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STUDY OF CAR TRAFFIC FLOW STRUCTURE ON ARRIVAL AND DEPARTURE AT THE MARSHALLING YARD X

Purpose. The paper is aimed to analyse the existing car traffic organization at the marshalling yard aimed to reduce downtime of cars. **Methodology.** The methods of mathematical statistics allowed building the histogram of car traffic flow distribution at the marshalling yard and assessment of their parameters. The key quantitative and qualitative indicators of the station operation were analyzed. In order to analyze the effect of rehandling volume on the rehandled transit car downtime elements at the station we plotted the dependence graph of the car downtime elements on the rehandling volume. The curve variation on the graph clearly shows the effect of rehandling volume on two downtime elements: during formation and in expectation of operations. **Findings.** The question of reducing the average downtime of all car categories at the station should be solved by reducing unproductive downtime was proved. The correct determination of the average time spent by a rehandled transit car at the station is essential, especially in the conditions of new system of economic incentives. But still there is no separate methodology for determining the car downtime, which would allow to objectively consider the equipment and operation technology and exclude the possibility for subjective decisions. **Originality.** One of the main kinds of unproductive downtime during the carriage of goods by rail is a downtime on the marshalling yards in expectation of technological operations because of the system congestion. Reduction of this indicator is possible due to rational use of the marshalling yard capacity provided the rational distribution and car – and train flows between the major marshalling yards of Ukrzaliznytsia. **Practical value.** The analysis of changes in downtime elements, depending on the rehandling volume allows not only to identify the car downtime reduction methods, but also to make a correct assessment of station staff work, as well as to adjust the rate of idle wagons.

Keywords: car traffic flow; marshalling yard; rehandling volume; downtime of cars; formation parameter

Introduction

The marshalling yard is a complex set of technologically interrelated elements intended for car flow rehandling.

Marshalling yards of Ukrainian railway network are usually located at the junctions. They rehandle the flows coming from different directions. These stations were always the busiest and the capacity of the entire line is dependent on them as 70% of all car traffic flows are rehandled at the junctions. That is why, the question of improvement of marshalling yard operation at the junctions is of high importance.

Behavior of incoming and outgoing flows is one of the most important requirements for the components taken into account when describing the performance of any queuing system.

Train arrival analysis was investigated by the scientists V. M. Akulinichev, T. V. Butko, N. N. Shabalin, I. B. Sotnikov, K. K. Tal, P. S. Hruntovy, A. M. Makarochkin and others [1-14]. The studies have shown that the distribution of intervals between them with a sufficient degree of accuracy can be approximated by the exponential law or generalized Erlang law and in rare cases – by Erlang law of a higher order.

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Purpose

Analysis of the existing car traffic organization at the marshalling yard aimed to reduce downtime of cars.

Methodology

Using the methods of mathematical statistics we build the histograms of car traffic flow distribution at X marshalling yard and assess their parameters (mathematical expectation, standard deviation, variation coefficient, irregularity coefficient) [1, 2, 14].

Of the total car traffic flow of the station we should distinguish the car flows in unpaired and paired directions. The general car traffic flow includes the cars of working and non-working fleet. The working cars in their turn depending on the destination station are divided into transit (with and without rehandling) and local ones [3-6].

For transit car traffic flow without rehandling, given the negligible downtime at the station and a small amount of coupled and uncoupled cars, it is possible to assume that the ingoing flow equals the outgoing one for the selected period. To determine the average value, variance and standard deviation the month car flow must be divided into intervals. Calculation of average values of the intervals in ranges, their share of the total interval weight and variances of daily transit car flow without rehandling is shown in the text. Daily transit car traffic flow without rehandling is broken into 100 *car.* intervals.

Average daily transit car traffic flow without rehandling in unpaired direction N_{av}= 537 *car*. The variance describes the deviation of the actual number of car traffic flow from the average value and equals 28 809 *car*^{2}. For ease of comparison of the car traffic flow average value and the deviation of actual car traffic flow from this average value one uses the standard deviation that equals $\sigma = 170$ *wag*. Histogram of daily transit car traffic flow volume without rehandling in unpaired direction is shown in Fig. 1.

Average daily transit car traffic flow without rehandling in paired direction N_{av}= 620 *car*. The variance is 65108 *car*^{2}. Standard deviation is $\sigma = 255$ *car.* Histogram of daily transit car traffic flow volume without rehandling in paired direction is shown in Fig. 2.

Average total daily transit car traffic flow without rehandling N_{av} = 1151 *car*. The variance is 106881 *car*^{2}. Standard deviation is $\sigma = 327$ *car*. Histogram of total daily transit car traffic flow volume without rehandling is shown in Fig. 3.

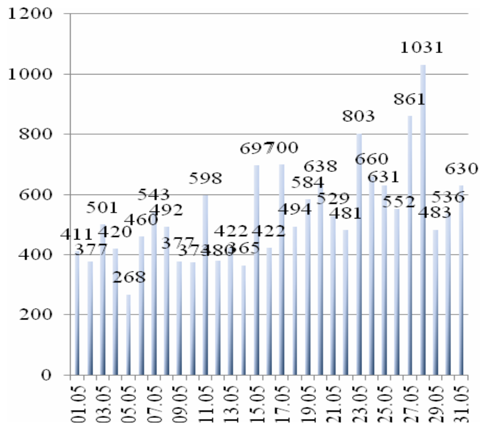

Fig. 1. Histogram of daily transit car traffic flow volume without rehandling in unpaired direction

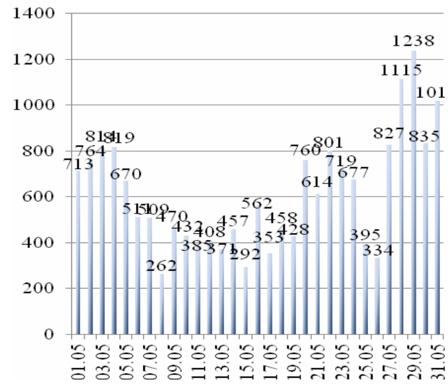

Fig. 2. Histogram of daily transit car traffic flow volume without rehandling in paired direction

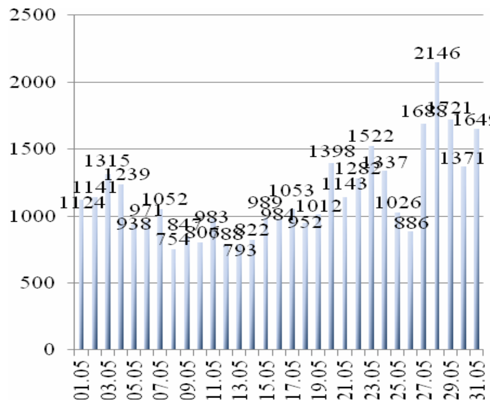

Fig. 3. Histogram of total daily transit car traffic flow volume without rehandling

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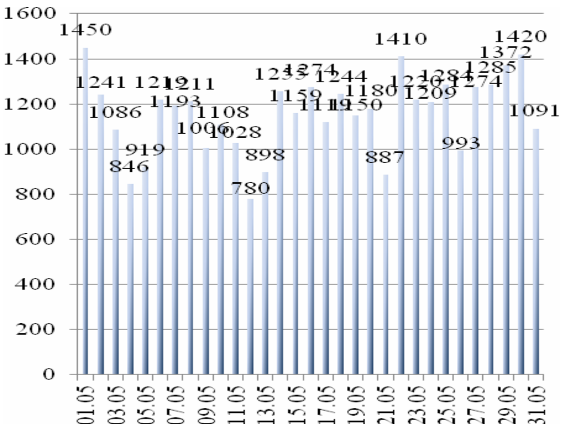

Fig. 4. Histogram of daily rehandled transit and local car traffic flow volume

Transit flow with rehandling can be combined with local one due to the fact that both car categories arrive in trains rehandled at X station. The ingoing flow does not equal to the outgoing one for a certain period because of the considerable time of car stay at the station and the corner flow.

Average rehandled transit and local car traffic flow on arrival from unpaired direction is N_{av} = 1 154 car. The variance is 31 291 car^2. Standard deviation is $\sigma = 177$ car. Histogram of daily rehandled transit and local car traffic flow volume on arrival is shown in Fig. 4.

Average daily rehandled transit and local car traffic on arrival from paired direction N_{av}= 808 car. The variance is 17251 car^2. Standard deviation is $\sigma = 131$ car. Histogram of daily rehandled transit and local car traffic flow volume on arrival from paired direction is shown in Fig. 5.

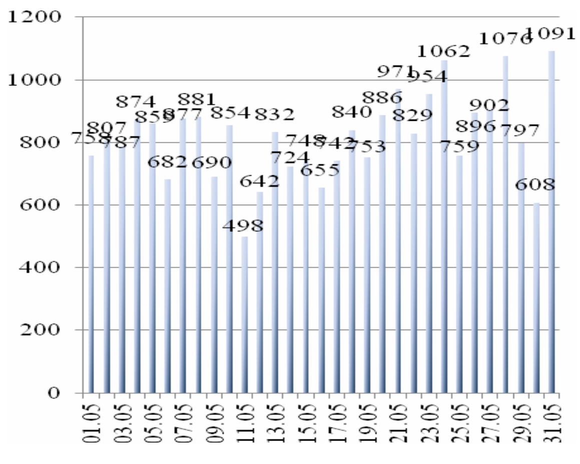

Fig. 5. Histogram of daily rehandled transit and local car traffic flow volume on arrival from paired direction

Average total daily rehandled transit and local car traffic flow on arrival N_{av}= 1970 car. The variance is 42056 car^2. Standard deviation is $\sigma = 205$ *car*. Histogram of total daily rehandled transit and local car traffic flow volume on arrival is shown in Fig. 6.

Average daily rehandled transit and local car traffic flow on departure to unpaired direction N_{av}= 1018 *car*. The variance is 38843 car^2. Standard deviation is $\sigma = 197$ car. Histogram of daily rehandled transit and local car traffic flow on departure to unpaired direction is shown in Fig. 7.

Average daily rehandled transit and local car traffic on departure to paired direction N_{av} = 931 car. Nsr = 931 wt. The variance is 22 145 car^2. Standard deviation is $\sigma = 149$ car^2. Histogram of daily rehandled transit and local car traffic flow on departure to paired direction is shown in Fig. 8.

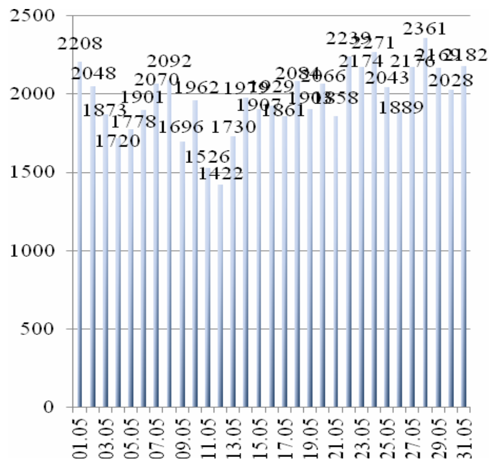

Fig. 6. Histogram of total daily rehandled transit and local car traffic flow volume on arrival

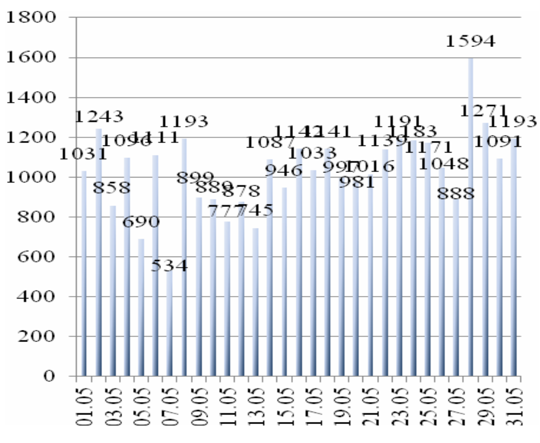

Fig. 7. Histogram of daily rehandled transit and local car traffic flow on departure to unpaired direction

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Average total daily rehandled transit and local car traffic on arrival $N_{av} = 1971$ car. The variance is 85322 car^2. Standard deviation is $\sigma = 292$ car. Histogram of total daily rehandled transit and local car traffic flow on departure is shown in Fig. 9.

Average daily car traffic flows on arrival and departure in unpaired and paired directions for May 2015 are shown in Fig. 10, 11.

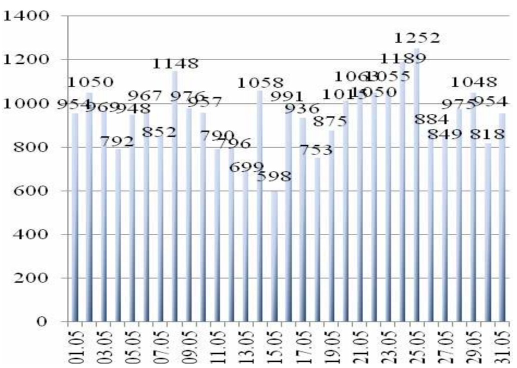

Fig. 8. Histogram of daily rehandled transit and local car traffic flow on departure to paired direction

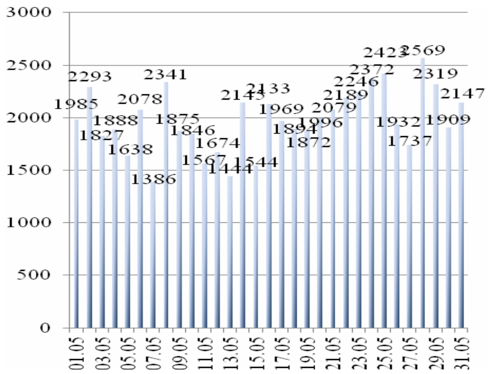

Fig. 9. Histogram of total daily rehandled transit and local car traffic flow on departure

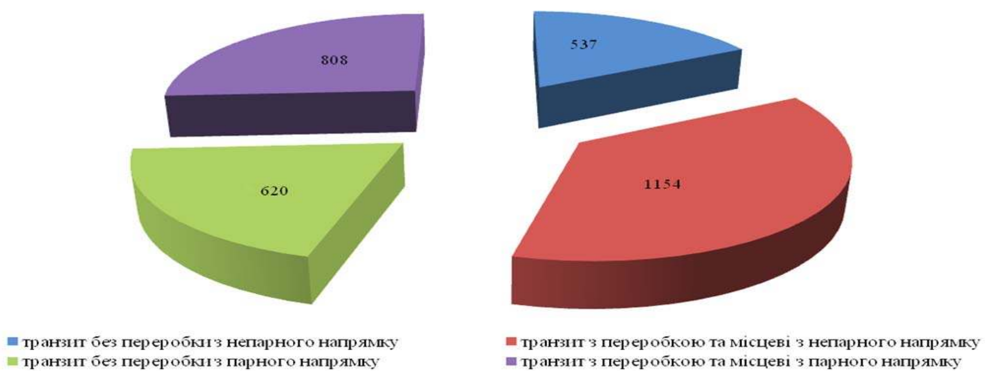

Fig. 10. Histogram of average daily car traffic flow volume on arrival for May 2015

Transit without rehandling from unpaired direction	Transit rehandled and local from unpaired direction
Transit without rehandling from paired direction	Transit rehandled and local from paired direction

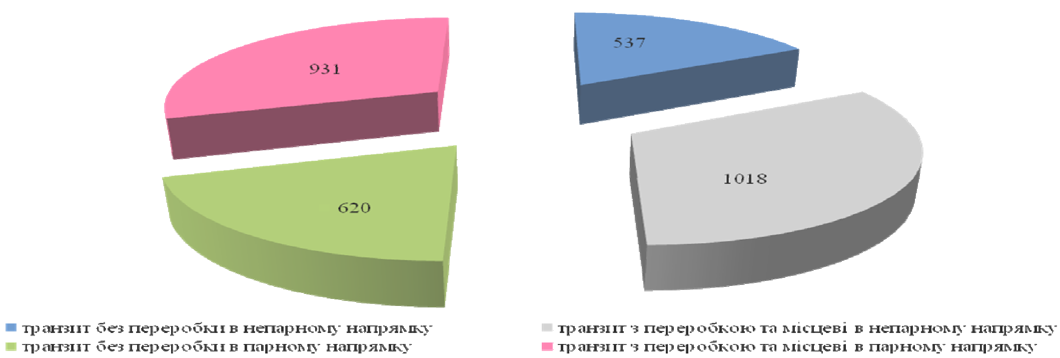

Fig. 11. Histogram of average daily car traffic flow volume on departure for May 2015

Transit without rehandling to unpaired direction	Transit rehandled and local to unpaired direction
Transit without rehandling to paired direction	Transit rehandled and local to paired direction

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Table 1

The annual analysis of total daily transit car traffic flow volume without rehandling at X marshaling yard

№ of range	Range limits		Range centre, min	Number of observa-tions	B_j	N_jB_j	$N_j^2B_j$	h_j
	left	right		K_j				
1	679	862	771	65	0.1781	11.575	752.397	0.000973
2	862	1 045	954	86	0.2356	20.263	1 742.619	0.001288
3	1 045	1 228	1 137	75	0.2055	15.411	1 155.822	0.001123
4	1 228	1 411	1 320	41	0.1123	4.605	188.825	0.000614
5	1 411	1 594	1 503	33	0.0904	2.984	98.458	0.000494
6	1 594	1 777	1 686	28	0.0767	2.148	60.142	0.000419
7	1 777	1 960	1 869	13	0.0356	0.463	6.019	0.000195
8	1 960	2 143	2 052	12	0.0329	0.395	4.734	0.000180
9	2 143	2 326	2 235	7	0.0192	0.134	0.940	0.000105
10	2 326	2 509	2 418	5	0.0137	0.068	0.342	0.000075
Total				365	0.9123	45.866	2 638.677	

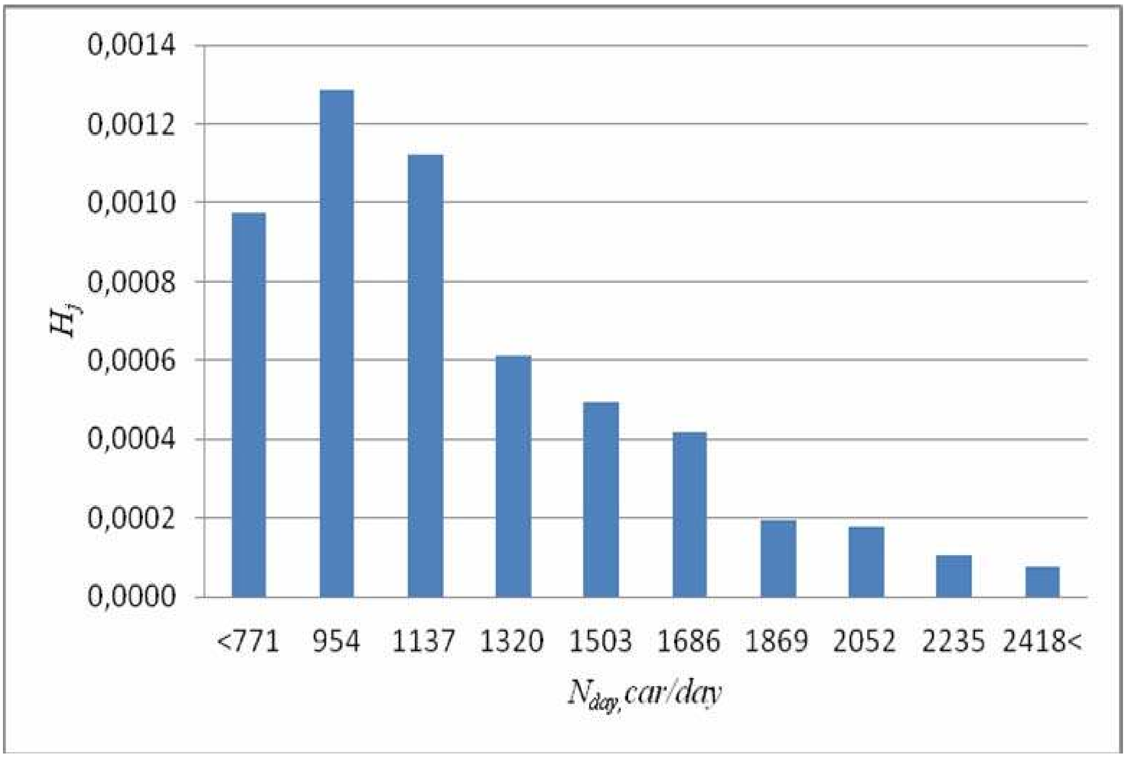

Fig. 12. Histogram of distribution of the total daily transit car traffic flow without rehandling

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Table 2

The annual analysis of total daily rehandled transit and local car traffic flow volume on arrival at X marshaling yard

№ of ranges	Range limits		Range centre, min	Number of observa-tions	B_j	N_jB_j	$N_j^2B_j$	h_j
	left	right		K_j				
1	1 280	1 423	1 352	5	0.1613	0.806	4.032	0.001128
2	1 423	1 566	1 495	17	0.5484	9.323	158.484	0.003835
3	1 566	1 709	1 638	27	0.8710	23.516	634.935	0.006091
4	1 709	1 852	1 781	36	1.1613	41.806	1 505.032	0.008121
5	1 852	1 995	1 924	91	2.9355	267.129	24 308.742	0.020528
6	1 995	2 138	2 067	71	2.2903	162.613	11 545.516	0.016016
7	2 138	2 281	2 210	63	2.0323	128.032	8 066.032	0.014212
8	2 281	2 424	2 353	24	0.7742	18.581	445.935	0.005414
9	2 424	2 567	2 496	19	0.6129	11.645	221.258	0.004286
10	2 567	2 710	2 639	12	0.3871	4.645	55.742	0.002707
Total				365	9.0323	592.645	44 643.226	

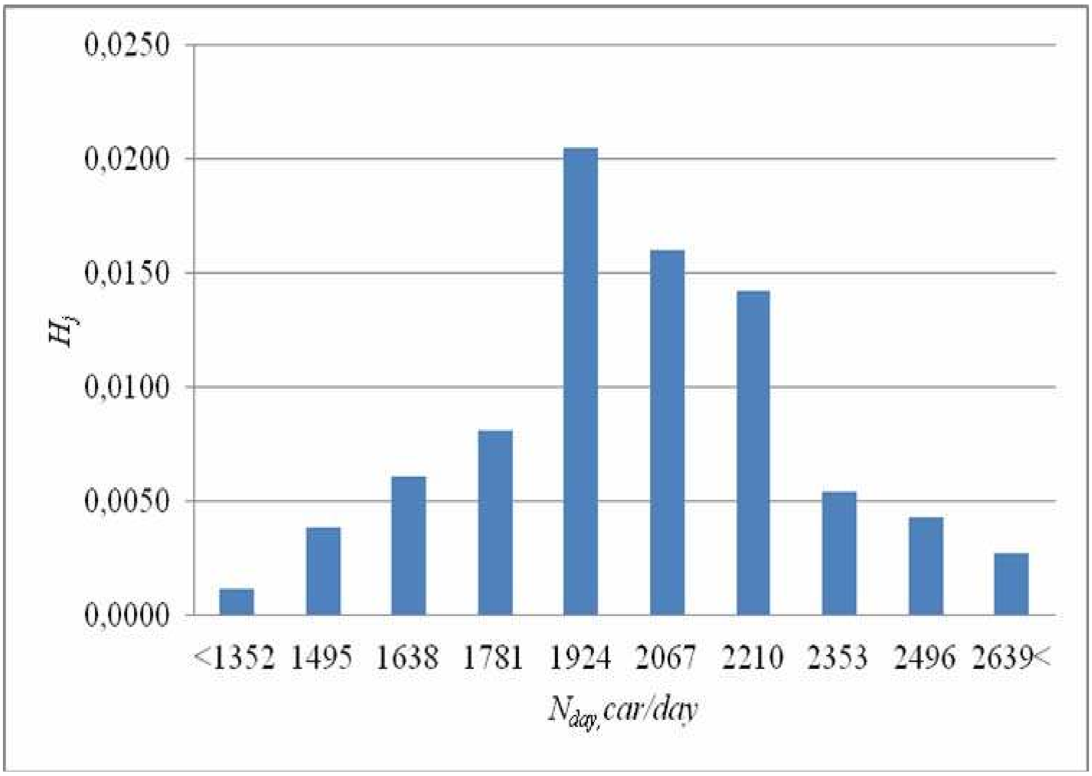

Fig. 13. Histogram of distribution of total daily transit rehandled and local car traffic flow on arrival

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Table 3

The annual analysis of total daily rehandled transit and local car traffic flow volume on departure at O marshaling yard

№№ of ranges	Range limits		Range centre, min	Number of observa-tions	B_j	N_jB_j	$N_j^2B_j$	h_j
	left	rights		K_j				
1	1 247	1 419	1 333	12	0.0329	0.395	4.734	0.000191
2	1 419	1 591	1 505	33	0.0904	2.984	98.458	0.000526
3	1 591	1 763	1 677	35	0.0959	3.356	117.466	0.000558
4	1 763	1 935	1 849	39	0.1068	4.167	162.518	0.000621
5	1 935	2 107	2 021	79	0.2164	17.099	1 350.792	0.001258
6	2 107	2 279	2 193	56	0.1534	8.592	481.140	0.000892
7	2 279	2 451	2 365	51	0.1397	7.126	363.427	0.000812
8	2 451	2 623	2 537	28	0.0767	2.148	60.142	0.000446
9	2 623	2 795	2 709	20	0.0548	1.096	21.918	0.000319
10	2 795	2 967	2 881	12	0.0329	0.395	4.734	0.000191
Total				365	0.9123	45.866	2 638.677	

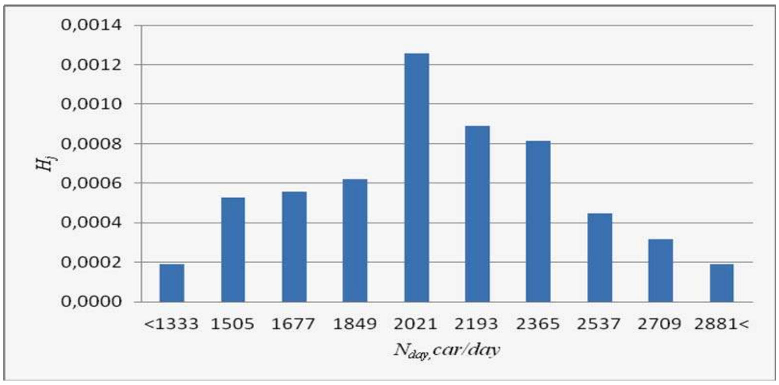

Fig. 14. Histogram of distribution of total daily transit rehandled and local car traffic flow on departure

The law of train arrival distribution is Poisson, and the intervals between them have exponential distribution (see Table 1-3, Fig. 12-14). Irre-gularity of train arrivals affects the station operation and must be taken into account both when developing the procedure and when solving the problems of the station technical equipment. [7-8].

The main indicator of the marshalling yard operation is the average downtime of rehandled transit cars. Station-time of cars consists of the time taken to perform successive operations on individual elements of the rehandling process and downtime in expectation of operations. The correct determination of the average time spent by a rehandled transit car at the station is essential, especially in the conditions of new system of economic incentives. But still there is no separate methodology for determining the wagon downtime, which would allow to objectively consider the equipment and operation technology and exclude the possibility for subjective decisions.

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Total station-time of rehandled transit car consists of the following elements [9-12]:

$$t_{reh} = t_{ha} + t_{qu}^{b} + t_{h} + t_{acc} + t_{qu}^{c} + t_{cc} + t_{hd} + t_{qu}^{d},$$

where t_{ha} − time for train handling on arrival, t_{ha} = 0.35 h; t_{qu}^{b} − average breaking-up queue time, hours; t_{h} – hump train breaking-up interval, t_{h} = 0.37 h; t_{acc} – average downtime of cars during formation, hours; t_{qu}^{c} – average composition queue time, hours; t_{cc} – time for composition completion and train launching to departure yard excluding locomotive return time, t_{cc} = 0.44 h; t_{hd} – time for train pre-departure handling, t_{hd} = 0.5 h; t_{qu}^{d} – departure queue time, hours.

Some downtime elements are the values, determined by the operation procedure and not dependent on the volume of work, which can be expressed as time to complete the operations.

Increase in workload leads to reduced downtime during formation but extends the queue downtime on the subsequent service element. Depending on the operation volume effect on the downtime elements, the latest can be divided into three groups

$$t_{\text{пер}} = (t_{\text{об}} + t_{\text{г}} + t_{\text{ф}} + t_{\text{обр}}) + t_{нак} + (t_{оч}^{р} + t_{оч}^{ф} + t_{\text{оч}}^{\text{о}})$$

Given Pollaczek-Khinchin formula [12], the last three downtime elements can be written as

$$t_{qu}^{b} = \frac{Nt_{h}^{2}(\upsilon_{in}^{2,5} + \upsilon_{h}^{2})}{48\text{-}2Nt_{h}};$$

$$t_{qu}^{c} = \frac{Nt_{c}^{2}(1 + \upsilon_{c}^{2})}{48M\text{-}2Nt_{c}};$$

$$t_{qu}^{d} = \frac{NI_{d}^{2}(1 + \upsilon_{d}^{2})}{48\text{-}2NI_{d}};$$

Average downtime during formation is determined by the formula

$$t_{acc} = \frac{ck}{N},$$

where N – number of trains rehandled at the station per day; k – number of appointments of the trains composed at the station; c – formation parameter.

In order to analyze the effect of rehandling volume on the rehandled transit car downtime elements at the station we plot the dependence graph of the car downtime elements on the rehandling volume. The dependence graph is shown in Fig. 15.

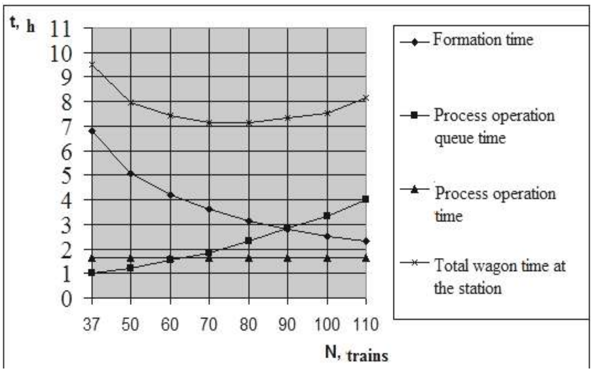

Fig. 15. Dependence of car downtime on rehandling volume

The curve variation on the graph clearly shows the effect of rehandling volume on two downtime elements: during formation and in expectation of operations.

In case of small rehandling volumes the car downtime decrease should be achieved mainly by reducing the car formation costs organizing the approach of locking groups, replacement of one-group minor purpoe trains with the group ones, etc. In case of large rehandling volumes the focus should be given to reducing the time of breaking-up, composition and departure processes, in order to shorten the queue downtime.

The analysis of changes in downtime elements, depending on the rehandling volume allows not only to identify the car downtime reduction methods, but also to make a correct assessment of station staff work, as well as to adjust the rate of idle cars. The station car downtime rate is set for a specified amount of work. But the actual rehandling is different from the scheduled one. In this regard for objective evaluation of station staff work it is necessary to adjust the rate on the amount of work performed.

One of the important elements of the time spent by the cars at technical stations that affects the car traffic management system is car downtime during formation. This downtime may be determined both by total car flow, that is from the moment of arrival at the station of these specific cars and to

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the moment of their departure from the station, and only by the flow at the marshalling track. To plan the composition for a specified period the car downtime during formation is determined with sufficient accuracy by analytical calculations. Analysis of the formation process in different conditions of car approach to the station and its operation makes it possible to determine more precisely the formation parameter *c*, and hence the formation car-hours for individual destinations or total value for the station.

The uncoordinated car approach to the station results in continuous formation process, with some cars queueing for the next train composition. In practice, there is uneven arrival of car groups and in different amounts, thus the formation parameter *c* may differ for certain destinations, and for certain categories of trains with the same destination that depart during the day. The formation parameter *c* is always averaged during the analytical calculations, that is its fluctuations are ignired.

One can conclude that the formation parameter is dependent on uneven approach of car groups to the station, but besdides it is dependent on a significant number of factors that affect the train formation process. The average number of car groups *e*, forming the trains m_{om}, depend on the number of car groups of a specific destination arriving during a certain period (day or $T_{\text{н}}$).

But we need to pay attention to the fact that continuous and uniform flow to the station of car groups with the same volume does not affect the formation parameter. Thus, the formation parameter is dependent on the interval between the car group arrivals, frequency and duration of interruptions in the train formation, the value of completing group, the number of cars in the first and other groups.

Analysis of execution of the main indicators at X station was conducted for the 1st half of 2015 and is presented in Table 13.

Table 4

Analysis of execution of major quantitative and qualitative indicators

Description of indicator	Plan for 1 half year of 2015	Execution			
		1 half year of 2014	1 half year of 2015	Till 2014, %	To plan, %
Total daily departure, incl., car	3 099	5 036	3 002	60	97
– transit with rehandling, car	1 987	2 401	1 940	81	98
– transit without rehandling, car	1 092	2 540	1 002	39	92
– local, car	20	46	17	37	85
Average arrival per day, *train*	62	95	63	66	102
Average departure per day, incl., *train*	60	91	57	63	95
– own composition, *train*	–	47	39	83	-
Operating fleet, car	1 218	1 144	1 165	102	96
Average loading per day, car	–	6	3	50	–
Average unloading per day, car	–	36	7	19	–
Downtime of relandled transit cars, *h*	10.50	10.28	13.05	79	80
Downtime of transit cars without relandling, *h*	1.40	1.37	1.50	91	93
Downtime during 1 load operation, *h*	95.0	154.73	133.02	116	71
Static loading, *ton/car*	48.09	50.19	59.02	118	123
Wagon turnover, *car*	6 199	10 071	5 996	60	97

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Downtime of transit car without rehandling for the I half of 2015 is not executed and makes 1.50 hours, that is overvalued compared to the planned target by 0.10 hours. Total losses in car -hours due to non-execution of downtime for transit car without rehandling make 18,127 car -*h* and occured for the following reasons:

– The target «Locomotive supply queue time» exceeds by 0.08 *h* (losses of 15,436 car -*h*) due to lack of train locomotives and foot-plate staff;

– «Departure queue time» by 0.02 *h* (losses of 2,691 car -*h*) due to occurence of non-productive element:

– Making way for passenger and suburban trains (losses of 217 car -*h*);

– Regulation by train dispatcher (losses of 2,474 car -*h*).

Compared to last year fact, the downtime of transit cars without rehandling exceeded by 0.13 *h*. Total losses in car-hours due to non-execution of downtime for transit car without rehandling make 23,565 car -*h* and occured for the following reasons:

– The target «Locomotive supply queue time» exceeds by 0.11 *h* (losses of 20,874 *wag-h*) due to lack of train locomotives and foot-plate staff;

– By 0.02 *h* (losses of 2,691 car -*h*) due to occurence non-productive element «Departure queue time» through waiting for departure after delivery trains.

Downtime of rehandled transit car for the I half of 2015 is not executed and makes 13. 05 *h*, that is overvalued compared to the planned target by 2.55 *h*. Total losses in car -hours due to non-execution of downtime for rehandled transit car make 887,586 car -*h*.

The element «For breaking-up» is overvalued by 0.12 *h* (losses of 41,769 car -*h*), for the following reasons:

– The target of unproductive element «Breaking-up queue time» is overvalued because of:

– The lack of free tracks at yards «B», «D» for formation of a new train on the free track (losses weights 4,993 *car-h*);

– Inability to transfer corner wagon traffic flow (losses of 27,744 *car-h*);

– Work with long trains (losses of 8,220 *car-h*);

– Work with nomenclature cargo (losses of 812 *car-h*).

The element «Formation» is overvalued by 2.35 *h* (total losses of 817,972 *car-h*) for the following reasons:

– Long-term formation of certain destinations (losses of 709,205 car -*h*);

– Expectation for formation completion and supply of formed trains to the departure yard due to lack of shunting locomotives (losses of 14 045 car -*h*);

– Downtime of wagons with guard, with destination to Volnovakha station due to lack of suitable covered cars for guard travel (losses of 10,378 car -*h*);

– Downtime of formed trains with destination of Donetsk railways station (total losses of 84,344 car -*h*)

The element «Departure» is overvalued by 0.08 *h* (total losses of 27 845 car-*h*) for the following reasons:

– the target of unproductive element «Locomotive supply queue time» is exceeded by 0.06 *h* (losses of 21 784 car-*h*) due to lack of train locomotives and foot-plate staff;

– The target of unproductive element «Departure queue time is overvalued by 0.02 *h* (total losses of 6,061 *wag-h*) because of:

– Regulation by train dispatcher (losses of 2,656 car-*h)*;

– Closure of the station O at the section from the point No. 344 to 203 km pk.3, closure at the line H – I (losses of 2,395 car-*h*);

– Making way for passenger and suburban trains (losses of 714 *car-h*);

– Car accounting of 20.05.2015 (losses of 296 *car-h*).

Compared to last year fact, the downtime of transit rehandled cars exceeded by 2.77 *h*. Total losses in car-hours due to non-execution of downtime for transit rehandled car make 964,162 *car-h*.

The element «Formation» is overvalued by 2.88 *h* through expectation of sending the finished trains to the destination yard.

Process operation queue downtime amounted to elements:

– «from arrival to supply» – 50.36 *h*;

– «from cleaning to departure» – 30.41 *h*.

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Table 5

Analysis of the local car during 1 loading operation

Description of indicator	Plan for 1 half year of 2015	Execution 1 half of 2015	Execution / plan
Downtime during 1 load operation, incl., *h*	95.00	133.02	+38.02
– from arrival to supply, *h*	29.34	60.97	+31.63
– during loading operations, *h*	38.02	28.71	-9.31
– from cleaning to departure, *h*	27.64	43.34	+15.70

Table 6

Analysis of hump operation

Description of indicator	Plan for 1 half year of 2015	Execution			
		1 half year of 2014	1 half year of 2015	Till 2014, %	To plan, %
Relandling of cars per day, incl., *car*	2 776	3 211	2 845	88.60	102.48
– unpaired system, *car*	1 442	1 582	1 521	96.14	105.48
paired system, *car*	1 334	1 629	1 324	81.28	99.25
Repeated rehandling	–	766	942	122.98	–
Corner flow per day, incl., *car*	–	345	415	120.29	–
– unpaired system, *car*	–	176	182	103.41	–
– paired system, *car*	–	169	233	137.87	–
Local wagons per day, incl., *car*	–	421	527	125,18	–
– unpaired system, *car*	–	208	258	124.04	–
– paired system, *car*	–	213	269	126.29	–

Repeated rehandling is required for 942 *car*, incl.:

– Corner flow wagons – 415 *car*;

– Cars from ap/tracks – 10 *car*;

– Cars of productive rehandling – 294 *car*, incl.:

– Buffer cars for dangerous goods – 48 *car*;

– Cars of separating track after repair, cars without documents – 56 *car*;

– Rebuilding of trains because of the cars traveling by the 1st freight document – 51 *car*;

– Composition of pickup trains – 48 *car*;

– Rebuilding of trains of extra-length and weight – 48 *car*;

– For composition of cars with metal products, setting of covered wagon for MSS escorting – 43 *car*;

– Cars to be placed into train main part – 223 *car*, incl.:

– Cars, requiring MSS escorting – 92 *car*;

– Cars loaded with metal and metal products – 131 *car*.

Total car downtime at the station consists of productive and unproductive downtime. Productive downtime includes time for process operations, time for car formation, while unproductive downtime includes the process operation queue time.

The question of reducing the average downtime of all car categories (transit without rehandling, rehandled, local) at the station should be solved by reducing unproductive downtime.

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Findings

The methods of mathematical statistics allowed building the histogram of car traffic flow distribution at the marshalling yard and assessment of their parameters. The key quantitative and qualitative indicators of the station operation were analyzed. In order to analyze the effect of rehandling volume on the rehandled transit car downtime elements at the station we plotted the dependence graph of the car downtime elements on the rehandling volume. The curve variation on the graph clearly shows the effect of rehandling volume on two downtime elements: during formation and in expectation of operations.

In case of small rehandling volumes the car downtime decrease should be achieved mainly by reducing the car formation costs organizing the approach of locking groups, replacement of one-group minor purpoe trains with the group ones, etc. In case of large rehandling volumes the focus should be given to reducing the time of breaking-up, composition and departure processes, in order to shorten the queue downtime.

Originality and practical value

One of the main kinds of unproductive downtime during the carriage of goods by rail is a downtime on the marshalling yards in expectation of technological operations because of the system congestion. Reduction of this indicator is possible due to rational use of the marshalling yard capacity provided the rational distribution and car- and train flows between the major marshalling yards of Ukrzaliznytsia. The analysis of changes in downtime elements, depending on the rehandling volume allows not only to identify the car downtime reduction methods, but also to make a correct assessment of station staff work, as well as to adjust the rate of idle cars. The rate of car downtime at the station is set for a specified amount of work. But the actual rehandling is different from the target one. In this regard the objective evaluation of station staff work requires adjustment of the rate on the amount of work performed.

Conclusions

The question of reducing the average downtime of all car categories at the station should be solved by reducing unproductive downtime. The correct determination of the average time spent by a rehandled transit car at the station is essential, especially in the conditions of new system of economic incentives. But still there is no separate methodology for determining the car downtime, which would allow to objectively consider the equipment and operation technology and exclude the possibility for subjective decisions.

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ИССЛЕДОВАНИЕ СТРУКТУРЫ ВАГОНОПОТОКОВ ПО ПРИБЫТИЮ И ОТПРАВЛЕНИЮ СОРТИРОВОЧНОЙ СТАНЦИИ Х

Цель. Научная работа своей целью имет анализ имеющейся организации вагонопотоков по сортировочной станции с целью уменьшения простоя вагонов. **Методика**. Используя методы математической статистики, были построены гистограммы распределения вагонопотоков сортировочной станции и проведена оценка их параметров. Проанализировано выполнение основных количественных и качественных показателей работы станции. Для анализа влияния объема переработки на элементы простоя на станции транзитного вагона с переработкой построен график зависимости элементов простоя вагонов от объема переработки. Характер изменения кривых на графике наглядно отображает влияние объема переработки на два элемента простоя: под накоплением и в ожидании выполнения операций. **Результаты**. Подтверждено, что вопрос сокращения среднего времени простоя вагонов всех категорий на станции нужно решать за счет уменьшения времени непроизводительного простоя. Верное определение среднего времени нахождения на станции транзитных вагонов с переработкой имеет важное значение, тем более в условиях новой системы экономического стимулирования. Но до сих пор так и не существует отдельной методики определения простоя вагонов, которая позволяла бы объективно учитывать техническую оснащенность и технологию работы и не давала места для субъективных решений. **Научная новизна**. Одним из основных видов непроизводительного простоя при перевозке грузов железнодорожным транспортом является простой на сортировочных станциях в ожидании выполнения технологических операций из-за загруженности системы. Уменьшение этого показателя возможно при рациональном использовании пропускной способности сортировочных станций при условии рационального распределения вагоно- и поездопотоков между основными сортировочными станциями Укрзализныци. **Практическая значимость**. Анализ изменения элементов простоя в зависимости от объема переработки позволяет не только целенаправленно определять методы по сокращению простоя вагонов, но и осуществлять точную оценку работы коллектива станции, а также корректировать норму простоя вагонов.

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Ключевые слова: вагонопоток; сортировочная станция; объем переработки; простой вагонов; параметр накопления.

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ДОСЛІДЖЕННЯ СТРУКТУРИ ВАГОНОПОТОКІВ ПО ПРИБУТТІ ТА ВІДПРАВЛЕННІ СОРТУВАЛЬНОЇ СТАНЦІЇ Х

Мета. Наукова робота має за мету аналіз наявної організації вагонопотоків по сортувальній станції із метою зменшення простою вагонів. **Методика**. Використовуючи методи математичної статистики, були побудовані гістограми розподілу вагонопотоків сортувальної станції та проведено оцінювання їх параметрів. Проаналізовано виконання основних кількісних та якісних показників роботи станції. Для аналізу впливу об'єму переробки на елементи простою на станції транзитного вагону із переробкою побудувано графік залежності елементів простою вагонів від об'єму переробки. Характер зміни кривих на графіку наглядно відображує вплив об'єму переробки на два елементи простою: під накопиченням та в очікуванні виконання операцій. **Результати**. Підтверджено, що питання скорочення середнього часу простою вагонів усіх категорій на станції потрібно вирішувати за рахунок зменшення часу непродуктивного простою. Вірне визначення середнього часу знаходження на станції транзитних вагонів із переробкою має важливе значення, тим паче в умовах нової системи економічного стимулювання. Але до цього часу так і немає окремої методики визначення простою вагонів, яка б дозволяла об'єктивно враховувати технічну оснащеність та технологію роботи і не давала місця для суб'єктивних рішень. **Наукова новизна**. Одним із основних видів непродуктивного простою при перевезенні вантажів залізничним транспортом є простій на сортувальних станціях в очікуванні виконання технологічних операцій через завантаженість системи. Зменшення цього показника можливе при раціональному використанні пропускної спроможності сортувальних станцій за умови раціонального розподілу вагоно- та поїздопотоків між основними сортувальними станціями Укрзалізниці. **Практична значимість**. Аналіз зміни елементів простою в залежності від об'єму переробки дозволяє не тільки цілеспрямовано визначати методи по скороченню простою вагонів, але й здійснювати вірну оцінку роботи колективу станції, а також корегувати норму простою вагонів.

Ключові слова: вагонопотік; сортувальна станція; об'єм переробки; простій вагонів; параметр накопичення.

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