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The Provision Terms of Train with Locomotives and their Standing Time

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ABSTRACT: Efficient use of the locomotive fleet can reduce the cost of rail transport and improve the delivery of goods to their destination on time.This article describes the use of the movement of freight locomotives and the current state of scientific analysis performed.As a result, it was found that the calculation of the fleet of freight locomotives uses the condition of "no train expects the locomotive to depart from the station" pprinciples identified. As a result of non-application of this condition, the positive dynamics of locomotives and train at the points of departure was determined by modeling.As a result, the movement of freight locomotives offered an improved methodology for the calculation of the fleet.

KEYWORDS:freight movement, locomotive, use park, methodology, departure time, arrival time, standing time, turning point, modeling.

I. INTRODUCTION

The use of railway locomotives is the main part of the expenses. In the joint-stock company "Uzbekiston Temir Yollari", 35% of total operating expenses falls on locomotive depots, 12% fuel and 30% electricity [1]. In Russian Railways this figure was 30% [2]. This positive trend can be achieved through the introduction of new resource-saving technologies and efficient use of existing locomotives.As a result of inefficient use of the existing locomotives, not only will there be an increase in operating costs of the locomotive, but there will also be cases of train locomotives waiting for departure.

II. THE CURRENT MODE OF USE THE LOCOMOTIVES ON THE MOVEMENT OF CARGO AND PROCESSING ANALYSIS

When analyzing the normal stay of the transit wagons at the Chukursay station, 46.9% of the station's excessive wait times for the station were correctly assigned to the departure park [3].

[4] it carried out an analysis of the cost of waiting time for the transmission of train locomotives at Ukrainian qualifying stations.It was found out that one of the main reasons for the delay in the departure of train locomotives at stations receiving stations is the ineffective use of the existing locomotive fleet.It was concluded that wagons can be reduced from 10% to 50% by reducing inefficient time, such as waiting for train locomotives to pass.

[5] the scientific work presents a model of calculation of optimal modes of operation of train locomotives in service of train flow.As a result of the calculations, it was proved that there were 180 locomotives operating at this site and that 195 locomotives had to be operated, and that these 195 locomotives had to be met.

[6] The article simulates the locomotive interconnection of six locomotives at each turn of the train in the case of 13, 17, 22, 26, 33 and 38 pairs of trains per day to determine the actual value of the freight locomotive's standing at the point of departure.As a result, the calculations of freight locomotive fleet require a more precise determination of the waiting time at the locomotive turning point.

The fleet of freight locomotives is defined as the sum of the locomotive fleet at service stations.In rapid planning the number of locomotives required for freight traffic can also be determined by the following method [7]:

- according to total daily locomotive-clock consumption;
- according to the average daily movement of locomotives;
- according to on average daily productivity of locomotives;

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• according to the need for locomotives for one pair of trains.

According to the analytical methods considered, the calculation is most accurate.

[8] The article presents a graphoanalytical method for calculating the fleet of freight locomotives in the C # programming language.Arrive at the point the freight train crossing by this method ($t_{arriving\ to\ point.}$) and based on departure times from this point ($t_{departure.the.point}$) the time at which the freight locomotives stand at the point of departure is defined as follows:

- the condition that the freight train locomotive at the beginning of the day can connect to the first train departing, has been checked as follows:

$$t_{departutre.the.pont} - t_{arriving.the.point} \geq t_{turning.points}, \text{ hour} \quad (1)$$

here$t_{аў.п.м}$ – turning point locomotives standard time, min.

- (1) if the condition is not met, the freight train arriving at the beginning of the day will be connected to the second train departing and (1) checked for condition, In case of failure to fulfill the conditions again, the process of the third train and so on, until the conditions were met, the time of each freight locomotive's departure point was determined.

(1) the condition of the freight locomotives at the point of fulfillment of the requirement, which can be determined by the coefficient of the locomotive required for the pair of trains and the fleet of locomotives involved in the organization of train movement.In practice, this condition is based on the condition that "no train expects the locomotive to depart from the station" [9-10].In practice, there is a difference between train departure and arrival times, which is slightly different from the technological standard of locomotive stay, and in this case some train staff have to wait for a certain time to depart from the station.With the train's staffs waiting for the locomotive to depart from the station for a certain period, the departure time at the departure point of freight locomotives is reduced.

III. DEVELOPMENT OF METHOD TO CALCULATE THE FLEET OF FREIGHT LOCOMOTIVES PARK

From condition “The first arriving locomotive is connected to the first train” (condition 1) to process (until the end) "no train expects the locomotive to leave the station" this process consists of some stages.By modeling this process, it is possible to improve the methodology for calculating the fleet of freight locomotives.

Phase 1 of the modeling begins with condition 1, namely, "the first arriving locomotive is connected to the first departure train."At the beginning of the modeling phase (usually the day), the locomotive of the first train arrives at the beginning of the modeling train, even if it is preceded by the locomotive on the first train that arrived at that time.If during the first phase, no train staff expects the locomotive to depart from the station, the modeling process will consist of one stage (as the first stage is the last one).So, there are 3 things that can be observed in the modeling process:

1. Departure of freight train by schedule($t_{dep.plan}$) and arriving ($t_{arriving}$)time difference (Δt_{st}) at station (point) a condition greater or equal to the technological norm of the locomotive's standard standing ($t_{turning\ pointstandart}$)(1-figure), as follows

$$\Delta t_{station} \geq t_{turning.point.standart} \quad (2)$$

In case 1, the time for standing at the turning point of the first locomotive that came with the 2002 train ($t_{turning.\ loc(1)}$) 2001 is the difference between the scheduled departure of the train and the 2002 train arrival time, that is

$$t_{turning.\ loc(1)} = \Delta t_{station(1)} = t_{departure.\ schedule(1)} - t_{arriv(1)} = 2{:}41 - 1{:}25 = 76 \text{ min.} = 1{,}27 \text{ hour} \quad (3)$$

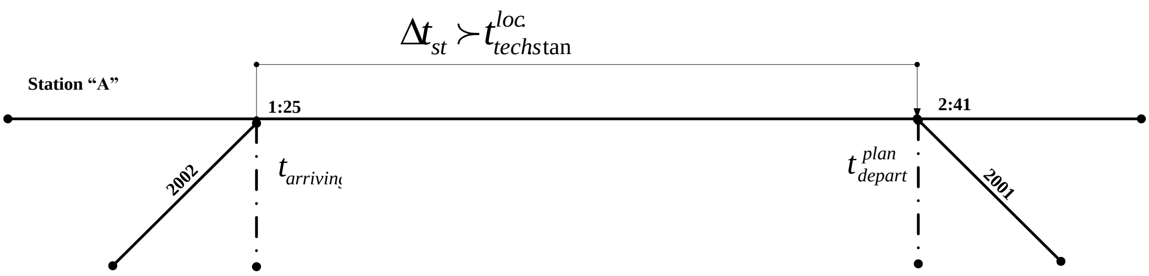

Figure 1. $\Delta t_{station} \geq t_{turning.point.standart.}$an example of a situation in which ($t_{turning.point.\ standart.}$=0,5 houris accepted).

It does not wait for departure at the first train station turning point of 2001, ie

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$$t_{turning\ (1)}=0. \quad (4)$$

Apparently, condition 1 corresponds to the condition that "no train staff expects the locomotive to depart from the station", meaning that the train does not expect the locomotive at all, and the actual departure time of the train coincides with the time of departure. ($t_{departure.actual}$).

2. The difference between the departure ($t_{departure.time}$) and arrival time of the train($t_{arriving}$)at the station ($\Delta t_{station}$) of departure time is less than or equal to the technological norm of the locomotive's standard standing ($t_{turning.\ point.\ standart.}$) (Fig. 2),

$$0 \le \Delta t_{station} < t_{turning\ point\ standard.} \quad (5)$$

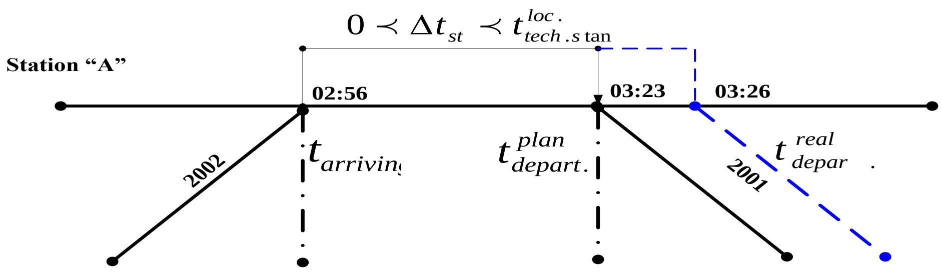

Figure 2.An example for condition of $0 \le \Delta t_{station} < t_{turning.\ point.\ standard.}$

In case 2, the time of standing at the turning point of the first locomotive arriving with train 2002 ($t_{turning.\ loc(1)}$) is equal to locomotive's turning point standard time ($t_{turning\ point\ standard.}$) at this station.

$$t_{turning.\ loc(1)} = t_{turning\ point\ standard} = 0.5 \text{ hours.} \quad (6)$$

As the difference between actual departure time ($t_{act.\ dep.}$) and arriving time (t_{ar}) of train ($\Delta t_{st}(1)$ = 03: 23-02: 56 = 00: 27 = 0.45 hours) is less than technological standard of locomotive's standard standing time, standing time till departure of scheduled first train 2001 is clarified as below:

$$t_{standing.train1} = t_{turning.point.standard} - \Delta t_{st}(1) = 0{,}5 - 0{,}45 = 0{,}05 \text{ hours} \quad (7)$$

Clearly, in modeling the operation of locomotive turning stations in case 2, the train's composition has to wait for the locomotive for some time, and the actual departure time of the train ($t_{actual.departure}$)is slightly different.

3. The difference between the scheduled train departure time ($t_{departure\ schedule}$)and arrival time(t_{arrive})at station ($\Delta t_{station}$) is a negative value, that is, the locomotive for the train with the next train (Figure 3).

$$\Delta t_{cm} < 0 \quad (8)$$

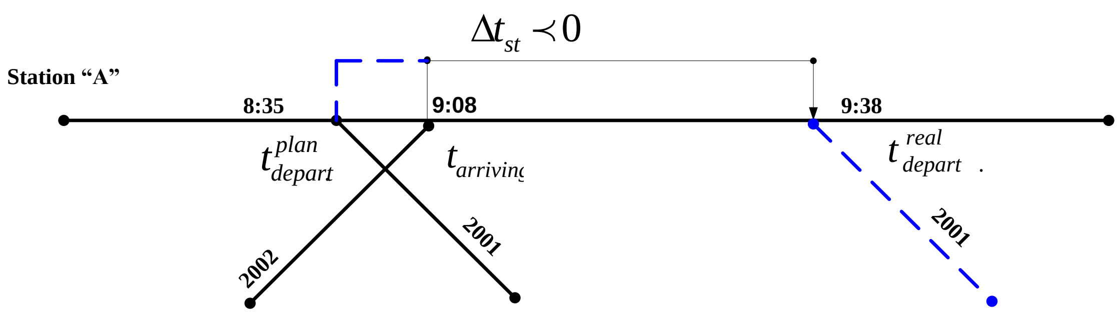

Figure 3.$\Delta t_{station} < 0$an example.

In case 3, the time at station locomotive of the first train that arrived by train in 2002 ($t_{turning\ loc(1)}$) is equal to the standard locomotive stay time ($t_{turnin.point.standard}$) at station, that is, the value of$t_{turning.loc\ (1)}$determined by) by formula (6).

As the difference($\Delta t_{st(1)}$=8:35-9:08=-00:33=-0,55 hours) between scheduled departure($t_{sched.depar.}$) and arriving($t_{sched.arriv.}$) is negative, the time which first train 2001 spent on waiting in turning point is defined as follows:

$$T_{turn.train(1)} = |\Delta t_{st(1)}| + t_{turn.p.s} = 0{,}55+0{,}5=1{,}05 \text{ hours} \quad (9)$$

It is evident that in case of model 3 of locomotive station work, the train's composition has to wait longer than normal locomotive stay, and the actual departure time ($t_{depar.time}$) of train is very different from planned departure time.

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Consequently, for the 3 cases that can be observed under the condition that "the first locomotive connects to the first departure train", the time of i-locomotive and j-contents at the turning point($t_{turning.\ loc(i)}$ and $t_{turning.order(j)}$), respectively) are defined as follows:

1st condition - if $\Delta t_{st} \geq t_{turning.point.standard}$ $\begin{cases} t_{turning\ loc\ (i)} = \Delta t_{st}; \\ t_{turn.train.(j)} = 0 \end{cases}$ (10)

2nd condition - if $0 \leq \Delta t_{st} < t_{turn.point.standard}$ $\begin{cases} t_{turning\ loc\ (i)} = t_{turn.point.standard}; \\ t_{turn.train} = t_{turn.point.standard} - \Delta t_{st} \end{cases}$ (11)

3rd condition–if $\Delta t_{st} < 0$ $\begin{cases} t_{turning.loc.(i)} = t_{ай.п.м.}; \\ t_{turn.train(j)} = |\Delta t_{st(1)}| + t_{turn.p.s.} \end{cases}$ (12)

Average time of locomotives stay at turning point is defined as below:

$$\bar{t}_{turn.loc} = \frac{\sum_{i=1}^{N_{freight}} t_{turn.loc.}}{N(fr)} \qquad (13)$$

here N_{freigh} - isnumber of freight trains at the checkpoint, train (equal to the number of trains with the highest number of trains under no-load schedule).

Average time of train's stay at turning point is defined as below:

$$\bar{t}_{turn.train} = \frac{\sum_{j=1}^{N_{freight}} t_{turn.train}}{N_{freight}}, \text{ hours} \qquad (14)$$

In summary, one of the three most common occurrences of i-locomotive and j-station rotation periods, determined by the daily modeling of locomotive rotation stations, under the condition of "First locomotive connects to the first departure train":In case of condition 1, the locomotive will have more time to stand at the turning point, and in case 3 more often it will have more time to stand at the turning point. Thus, the correct determination of the freight locomotive fleet use depends not only on the number and disparity of trains, the type of train schedule, but also on which of the three possible cases.

In the example of a train station with 18 pairs of trains (Table 1), the steps to model the process from “the first locomotive connects to the first train” (condition 1) to “no train structure expects the locomotive to depart from the station” (final condition). We will develop their modeling steps.

In the first stage at 1:25 the locomotive came with train 2002 is linked to planned train 2001 and according to condition $t_{turning.\ loc.} = t_{turning.\ train} = 0{,}5$ hours.

Table 1 - Results of Stage 1 Modeling of Locomotive and Train turning and standing at Station

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{arri.}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{dep.plan}$)	The difference between departure and arriving time of train according to condition (Δt_{st})	Freight train's standing time at turning point ($t_{turn.loc}$)	Freight train's time till departure at turning point ($t_{turn.train}$)	Freight train's real departure time from turning point ($t_{real.depar.}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	-0,47	0,50	0,97	1:55
2004	2:56	2003	1:34	-1,37	0,50	1,87	3:26
2006	3:21	2005	2:41	-0,67	0,50	1,17	3:51
2008	4:28	2007	3:23	-1,08	0,50	1,58	4:58
2010	6:08	2009	5:00	-1,13	0,50	1,63	6:38
2012	9:08	2011	5:07	-4,02	0,50	4,52	9:38
2014	10:35	2013	8:11	-2,40	0,50	2,90	11:05
2016	11:57	2015	8:21	-3,60	0,50	4,10	12:27
2018	12:19	2017	9:28	-2,85	0,50	3,35	12:49
2020	13:14	2019	9:38	-3,60	0,50	4,10	13:44

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2022	14:15	2021	10:44	-3,52	0,50	4,02	14:45
2024	15:27	2023	12:05	-3,37	0,50	3,87	15:57
2026	16:03	2025	15:48	-0,25	0,50	0,75	16:33
2028	16:52	2027	18:34	1,70	1,70	0,00	18:34
2030	18:16	2029	20:08	1,87	1,87	0,00	20:08
2032	18:38	2031	21:21	2,72	2,72	0,00	21:21
2034	21:24	2033	21:58	0,57	0,57	0,00	21:58
2036	23:10	2035	22:11	-0,98	0,50	1,48	23:40
Average					0,77	2,02	---

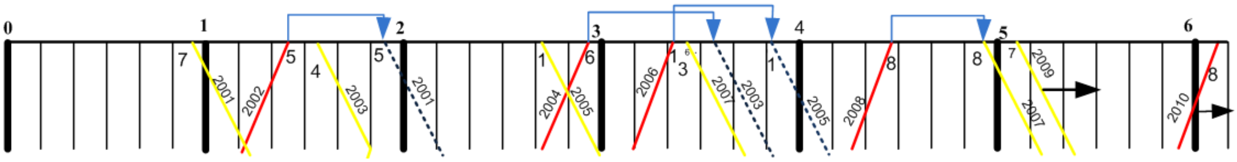

Figure 4. Part 1 Modeling of Locomotive and Train Station standing at Stage 1.

Waiting for departure at the train station 2001:

$$T_{turning.order(1)} = |\Delta t_{station(1)}| + t_{turning.point.standard}, =(|0:57-1:25|/60)+0,5=0,97 \text{ hour}$$

According to the results of Stage 1, the average time for freight locomotives $\bar{t}_{turn.loc.(1)} = 0,77$ at the point of departure is hour, and the average waiting time of train departure at the departure point $\bar{t}_{turn.train(1)} = 2,02$ is hour.

Obviously, the average length of the train's composition at the point of departure is greater than the average standing time at the turning point of the locomotive. As a result of the first stage, the condition "no train staff will wait for the locomotive to depart from the station" will be transferred to the next stage of the modeling.

In Phase 2 of the modeling, the first train locomotive at the start of the day connects to the second train scheduled to depart at 1:25, with the 2002 train scheduled to depart at 1:34 at 1:34 (Table 2, Figure 5) and (11) as a condition $t_{turning.loc(1)} = t_{turning.point.standard.} = 0,5$ hour, $t_{turning.loc(2)} = 0,5$ hours.

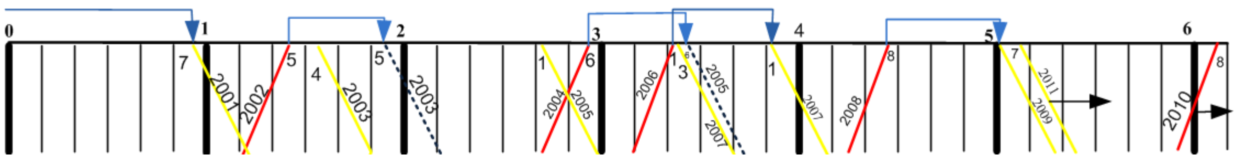

Figure 5. Modeling part of locomotive and train's standing time in turning pointaccording to stage 2.

Train 2003's standing time till departure at turning point according to condition (11):

$$t_{turn.train.(1)} = t_{turn.point.standard.} - \Delta t_{cm(1)} = 0,5-[(1:34-1:25)/60]=0,5-0,15=0,35 \text{ hours}$$

Table 2 - The results of modeling part of locomotive and train's standing time in turning pointaccording to stage 2.

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{arri.}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{dep.plan}$)	The difference between departure and arriving time of train according to condition (Δt_{st})	Freight train's standing time at turning point ($t_{turn.loc}$)	Freight train's time till departure at turning point ($t_{turn.train}$)	Freight train's real departure time from turning point ($t_{real.depar.}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	0,15	0,50	0,00	0:57
2004	2:56	2003	1:34	-0,25	0,50	0,35	1:55
2006	3:21	2005	2:41	0,03	0,50	0,75	3:26

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2008	4:28	2007	3:23	0,53	0,53	0,47	3:51
2010	6:08	2009	5:00	-1,02	0,50	0,00	5:00
2012	9:08	2011	5:07	-0,95	0,50	1,52	6:38
2014	10:35	2013	8:11	-2,23	0,50	1,45	9:38
2016	11:57	2015	8:21	-2,48	0,50	2,73	11:05
2018	12:19	2017	9:28	-2,68	0,50	2,98	12:27
2020	13:14	2019	9:38	-2,50	0,50	3,18	12:49
2022	14:15	2021	10:44	-2,17	0,50	3,00	13:44
2024	15:27	2023	12:05	0,35	0,50	2,67	14:45
2026	16:03	2025	15:48	2,52	2,52	0,15	15:57
2028	16:52	2027	18:34	3,27	3,27	0,00	18:34
2030	18:16	2029	20:08	3,08	3,08	0,00	20:08
2032	18:38	2031	21:21	3,33	3,33	0,00	21:21
2034	21:24	2033	21:58	0,78	0,78	0,00	21:58
2036	23:10	2035	22:11	1,78	1,78	0,00	22:11
Average					1,16	1,07	---

According to the results of Stage 2, the average time for the freight locomotives to stand at the departure point is $\bar{t}_{turn.loc.(1)} = 1{,}16$ hours and $\bar{t}_{turn.train.(1)} = 1{,}07$ is the average wait time for the train's departure at the departure point. As you can see, the average length of train composition at the point of departure is almost the same as the average standing time of the locomotive at the turning point. As a result of Stage 2, the condition that "no train staff expects a locomotive to depart from the station" will be transferred to the next phase of the modeling.

In the modeling phase, the first train locomotive at the start of the day connects to the third train scheduled to depart at 1:25, with the 2005 train scheduled to depart at 2:41 at 1:25 (Table 3, Figure 6) and (10) on condition that

$$t_{ай.лок(1)} = \Delta t_{cm(1)} = (2:41-1:25)/60] = 1{,}27 \text{hour}$$

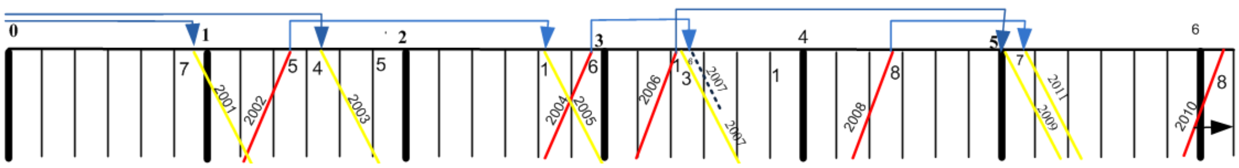

Figure 6. Modeling part of locomotive and train's standing time in turning point according to stage 3.

Train (10) does not wait for departure at the departure point. According to the results of Stage 3, the average time for the freight locomotives to stand at the departure point is the hour and the average wait time for the train's departure at the departure point. Obviously, the average length of train composition at the point of departure is considerably less than the average length of the locomotives at the turning point. As a result of Stage 3, the condition that "no train will wait for the locomotive to depart from the station" (2015, 2017, 2019, 2021, 2023 train crews are waiting for departure) will move to the next stage of the modeling.

In Model 4, the first train locomotive at the start of the day connects to the fourth train scheduled to depart, namely, 1:25 to connect the 2002 train locomotive at 3:23 to the 2007 train scheduled to depart at 3:23 (Table 4, Figure 7) and (10).) on condition that

$$t_{turn.loc.} = \Delta t_{st}(1) = (3:23-1:25)/60] = 1.97 \text{ hours}$$

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Table 3 - The results of modeling part of locomotive and train's standing time in turning pointaccording to stage 3.

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{arri.}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{dep.plan}$)	The difference between departure and arriving time of train according to condition (Δt_{st})	Freight train's standing time at turning point ($t_{turn.loc}$)	Freight train's time till departure at turning point ($t_{turn.train}$)	Freight train's real departure time from turning point ($t_{real.depar.}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	1,27	1,27	0,00	0:57
2004	2:56	2003	1:34	0,45	0,50	0,00	1:34
2006	3:21	2005	2:41	1,65	1,65	0,00	2:41
2008	4:28	2007	3:23	0,65	0,65	0,05	3:26
2010	6:08	2009	5:00	2,05	2,05	0,00	5:00
2012	9:08	2011	5:07	-0,78	0,50	0,00	5:07
2014	10:35	2013	8:11	-1,12	0,50	0,00	8:11
2016	11:57	2015	8:21	-2,32	0,50	1,28	9:38
2018	12:19	2017	9:28	-1,58	0,50	1,62	11:05
2020	13:14	2019	9:38	-1,15	0,50	2,82	12:27
2022	14:15	2021	10:44	1,55	1,55	2,08	12:49
2024	15:27	2023	12:05	3,12	3,12	1,65	13:44
2026	16:03	2025	15:48	4,08	4,08	0,00	15:48
2028	16:52	2027	18:34	4,48	4,48	0,00	18:34
2030	18:16	2029	20:08	3,70	3,70	0,00	20:08
2032	18:38	2031	21:21	3,55	3,55	0,00	21:21
2034	21:24	2033	21:58	3,55	3,55	0,00	21:58
2036	23:10	2035	22:11	2,40	2,40	0,00	22:11
Average					1,95	0,53	---

Table 4 - The results of modeling part of locomotive and train's standing time in turning pointaccording to stage 4

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{arri.}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{dep.plan}$)	The difference between departure and arriving time of train according to condition (Δt_{st})	Freight train's standing time at turning point ($t_{turn.loc}$)	Freight train's time till departure at turning point ($t_{turn.train}$)	Freight train's real departure time from turning point ($t_{real.depar.}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	1,97	1,97	0,00	0:57
2004	2:56	2003	1:34	2,07	2,07	0,00	1:34
2006	3:21	2005	2:41	1,77	1,77	0,00	2:41
2008	4:28	2007	3:23	3,72	3,72	0,00	3:23
2010	6:08	2009	5:00	2,22	2,22	0,00	5:00
2012	9:08	2011	5:07	0,33	0,50	0,00	5:07
2014	10:35	2013	8:11	-0,95	0,50	0,00	8:11
2016	11:57	2015	8:21	-1,22	0,50	0,00	8:21
2018	12:19	2017	9:28	-0,23	0,50	0,17	9:38
2020	13:14	2019	9:38	2,57	2,57	1,45	11:05
2022	14:15	2021	10:44	4,32	4,32	1,72	12:27
2024	15:27	2023	12:05	4,68	4,68	0,73	12:49
2026	16:03	2025	15:48	5,30	5,30	0,00	15:48

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2028	16:52	2027	18:34	5,10	5,10	0,00	18:34
2030	18:16	2029	20:08	3,92	3,92	0,00	20:08
2032	18:38	2031	21:21	6,32	6,32	0,00	21:21
2034	21:24	2033	21:58	4,17	4,17	0,00	21:58
2036	23:10	2035	22:11	3,52	3,52	0,00	22:11
Average					2,98	0,23	---

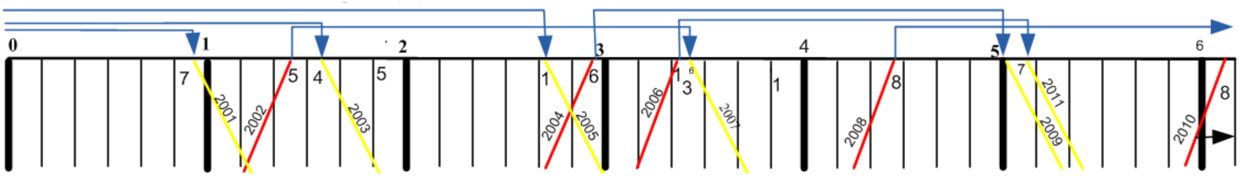

Figure 7. Modeling part of locomotive and train's standing time in turning point according to stage 4.

Train 2007 (10) does not wait for departure at the departure point. According to the results of Stage 4, the average time for the freight locomotives to stand at the departure point is the hour and the average wait time for the train's departure at the departure point. As you can see, the average time for locomotives at the point of departure has increased, and the average length of train staff has significantly decreased. As a result of Stage 4, the condition that "no train will wait for the locomotive to depart from the station" (2017, 2019, 2021, 2023 is waiting for departure) will move on to the next 5th modeling.

According to the results of Stage 4, the average time for the freight locomotives to stand at the departure point is the hour and the average wait time for the train's departure at the departure point. As you can see, the average time for locomotives at the point of departure has increased, and the average length of train staff has significantly decreased. As a result of Stage 4, the condition that "no train will wait for the locomotive to depart from the station" (2017, 2019, 2021, 2023 is waiting for departure) will move on to the next 5th modeling.

In Model 5, the first train locomotive at the start of the day connects to the fifth train scheduled to depart, namely, 1:25 to connect the 2002 train locomotive at 5:00 pm (Table 5, Figure 8) and (10).) on condition that

$$t_{turn.loc.} = \Delta t_{st}(1)=(5:00-1:25)/60]= 3,58hours$$

Table 5 - The results of modeling part of locomotive and train's standing time in turning point according to stage 5

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{arri.}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{dep.plan}$)	The difference between departure and arriving time of train according to condition (Δt_{st})	Freight train's standing time at turning point ($t_{turn.loc}$)	Freight train's time till departure at turning point ($t_{turn.train}$)	Freight train's real departure time from turning point ($t_{real.depar.}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	3,58	3,58	0,00	0:57
2004	2:56	2003	1:34	2,18	2,18	0,00	1:34
2006	3:21	2005	2:41	4,83	4,83	0,00	2:41
2008	4:28	2007	3:23	3,88	3,88	0,00	3:23
2010	6:08	2009	5:00	3,33	3,33	0,00	5:00
2012	9:08	2011	5:07	0,50	0,50	0,00	5:07
2014	10:35	2013	8:11	0,15	0,50	0,00	8:11
2016	11:57	2015	8:21	0,13	0,50	0,00	8:21
2018	12:19	2017	9:28	3,48	3,48	0,00	9:28
2020	13:14	2019	9:38	5,33	5,33	0,00	9:38
2022	14:15	2021	10:44	5,88	5,88	0,35	11:05
2024	15:27	2023	12:05	5,90	5,90	0,37	12:27
2026	16:03	2025	15:48	5,92	5,92	0,00	15:48

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2028	16:52	2027	18:34	5,32	5,32	0,00	18:34
2030	18:16	2029	20:08	6,68	6,68	0,00	20:08
2032	18:38	2031	21:21	6,93	6,93	0,00	21:21
2034	21:24	2033	21:58	5,28	5,28	0,00	21:58
2036	23:10	2035	22:11	4,22	4,22	0,00	22:11
Average					4,13	0,04	---

According to the results of Stage 5, the average time for the freight locomotives to stand at the departure point is the hour and the average wait time for the train's departure at the departure point. Apparently, the average time for locomotives at the point of departure was increased, and the average train life time was significantly reduced (one compound waits for the locomotive on the average 0.04 hours and 2.4 minutes). As a result of Stage 5, the condition that "no train staff expects a locomotive to depart from the station" (the train structures 2021, 2023 are waiting for departure) will move on to the next 6th modeling.

In Model 6, the first locomotive at the start of the day connects to the sixth train, which is scheduled to depart, namely, 1:25 to connect the 2011 train locomotive at 5:07, with the 2011 train scheduled to depart at 5:07 (Table 6, Figure 9) and (10).) on condition that

$$t_{turn.loc.} = \Delta t_{st}(1)=(5:07-1:25)/60]= 3,70\text{hours}$$

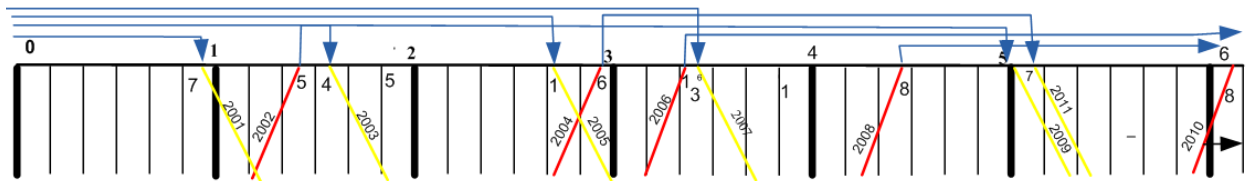

Figure 8. Modeling part of locomotive and train's standing time in turning point according to stage 5.

Table 6 - The results of modeling part of locomotive and train's standing time in turning pointaccording to stage 6

The number of train with odd number	Arriving time of freight train at turning point hours-minutes ($t_{кел}$)	The number of train with odd number	Scheduled departure time of freight train from turning point hours-minutes ($t_{жўн.режа}$)	The difference between departure and arriving time of train according to condition (Δt_{cm})	Freight train's standing time at turning point ($t_{ай.лок}$)	Freight train's time till departure at turning point ($t_{ай.тар}$)	Freight train's real departure time from turning point ($t_{жўн.хақ}$)
1	2	3	4	5	6	7	8
2002	1:25	2001	0:57	3,70	3,70	0,00	0:57
2004	2:56	2003	1:34	5,25	5,25	0,00	1:34
2006	3:21	2005	2:41	5,00	5,00	0,00	2:41
2008	4:28	2007	3:23	5,00	5,00	0,00	3:23
2010	6:08	2009	5:00	3,50	3,50	0,00	5:00
2012	9:08	2011	5:07	1,60	1,60	0,00	5:07
2014	10:35	2013	8:11	1,50	1,50	0,00	8:11
2016	11:57	2015	8:21	3,85	3,85	0,00	8:21
2018	12:19	2017	9:28	6,25	6,25	0,00	9:28
2020	13:14	2019	9:38	6,90	6,90	0,00	9:38
2022	14:15	2021	10:44	7,10	7,10	0,00	10:44
2024	15:27	2023	12:05	6,52	6,52	0,00	12:05
2026	16:03	2025	15:48	6,13	6,13	0,00	15:48
2028	16:52	2027	18:34	8,08	8,08	0,00	18:34
2030	18:16	2029	20:08	7,30	7,30	0,00	20:08
2032	18:38	2031	21:21	8,05	8,05	0,00	21:21

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2034	21:24	2033	21:58	5,98	5,98	0,00	21:58
2036	23:10	2035	22:11	5,83	5,83	0,00	22:11
Average					5,42	0,00	---

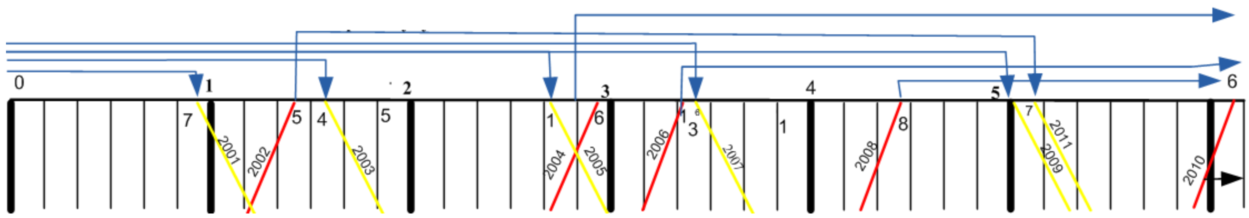

Figure 9. Modeling part of locomotive and train's standing time in turning pointaccording to stage 6.

According to the results of Stage 6, the average time for the freight locomotive to remain at the point of departure is that no locomotive is waiting for the train to depart from the station. This means that the final condition is met after 6 steps. Figure 10 shows the average locomotive standing time at the turning point and the average train stop time for the six steps in which the model is simulated.

As can be seen from Figure 10, the transition from stage 1 to stage 6 (final) will result in an increase in the average locomotive time and a reduction in the train's average standing time. Consequently, connecting the locomotives to the trains at turning points will save the fleet of locomotives involved in the organization of train movement, but will increase the average length of the train's composition.

Figure 10 shows the use of freight locomotives (Mfp) for a particular railway section as follows:

$$M_{fp}^{k} = \frac{N_{fr}}{24}(2 \cdot T_{fr} + \bar{t}_{tp} + \bar{t}_{ttp}), \text{loc.} \quad (15)$$

there: N_{fr} - number of freight trains on the studied railway section, double train (in this case 18 trains);

T_{fr}- train's time on the railway section, hours (for example, 1,64 hours);

t_{tp}, t_{ttp} - the time of locomotives stay at the main and rotating stations, respectively, during the "k" modeling phase (Fig. 10).

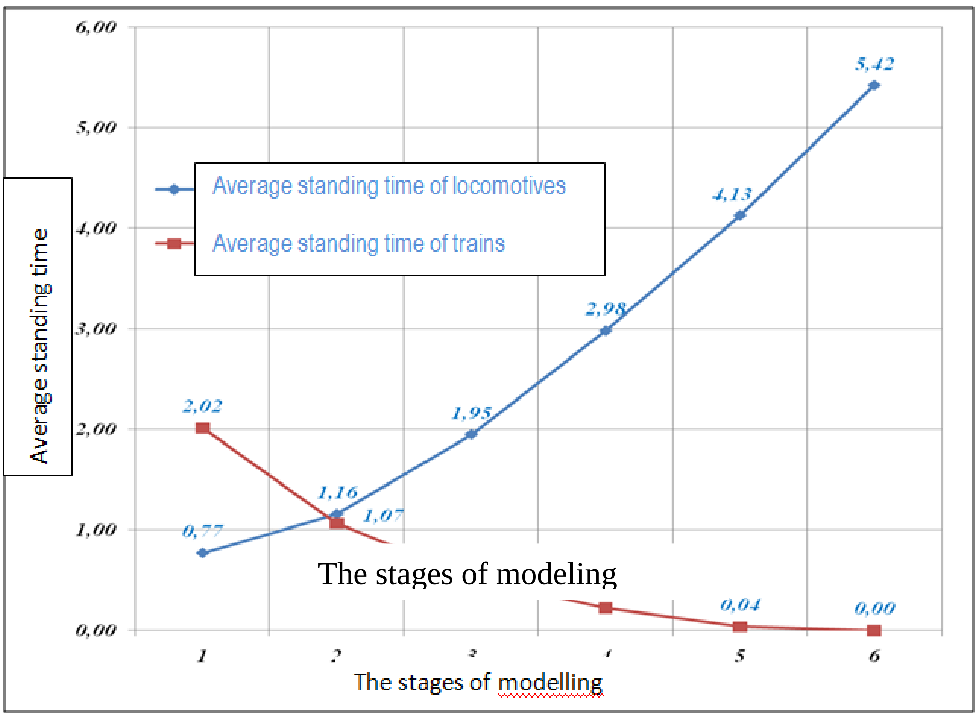

Figure 10. Changes of locomotive and train composition with modeling stages of average stay time at turning point.

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Figure 10 shows the value of Mfp in locating locomotives at main and rotating stations in 6 modeling stages (Figure 11).

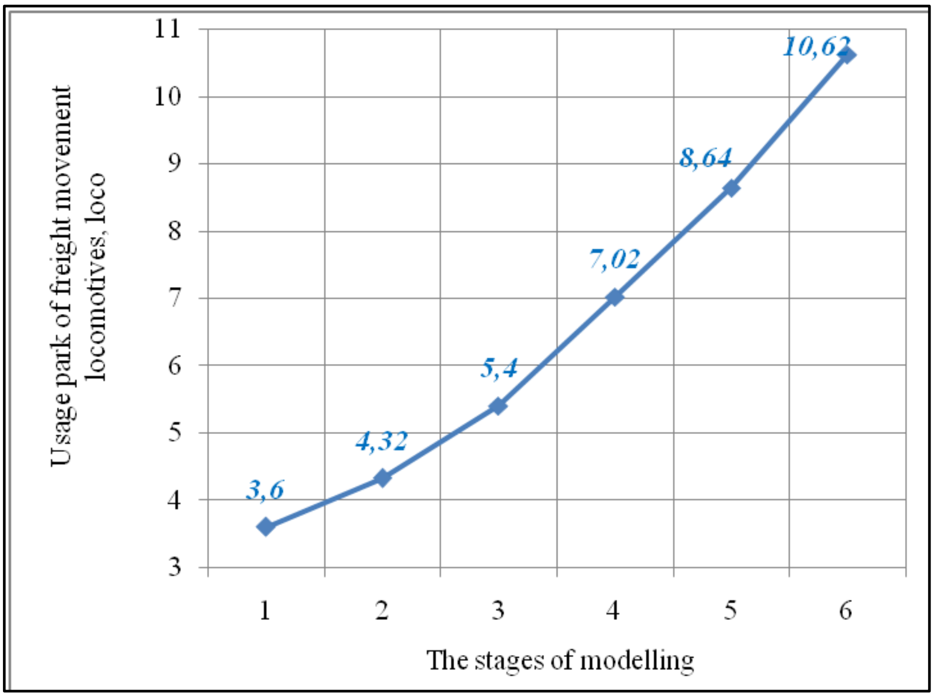

Figure 11. Variation of freight locomotives using the model of the fleet.

Figure 10-11 shows that for the planned 18 trains a total of 10.62 locomotives are required when the train traffic is under the condition that "no train structure expects the locomotive to depart from the station". If some trains are allowed to wait for the locomotive to leave the station for a certain period of time, that is, the station will need 8.64 locomotives, which will save 1.98 locomotives per day. However, at train stations, each train waits for the locomotive for an average of 2.4 minutes, or 0.04 hours. If you switch to "k-2" condition, you will save 3.6 locomotives per day. However, at train stations, each train waits for the locomotive for an average of 13.8 minutes or 0.23 hours. Thus, it is possible to effectively use locomotives when some train components allow the locomotive to wait for a certain period of time to depart from the station when calculating the freight fleet of locomotives. This, in turn, indicates the need to improve the fleet of freight locomotives using the proposed methodology.

IV. CONCLUSION

Currently, the existing methods of calculating the fleet of locomotives, including the automated methods, are carried out on the condition that "no train structure expects the locomotive to depart from the station". In this article, some of the components of the train were allowed to wait for the locomotive to depart from the station for a certain period, and as a result it was modeled that the locomotives at the departure points had a positive change. As a result, an improved method of calculating the fleet of freight locomotives is proposed. Determining the fleet of locomotives using the proposed methodology of freight traffic on railway sections clearly defines the need for locomotive fleet and results in efficient use of locomotives.

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