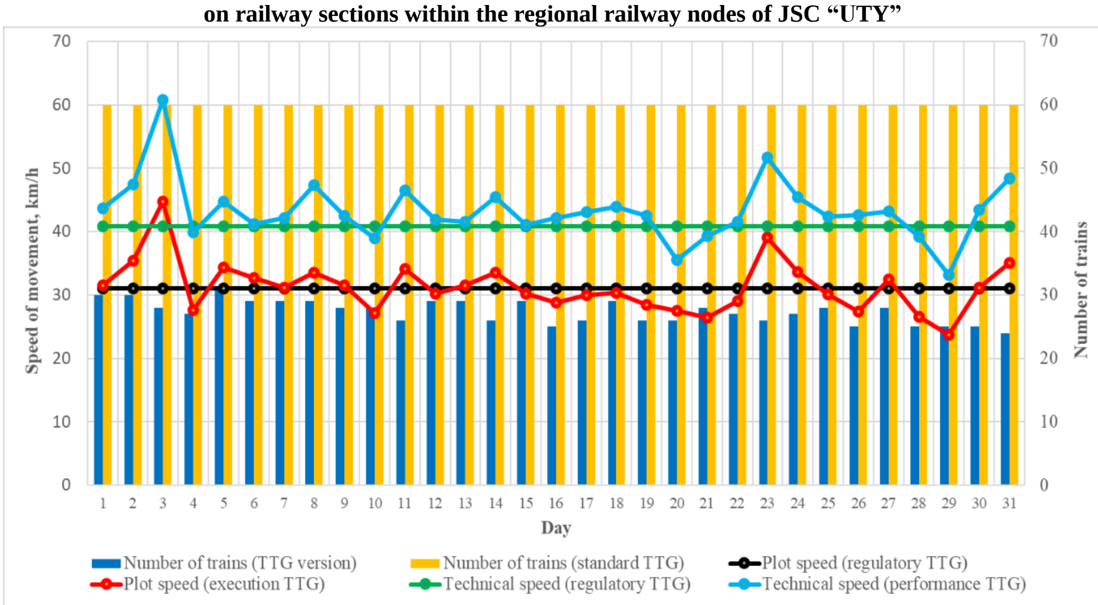


Fig. 2. Comparative analysis of the daily volume of freight trains in relation to technical and section speeds and the main indicators of the normative and implemented TTS (Uzbekistan-Khovos-Jizzakh)

The results of the analysis show that the dynamics of annual freight turnover (increase and decrease) does not significantly affect the speed of freight trains (SFT). Therefore, the factor of increase or decrease in the amount of freight turnover does not play a significant role in establishing the technical standards of SFT for specific sections and routes of "UTY" JSC.

Based on the statistical data of "UTY" JSC, a comparative analysis of the impact of the number of freight trains on the SFT (Uzbekistan-Khovos-Jizzakh) was carried out (Table 1). The comparative analysis was carried out for December, when the number of trains was the highest. Based on the data obtained from the analysis results, the impact of the change in the daily number of freight trains on the technical and section speeds and the main indicators of the normative and implemented SFT (Uzbekistan-Khovos-Jizzakh) was presented in the form of a diagram (Figure 2).

The technical and section speeds were determined as 41.8 and 32.95 km/h, respectively, when the average number of freight trains on the normative TTS was 21 pairs. The technical and section speeds were analyzed as 43.3 and 27.3 km/h, respectively, when the average number of freight trains on the operational PHG in December 2022 was 14 pairs. A comparative analysis of the main indicators of the normative and operational TTS showed that the number of freight trains was 7 pairs less, the technical speed was 1.5 km/h higher on average, and the section speed was 5.6 km/h lower.

In the analyzed month (Table 1), it can be seen that, in accordance with the change in the daily volume of freight trains, that is, on days when the number of trains increased, technical and section speeds decreased by more than 90% (for example, days 4 and 29), and in about 10% of cases, TTS indicators increased.

Table 1

Comparative analysis of the impact of the number of freight trains on the railway section "Uzbekistan-Khovos-Jizzakh" (December 2022)

Day	Distance traveled, km	Dwell times, hours	Time in motion, hours	Number of freight trains	Site speed, (average) km/h	Technical speed, (average) km/h
1	3351,4	29,51	76,74	30	31,54	43,67
2	3519,4	25,18	74,18	30	35,42	47,44
3	3930,7	23,13	64,72	28	44,74	60,73
4	2887,1	32,16	72,34	27	27,63	39,91
5	3304,1	22,56	73,78	31	34,30	44,78
6	3057,6	19,31	74,17	29	32,71	41,22
7	3074,3	25,78	72,89	29	31,16	42,18
8	3308,9	28,75	69,94	29	33,53	47,31
9	3080,6	25,14	72,48	28	31,56	42,50
10	3138,6	35,01	80,69	28	27,13	38,90
11	3002,9	23,55	64,51	26	34,10	46,55
12	3001,2	27,73	71,68	29	30,19	41,87
13	3151,4	23,97	75,89	29	31,56	41,53
14	2795,9	22,01	61,46	26	33,50	45,49
15	3128,6	27,27	76,08	29	30,27	41,12
16	2595,3	28,33	61,65	25	28,84	42,10
17	2699,9	27,26	62,71	26	30,01	43,05
18	3128,4	31,77	71,26	29	30,36	43,90
19	2758,5	32,12	65,01	26	28,40	42,43
20	2420,7	20,16	68,03	26	27,45	35,58
21	2659,5	33,02	67,71	28	26,40	39,28
22	2872,9	29,93	69,15	27	29,00	41,55
23	3086,8	19,42	59,66	26	39,03	51,74
24	2813,6	21,55	61,99	27	33,68	45,39
25	2679,6	25,83	63,19	28	30,10	42,41
26	2887,7	37,59	67,71	25	27,42	42,65
27	3079,3	23,47	71,31	28	32,49	43,18
28	2530,3	30,77	64,51	25	26,56	39,22
29	2921,7	35,15	88,14	25	23,70	33,15
30	2961,21	26,88	68,11	25	31,17	43,48
31	2833,93	22,38	58,53	24	35,03	48,42
General	**92662,04**	**836,69**	**2150,22**	**848**	**31,02**	**43,09**

It can be seen that the factors influencing the organization of train movement on the comparatively analyzed railway section have different effects on the level of fulfillment of the SFT normative values. In particular, it can be seen that the factors analyzed as the main factors (replacement of train locomotives, the number of seasonal freight trains, stopping times at stations along the route, the number of seasonal passenger trains) have high levels of influence.

Factors with high levels of influence have shown the feasibility of analyzing technical, technological, permanent and random factors affecting the RRT on railway sections not only in groups, but also in a comparative analysis of the main factors on specific sections [2, 10]. Therefore, the sections of the regional railway junction unitary enterprises (RRJUE) under the jurisdiction of UTY JSC (Tashkent RRN (Uzbekistan-Khovos-Jizzakh, Tashkent junction, Sergeli-Angren-Khojikent), Bukhara RRN (Khovos-Jizzakh-

Maroqand, Maroqand-Bukhara-Khojidavlat, Tinchlik-Uchkuduk 2-Misken, Bukhara-Misken), Kokand RRN (Kokand-Margilan Karasuv, Khovos-Kokand-Akhunboboyev, Pop-Angren), Karshi RRN (Bukhara-Karshi-Maroqand), Termez RRN (Tashguzar-Boysun-Kumqorgon, Karshi-Termez-Sarosiyo), Qongorod RRN (Qongorod-Taxiyatosh-Urgench-Misken-Nukus, a comparative analysis was carried out on the example of the main factors influencing the RRN on the Kungirat-Jaslyk-Qaraqalpak section.

The comparative analysis was carried out on the example of the following main factors:

- replacement of train locomotives;
- seasonal number of freight trains;
- stopping times at stations along the route;
- seasonal number of passenger trains.

In this case, the impact of the above factors on the reduction of the normative values of the SFT in the section of the RRN sections was analyzed comparatively based on the criteria of weak, medium and strong (Table 2).

Table 2

Results of assessment of the impact of the main factors on the level of safety of railway sections under the control of "UTY" JSC

Impact level criteria	RRJUE Tashkent			RRJUE Bukhara				RRJUE Kokand		RRJUE Karshi	RRJUE Termez		RRJUE Qongorod	
	Uzbekistan-Khovos-Jizzakh	Tashkent junction	Sergeli-Angren-Khojikent	Khovos-Jizzakh-Maroqand	Maroqand-Bukhara-Khojidavlat	Tinchlik-Uchkuduk 2-Misken	Bukhara-Misken	Kokand-Margilan Karasuv	Khovos-Kokand-Akhunboboyev	Bukhara-Karshi-Maroqand	Tashguzar-Boysun-Kumqorgon	Karshi-Termez-Sarosiyo	Qongorod-Taxiyatosh-Urgench-Misken-Nukus	Kungirat-Jaslyk-Qaraqalpak
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
replacement of train locomotives														
Weak			+			+			+					+
Average		+			+			+				+	+	
Strong	+			+			+			+	+			
seasonal number of freight trains														
Weak			+					+			+			+
Average		+			+	+	+		+	+		+	+	
Strong	+			+										
stopping times at stations along the route														
Weak			+				+				+		+	+
Average		+			+	+		+	+			+		
Strong	+			+						+				
seasonal number of passenger trainsr														
Weak							+		+			+	+	+
Average			+		+	+		+		+	+			
Strong	+	+		+										

From the results of the assessment of the degree of influence of factors on the SFT, it can be seen that, except for the factor of the number of seasonal freight trains of the Tashkent RRN (Table 2), the degree of influence of all types of factors on the SFT is the same, that is, from 33.3% (strong - 33.3%, weak - 33.3%, average - 33.3%).

Based on the results presented in Table 2, the share of the degree of influence of each factor (replacement of train locomotives, number of seasonal freight trains, stopping times at stations along the route, number of seasonal passenger trains) on the SFT was assessed in the RRN section (Figures 3÷6).

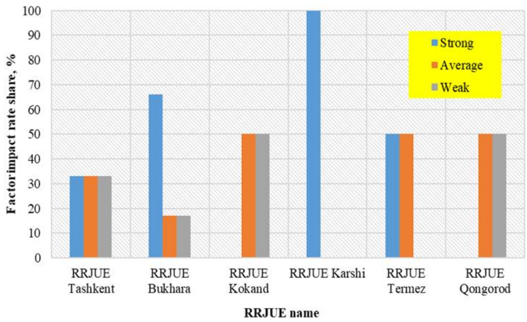


Fig. 3. The share of the impact of the locomotive replacement factor on the SFT of the RRJUEs under the jurisdiction of "UTY" JSC

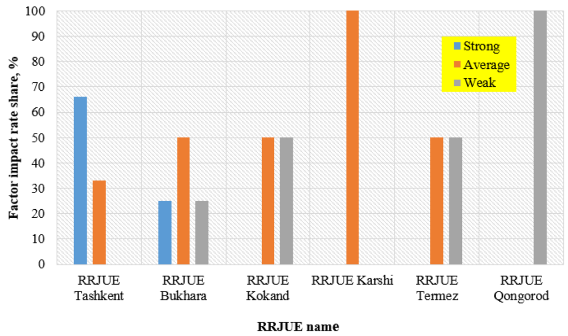


Fig. 4. The share of the impact of the seasonal freight train volume factor on the SFT for RRJUEs under the jurisdiction of "UTY" JSC

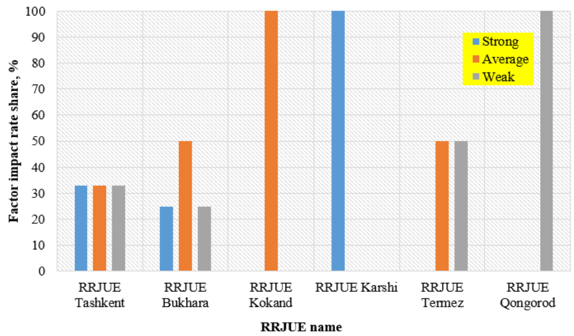


Fig. 5. The share of the impact of the factor of stopping times at stations along the route on the SFT for RRJUEs under the jurisdiction of "UTY" JSC

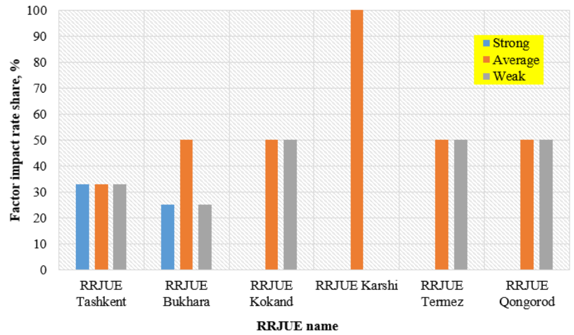


Fig. 6. The share of the impact of the seasonal passenger train volume factor on the SFT for RRJUEs under the jurisdiction of "UTY" JSC

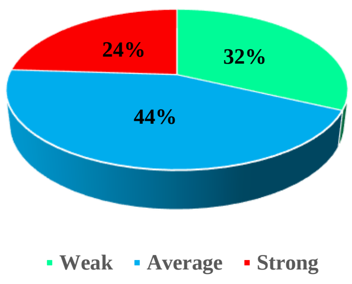


Fig. 7. The share of the main factors influencing the level of road safety on railway sections under the control of UTY JSC

The impact of factors that strongly influence the SFT is not significant. From the results presented in Figures 3÷6 and Table 1, it can be concluded that the negative impact of the main factors on the implementation of the SFT normative values is high. That is, the level of impact according to the strong and medium criteria is more than 60%. It can be seen that the negative impact of the main factors on the SFT on the railway sections under the control of "UTY" JSC is high (68% (strong - 24%, medium - 44%)) (Figure 7).

4. Conclusion

A comparative analysis of the degree of influence of the main factors on the speed of trains was conducted on the section of railway sections within the framework of the Tashkent State Railways and Transport Corporation under the jurisdiction of "UTY" JSC. The criteria for the degree of influence on the speed of trains (weak, medium, strong) on the sections of the railway sections of the RRN were assessed. As a result, it was possible to predict the daily, quarterly and annual indicators of the impact on the level of implementation of the established normative values of the RRN and the factors analyzed as the main indicators. A comparative comparative analysis of the main indicators of the normative and implemented speed of trains was carried out on the "Uzbekistan-Khovos-Jizzakh" railway section within the framework of the Tashkent State Railways and Transport Corporation under the jurisdiction of "UTY" JSC based on statistical and practical data.

The comparative analysis showed that despite the different number of freight trains in the implemented TTS during the days of December 2022, it was determined that the train speeds were at the lowest values on the 4th and 29th. Therefore, in the future, when establishing technical standards for the SFT on specific railway sections and routes under the jurisdiction of "UTY" JSC, it was proposed to establish TTS indicators based on the results of the comparative analysis.

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