JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 04, ISSUE 09
MOPNTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

CALCULATION OF THE THROUGHPUT AND PROCESSING CAPACITIES OF THE "Q" STATION

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Abstract. The purpose of the work is to determine the current throughput and processing capabilities of the "Q" station, taking into account changing operating conditions. Statistical analysis and analytical methods were used in the work. The workload of station "Q" was analyzed in the context of its fleets in a daily mode, and as a result, it was established that the train downtime is 187 hours and 41 minutes. The throughput and processing capacities of the station were determined by analytical methods, taking into account changing operating mode conditions. According to the calculation results, it was established that the "weak spot" in the operation of the "Q" station is a sorting hill. In order to improve the operation of the "Q" station, such proposals were made as the automatic centralization of the sorting hill, the system of automatic identification of rolling stock, and the optimization of the number of personnel processing rolling stock.

Keywords: Station, throughput capacity, processing capacity, variable operating mode, analytical method, vulnerability, sorting hill.

INTRODUCTION

One of the main goals of any type of transport is to provide timely, complete and high-quality transportation needs of the population in constantly changing conditions [1]. In particular, one of the urgent issues is the development of infrastructure for freight and passenger transportation in railway transport based on the demand for transportation volumes in the railway market. In this regard, the condition of the infrastructure of railway stations is of great importance for the efficient and smooth organization of the transportation process.

The Resolution of the President of the Republic of Uzbekistan No. PQ-329 dated October 10, 2023 "On measures to radically reform the railway transport sector of the Republic of Uzbekistan" [1] focuses on the fundamental reform of the sector, in particular, on improving transportation processes by creating competition in the transportation services market and creating an attractive investment environment. To implement these tasks, it is advisable to increase the throughput and processing capabilities of railway stations, taking into account changing operating modes.

LITERATURE ANALYSIS AND DISCUSSION

Many scientists have conducted scientific research on calculating the throughput and processing capabilities of railway stations in different years [2-4]. Analytical, graphical, tabular, mathematical and simulation modeling methods were used in this. Most scientists, despite the high level of error, widely used the analytical method, which is convenient for performing calculations [2].

Analytical methods were also used to calculate the throughput and processing capabilities of the "Q" station, taking into account the conditions of variability of the station operating mode [3].

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Table 1 presents analytical formulas for determining the throughput and processing capabilities of stations.

Table 1

Formulas for determining the throughput and processing capabilities of railway stations

№	Station name	Formulas for the throughput and processing capabilities
1	Technical (section, sorting)	$N_{thr.c.}^{RP(SP,DP)} = \frac{1440\ Z^{RP(SP,DP)} - T_{break.}}{t_{busy.}^{aver.}}\ m, train$
2	Technical (sorting hill)	$n_{proc.}^{hill.} = \frac{\sigma_{opp.rout.}\ 1440 - T_{oper.}^{hill.}}{t_{hill.}\ м_{proc.}\ (1 + c_{hill.})}\ m_{tar.}, train$
3	Technical (traction track)	$n_{proc.}^{break.} = \frac{(1440 - T_{oper.}^{break.})\ m_{aver.}}{t_{aver.}}, wagon$

Note: RP – receiving park; DP – departure park; SP – sorting park.

there 1440 – minutes of the day;
$Z^{RP(SP,DP)}$ – the number of existing roads in the park (excluding the traction track);
m – average number of wagons in a train;
$t_{busy.}^{aver.}$ – average track occupancy time by one train, minutes;
$T_{break.}$ – total time of breaks in the use of tracks to receive trains, minutes;
$T_{oper.}^{hill.}$ – time of occupancy of the sorting hill during the day (for performing continuous operations not related to the sorting of process), minutes;
$t_{hill.}$ – sorting hill technological interval, minutes;
$\alpha_{rec.m.}$ – A coefficient that takes into account possible interruptions in hill work due to opposing routes;
$\mu_{proc.}$ – a coefficient that takes into account the re-sorting of some wagons due to the insufficient number and length of sorting tracks;
$c_{hill.}$ – coefficient taking into account the failure of technical devices;
$m_{sor.}$ – number of wagons in the sorting line;
$T_{oper.}^{break.}$ – time of continuous operation of the traction track (irrespective of the volume of work), minutes;
m_{aver} – average number of wagons in the train;
$t_{aver.}$ – time taken by the locomotive to sort one train on the traction track, minutes.

RESULTS AND DISCUSSION

The current throughput and processing capabilities of the "Q" station, which is part of the "Karshi" regional railway junction branch under the jurisdiction of "Temiryo'linfratuzilma" JSC of "Uzbekistan railways" Joint Stock Company ("O'TY" JSC), were calculated. It was determined that the calculations would be carried out through a systematic analysis of the station's operation. The analysis was carried out in the following sequence according to the daily workload:

1) Trains arriving at and departing from station "Q";

Table 2

Information on received and departed trains (07.05.25)

Train number	Time of arrival at the station, hours and minutes	Received track number	Stopping time, minutes	Time of departure from the station, hours and minutes	Train type and destination
Receiving and departure park (RP-DP)					
6317	7:40	2	30	08:10	Suburban (B-K)
3471	9:10	10	-	-	Assembled (D-T)
2401	9:40	2	35	10:15	Passing (A)
768	10:10	1	445	17:35	Afrosiyob (T-Q)
2564	10:45	8	385	17:10	Passing (G‘)
2206	11:35	5	215	15:10	Passing (R)
3601	13:35	9	345	18:40	Assembled (Q-Q-or)
3004	13:40	10	90	15:10	Sectional (Q-T)
3017	14:00	7	-	-	Assembled (Q-M)
3602	14:50	4	80	16:10	Sectional (Q-SH)
716	14:15	2	715	17:40	Nasaf (T-Q)
2403	17:30	3	50	18:20	Passing (A)
6318	18:00	1	25	18:25	Suburban (K-B)
2024	19:40	8	160	22:00	Passing (G‘)
2510	20:00	7	210	22:30	Passing (G‘)
2208	21:00	5	180	23:00	Passing (R)
2003	20:35	4	80	21:55	Passing (A)
2204	20:50	8	190	23:00	Passing (R)
129	22:37	1	23	23:00	Passenger (A-T)
3471	00:01	10	-	-	Assembled (Q-T)
79	00:59	1	36	1:35	Passenger (T-T)
3004	2:10	10	-	-	Sectional (Q-B)
704	2:33	1	218	6:15	Passenger (Q-T)
80	2:58	2	50	3:48	Passenger (T-T)
3473	4:10	10	-	-	Assembled (Q-T)
3002	4:40	5	85	5:45	Assembled (Q-S)
130	5:52	2	24	6:16	Passenger (T-A)
3001	6:01	10	-	-	Assembled (Q-T)
Total			59:51		
Departure park (DP)					
3442	5:40	31	190	10:50	Assembled (Q-K)
3054	9:20	34	180	13:10	Sectional (Q-T)
3056	10:00	36	200	14:30	Sectional (Q-T)
3457	12:20	32	180	16:40	Assembled (Q-B)
3431	17:40	31	150	19:20	Assembled (Q-B)

2206	21:00	35	210	2:10	Passing (R)
3602	2:40	33	180	4:50	Sectional (Q-Sh)
2364	5:40	31	200	9:50	Passing (G‘)
3401	6:10	32	180	-	Assembled (Q-M)
Total			27:50		
Sorting park (SP)					
3471	10:00	23	10:50	450	Assembled (Q-T)
3457	12:00	17	13:00	560	Assembled (Q-B)
3431	15:00	19	16:20	480	Assembled (Q-Bu)
3017	18:30	21	19:20	650	Sectional (Q-T)
2364	20:20	27	21:20	760	Sectional (Q-B-suv)
2208	23:30	25	00:10	440	Passing (R)
2003	1:50	19	2:30	500	Passing (A)
3431	4:30	18	5:30	860	Assembled (Q-K)
3602	5:40	20	6:30	850	Sectional (Q-Sh)
3455	6:40	22	7:30	450	Assembled (Q-S)
Total			100:00		

As can be seen from the data presented in Table 1, the total time spent by trains at the station during the day is 187 hours and 41 minutes. Such delays, in turn, negatively affect the throughput and processing capabilities of the station.

2) conditional length of trains arriving at and departing from station “Q” (Figure 1);

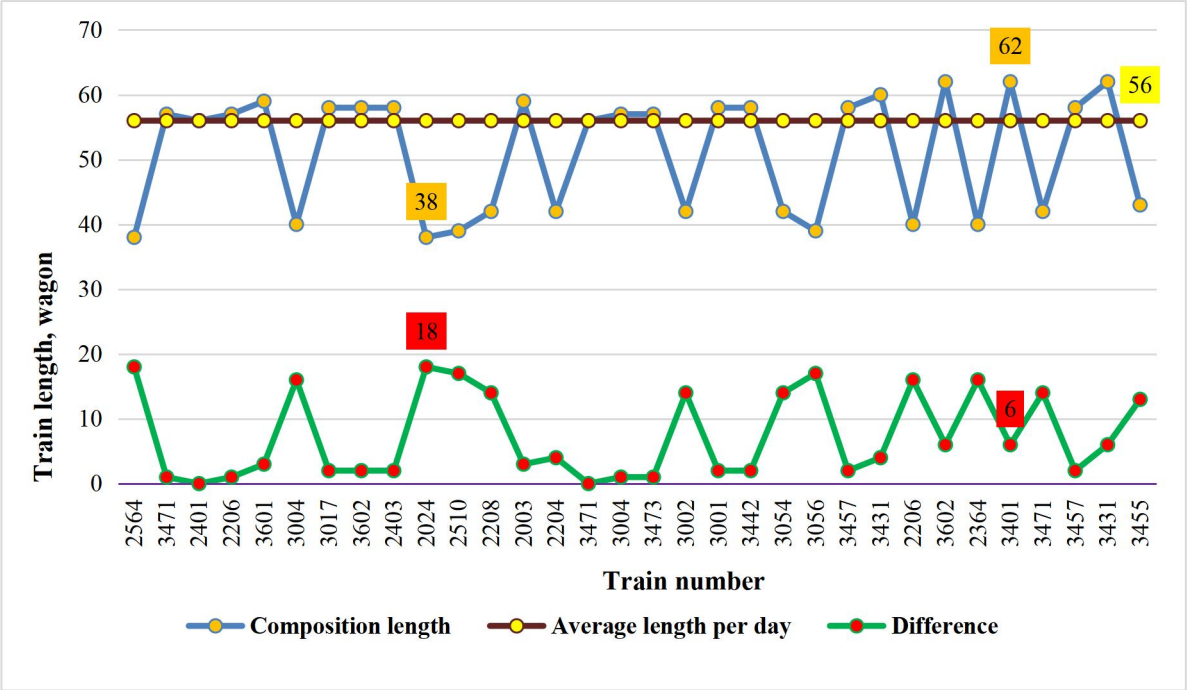

Figure 1. Dynamics of the conditional length of trains (07.05.25)

From the analysis of the actual use of the track lengths of the RPDP, SP and DP parks, it can be concluded that the train lengths of the trains processed and formed at the station are different.

3) Calculation of the throughput capacity of the “Q” station park;

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The throughput capacity of the RPDP, SP, and DP of the "Q" station was calculated according to formula (1) in Table 1.

"In this case, based on the TBD of "Q" station, the values are Z^{RPDP}-10, Z^{DP}-7, and Z^{SP}-16. The average number of wagons per train was assumed to be 56 wagons. The total time of breaks in the use of tracks for train reception is 240 minutes."

The average occupancy time of a track by one train was determined using the following formula:

$$n_{proc.}^{hill.} = \frac{\sigma_{opp.rout.}\ 1440 - T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{tar.}, train$$

$$t_{busy}^{aver} = \frac{N_1\ t_1 + N_2\ t_2 + N_3\ t_3 + N_4\ t_4 + N_5\ t_5}{N}, hour$$

there $N_1, N_2, N_3, N_4, N_5 -$ the number of trains forming at the station, respectively, transit, group, section, combined;

$t_1, t_2, t_3, t_4, t_5 -$ the time when a single train is occupied by transit, group, section, assembly, and station-formed trains, respectively.

The duration of train processing at the "Q" station according to the TIJ: RPDP - 80 minutes; DP - 180 minutes.

Calculation of the throughput capacity of the RPDP:

Based on the technological workflow (TIJ)

$$N_{thr.c.}^{RPDP} = \frac{1440\ Z^{RPDP} - T_{break.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 10 - 240}{80 + 50}\ 56 = 6100\ \text{wagon};$$

In practice

$$N_{thr.c.}^{RPDP} = \frac{1440\ Z^{RPDP} - T_{break.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 10 - 240}{110 + 50}\ 56 = 4956\ \text{wagon};$$

"Calculation of the throughput capacity of the departure park (DP).":

Based on the TIJ

$$N_{thr.c.}^{DP} = \frac{1440\ Z^{DP} - T_{break.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 7 - 240}{80 + 50}\ 56 = 4239\ \text{wagon};$$

In practice

$$N_{thr.c.}^{DP} = \frac{1440\ Z^{DP} - T_{break.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 7 - 240}{130 + 50}\ 56 = 3062\ \text{wagon};$$

"Calculation of the throughput capacity of the sorting park (SP).":

Based on the TIJ

$$N_{thr.c.}^{SP} = \frac{1440\ Z^{SP} - T_{braek.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 16 - 240}{450}\ 56 = 2838\ \text{wagon};$$

In practice

$$N_{thr.c.}^{SP} = \frac{1440\ Z^{SP} - T_{braek.}}{t_{busy.}^{aver.}}\ m = \frac{1440\ 16 - 240}{600}\ 56 = 2128\ \text{wagon}.$$

The calculation results were presented in the form of a histogram (Figure 2).

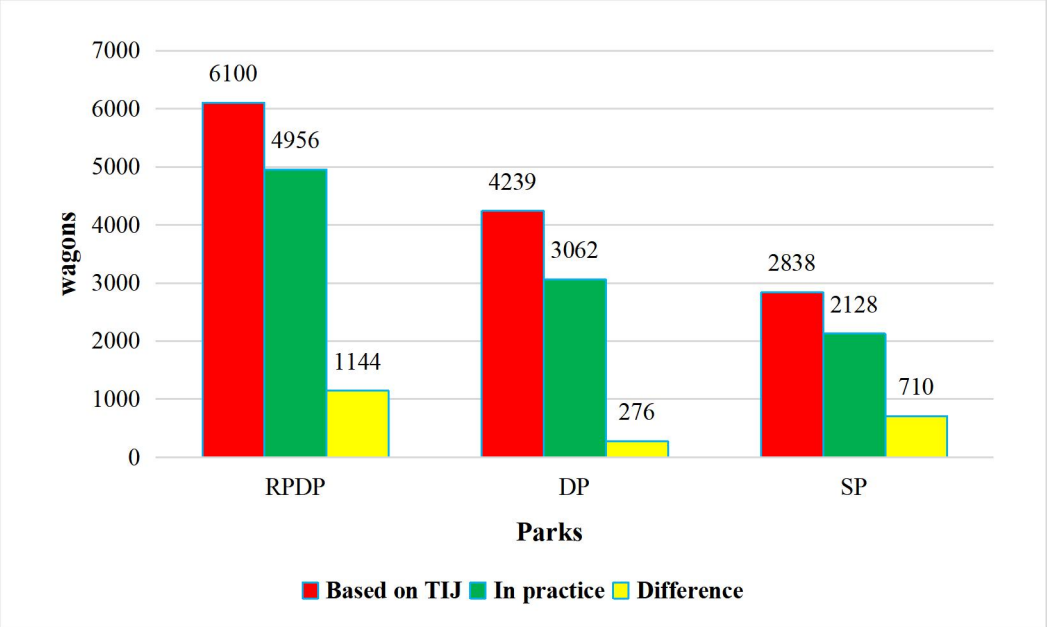

Figure 2. Throughput capacity of the "Q" station parks

The calculation results show that there is a difference of 276 to 1,144 wagons in practice, based on the TIJ.

4) Analysis of the sorting hill and traction track operations at "Q" station (Tables 2 and 3);

Table 3

Trains processed on the traction track

Train number	Number of wagons in the train composition	Time spent by the locomotive to break up one train composition on the traction track, minutes	Time of the traction track being occupied with regular operations, minutes	Train type
3442	57	28	45	Terma (Q-K)
3054	38	24	35	Uchastka (Q-T)
3056	40	25	35	Uchastka (Q-T)
3457	56	26	40	Terma (Q-B)
3431	58	28	45	Terma (Q-B)
2206	40	24	35	O'tkinchi (R)
3602	59	30	45	Uchastka (Q-Sh)
2364	41	24	40	O'tkinchi (G')
3401	63	32	50	Terma (Q-M)
Total (average)	50,2	27	06:10	

Calculation of the traction track processing capacity

$$n_{proc.}^{break.} = \frac{(1440 - T_{oper.}^{break.})\ m_{aver.}}{t_{aver.}}, wagon$$

there $T_{oper.}^{break.}$ – The time during which the road is occupied by continuous operations (irrespective of the volume of work) $T_{oper.}^{break.}$ – 40 minutes;

m_{aver} – the average number of wagons in the train (56 wagons according to the report of the "Q" station);

$t_{aver.}$ – Time spent by the locomotive to break up one train composition on the traction track (according to "Q" station's TIJ — 26 minutes).

Based on the TIJ

$$n_{proc.}^{break.} = \frac{(1440 - T_{oper.}^{break.})\ m_{aver.}}{t_{aver.}} = \frac{(1440 - 40)\ 56}{26} = 3016 \text{ wagon;}$$

In practice

$$n_{proc.}^{break.} = \frac{(1440 - T_{oper.}^{break.})\ m_{aver.}}{t_{aver.}} = \frac{(1440 - 42)\ 51}{27} = 2641 \text{ wagon;}$$

Table 3

Trains being processed on the sorting hill

Train number	**Number of wagons in the distributed composition**	**Sorting hill technological interval**	**Daily technological breaks, minutes**
3471	57	45	190
3457	58	50	200
3431	59	52	180
3017	56	42	190
2364	38	35	150
2208	40	35	150
2003	56	40	190
3431	57	45	200
3602	60	50	210
3455	56	40	180
Total (average)	53,7	43,4	184

Calculating the processing capacity of a sorting hill

$$n_{proc.}^{hill.} = \frac{\sigma_{rec.m}\ 1440 - T_{oper.}^{hil.}}{t_{hill}\ \mu_{proc.}\ (1 + c_{hill.})}\ m_{diss.}, wagon$$

there $\alpha_{rec.m.}$ – "Coefficient $\alpha_{q.m.}$=0,97, which accounts for possible interruptions in sorting hill operations due to opposing routes."

$t_{hill.}$ – "Technological interval of the sorting hill (based on TIJ at "Q" station – 40 minutes).";

$\mu_{proc.}$ – "Coefficient accounting for the re-sorting of some wagons due to the

insufficient number and length of sorting tracks (1.05 for sorting systems with departure parks, and 1.12 for systems without departure parks);

$c_{hill.}$ – "Coefficient accounting for failures of technical equipment (0.06–0.08)."

$m_{aver.}$ – "Number of wagons in the train to be dispatched (56 wagons)."

$T_{oper.}^{hil.}$ – "Daily occupancy time of the sorting hill (technological breaks for crew changes – 2*30=60 minutes, repairs of hill equipment – 60 minutes, preparation of locomotives and performing routine operations – 60 minutes; total – 180 minutes.

"Based on TIJ (including the time for placing wagon groups onto SP tracks – 5 minutes)."

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 180}{44\ 1,05\ (1 + 0,06)}\ 56 = 1531 \text{ wagon;}$$

In practice

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 184}{40\ 1,05\ (1 + 0,06)}\ 54 = 1338 \text{ wagon;}$$

"Based on TIJ (excluding the time for placing wagon groups onto SP tracks – 5 minutes)."

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 180}{35\ 1,05\ (1 + 0,06)}\ 56 = 1749 \text{ wagon;}$$

In practice

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 184}{39\ 1,05\ (1 + 0,06)}\ 54 = 1509 \text{ wagon;}$$

"Based on TIJ (excluding the time for placing wagon groups onto SP tracks – 5 minutes – and the time required for repairing the sorting hill equipment – 60 minutes)."

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 120}{35\ 1,05\ (1 + 0,06)}\ 56 = 1836 \text{ wagon;}$$

In practice

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 124}{39\ 1,05\ (1 + 0,06)}\ 54 = 1583 \text{ wagon;}$$

"Based on TIJ (considering the time for placing wagon groups onto SP tracks – 5 minutes – and not considering the time required for repairing the sorting hill equipment – 60 minutes)."

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 120}{40\ 1,05\ (1 + 0,06)}\ 56 = 1606 \text{ wagon;}$$

In practice

$$n_{pros.}^{hill.} = \frac{\sigma_{rec.m.}\ 1440 - \ T_{oper.}^{hill.}}{t_{hill.}\ \mathcal{M}_{proc.}\ (1 + c_{hill.})}\ m_{diss.} = \frac{0,97\ 1440 - 124}{44\ 1,05\ (1 + 0,06)}\ 54 = 1404 \text{ wagon;}$$

The calculation results are compared in Figure 3.

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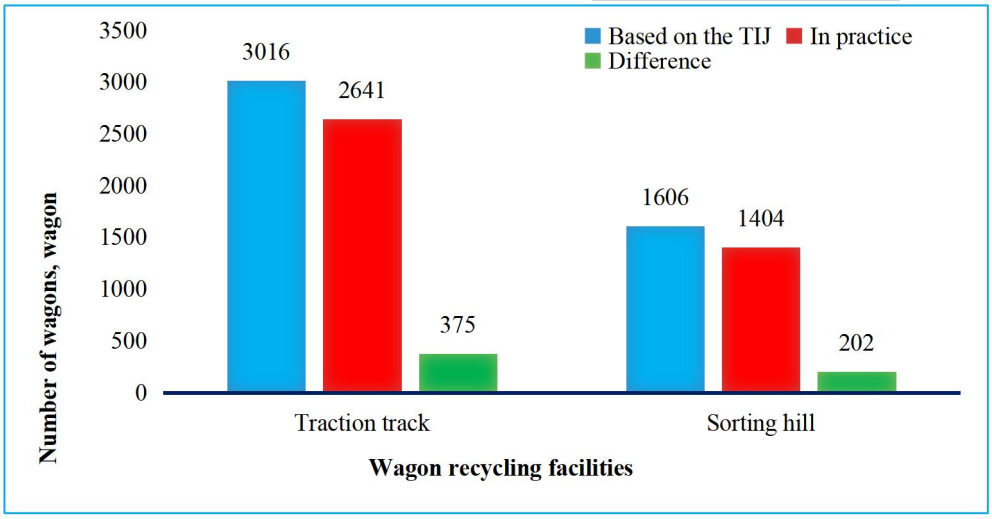

Figure 3. Capacity of wagon processing facilities at Station "Q"

The following conclusions can be drawn from Figure 3:

TIJ: According to the option that does not take into account the time required to place groups of wagons on the sorting hill (5 minutes) and repair the hill equipment (60 minutes): 1538÷1836 wagons.

In practice: According to the option, taking into account the placement of wagon groups on the sorting hill (5 minutes) and excluding the time required for repairing the hill equipment (60 minutes): 1404÷1606 wagons.

The analysis results revealed that the processing capacity of the sorting hill was 202 wagons short of the TIJ. Therefore, it is advisable to modernize the technical parameters of the sorting hill based on the volume of work.

RPDP: TIJ – $N_{thr.c.}^{RPDP}$=6500 vagon; In practice – $N_{thr.c.}^{RPDP}$=4956 wagon.

DP: TIJ – $N_{thr.c.}^{DP}$=3360 vagon; In practice – $N_{thr.c.}^{DP}$=3062 wagon.

SP: TIJ – $N_{thr.c.}^{SP}$=2365 vagon; In practice – $N_{thr.c.}^{SP}$=2128 wagon.

Traction track throughput capacity: TIJ – 3016 wagon; In practice – 2641wagon.

Sorting hill throughput capacity: TIJ – 1606÷1836 wagon; In practice –1404÷1583 wagon.

According to the results of the calculations performed above, it was determined that the "Weak spot" in the operation of station "Q" is the sorting hill (Figure 4).

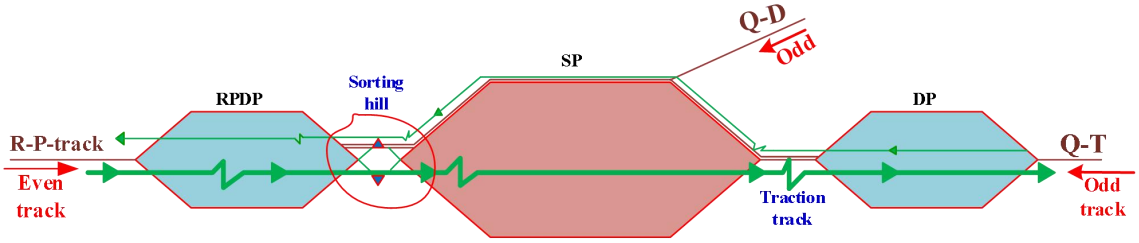

Figure 4. The "Weak spot" in the operation of the "Q" station

CONCLUSION

It was determined that it is urgent to increase the throughput and processing capabilities of the station, taking into account the unevenness of the freight and passenger flows passing through the station during the railway transportation process and the constant variability under

the influence of external factors. Based on this, the current state of the throughput and processing capabilities of the "Q" station was calculated based on real operating indicators, and based on the results, it was determined that the "Weak point" in the station's operation is the sorting hill.

Therefore, it is recommended to carry out the following measures to improve the operation of the "Q" station:

- introduction of modern technical means (for example, the use of automatic centering of the hill) - the processing capacity of the sorting hill will increase by 3-4 thousand wagons per day;

- introduction of modern innovative technologies (for example, an automatic rolling stock identification system) - rapid acquisition of information about the location of locomotives and wagons at any time;

- optimization of the number of personnel processing the trains - increased productivity.

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