Route management modeling of high-speed trains on the train dispatcher section

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Abstract. This article gives a brief overview on fragmentation and how to prepare for a high-speed train. Currently, on the sections where high-speed trains run, the train dispatcher uses his experience and high skills to solve this problem by preparing train routes, is the method of calculating the tracking and crossing stations, preparing tracks for trains at stations. This process is modeled using the Petri Nets. **Keywords:** train dispatcher, train dispatcher section, station, haul, route.

1 Introduction

Improving the train control system at the train dispatcher's station will reduce the time between different categories of trains, increase traffic safety and the capacity of the sections, as well as reduce the time of train stops at stations.

One of the most important tasks is to improve the quality of planning the passage through the train dispatcher section, based on the introduction of modern technologies in the transport process, taking into account the needs of transport.

The main task of the current plans is to identify the content of measures to address the difficulties that may arise during the movement of trains.

Currently, on the sections where high-speed trains run, the train dispatcher uses his experience and high skills to solve this problem by preparing train routes, ie the method of calculating the tracking and crossing stations, preparing tracks for trains at stations. [1-23]. In some cases, the decisions made by the train dispatcher are erroneous. According to a study conducted in [1-3], especially when there is a technological "MIRROR", the probability of making changes in the train schedule and making the right decision does not exceed 11%.

2 Methods

For high-speed trains on the train dispatcher section, we will consider modeling the process of allowing stations to receive/send routes using the matrix method of Petri Nets mathematics. The process of admitting/sending routes is carried out using the following indicators. We determine the mathematical performance of the Petri Nets by comparing the automation and telemechanics equipment at the station, the condition of the tracks at the station, and the time on the schedule of high-speed trains at each station [24-34]. Where is,

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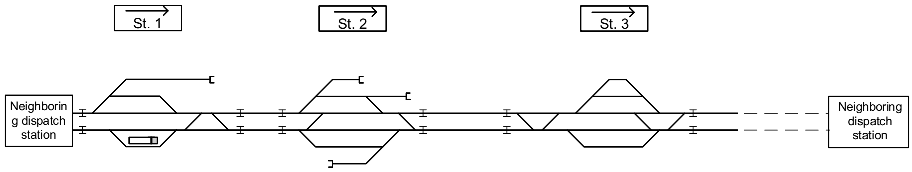

Fig. 1. A method of organizing the movement of ordinary trains on the moving part of a single train dispatcher section of high-speed trains.

$$C = (P, T, S) \tag{1}$$

$P = \{P_1, P_2, P_3, \ldots, P_n\}$ – cases of automation and telemechanics devices at the station for receiving or sending routes.

$Z = \{z_1, z_2, z_3, \ldots, z_n\}$ – the time when the train is fully received at the station or when the train leaves the station completely.

$Y = \{y_1, y_2, y_3, \ldots y_n\}$ – the state of the roads at the receiving station during the routing process.

$S = \{S_1, S_2, S_3, \ldots, S_n\}$ – the priority of the train departing from the station.

$\tau = \{\tau_1, \tau_2, \tau_3, \ldots, \tau_n\}$ – the time it takes to prepare routes for trains at the station.

$\delta = \{\delta_1, \delta_2, \delta_3, \ldots, \delta_n\}$ – the time according to the schedule of the high-speed train to the receiving station during the preparation of the route.

$T = \{t_1, t_2, t_3, \ldots, t_n\}$ – the conditions for allowing the receiving station in the preparation of the route.

I – checks access conditions when preparing routes.

O – checks the exit conditions when preparing routes.

The Petri Nets also states that the conditions $P \bigcup T = S \bigcup T = X$, $P \bigcap T = S \bigcap T = \varnothing$ must be met.

Tables 1-7 show the route preparation for the stations on the train dispatcher's section. Petri Netss can be represented by matrices of I and O forms of mathematics. The rows in each matrix are arranged according to the status of the station's automation and telemechanics equipment, as well as the priority of the train and the conditions for the transfer of trains from one station to another.

Figure 2 simulates the process of setting up a route for moving trains on the high-speed train section of the train dispatcher section using the Petri Nets. Figure 2 shows the conditions associated with the priority of the train, the state of the automation and telemechanics devices [8-11] in the process of creating routes, which are as follows: entry (

$$I(t_1)=\{P_1,S_1\},\ I(t_2)=\{P_2,S_1\},\ I(t_3)=\{P_2,S_1\},\ I(t_4)=\{P_3,S_1\})$$

exit ($O(t_1)=\{P_2\}$, $O(t_2)=\{P_1\}$, $O(t_3)=\{P_3\}$, $O(t_4)=\{P_2\}$).

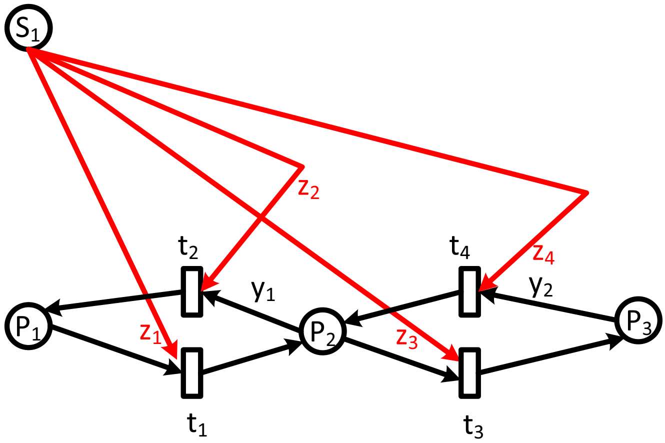

Fig. 2. Petri Nets-based model of the process of organizing the movement of ordinary trains on the moving part of high-speed trains on a single train dispatcher section.

Table 1. Conditions of automation and telemechanics devices in the process of routing.

№	**P_i**	**Multiple positions**
1	P_1	Checking the status of automation and telemechanics devices for receiving or dispatching a train at the first station
2	P_2	Checking the status of automation and telemechanics devices for receiving or dispatching a train at the second station
3	P_3	Checking the status of automation and telemechanics devices for receiving or dispatching trains at the third station

Table 2. Priorities of train departures from the station.

№	**S_i**	**Multiple positions**
1	S_1	Priority of the train departing from the first station

Table 3. The time the train arrives at the receiving station.

№	**Z_i**	**Multiple positions**
1	z_1	The time when the train departing from the first station is completely out and the opportunity to prepare for the next route begins
2	z_2	The time when the train departing from the first station is fully accepted at the second station
3	z_3	The time when the train departing from the second station is completely out and the opportunity to prepare for the next route begins
4	z_4	The time when the train departing from the second station is fully accepted to the third station

Table 4. Conditions of roads at the receiving station.

№	**Y_i**	**Multiple positions**
1	y_1	Check the condition of the roads at the second station
2	y_2	Check the condition of the roads at the third station

Table 5. Scheduled travel times of high-speed trains to stations.

№	**δ_i**	**Multiple positions**
1	δ_1	The time when the high-speed train departing from the first station is completely out
2	δ_2	The time when a high-speed train departing from the first station is fully accepted at the second station

3	δ_3	The time when the high-speed train departing from the second station is completely out
4	δ_4	The time when a high-speed train departing from the second station is fully accepted at the third station

Table 6. Route setup times at stations.

№	τ_i	Multiple positions
1	τ_1	The time it takes to prepare the route from the first station to the shipment
2	τ_2	The time it takes to prepare the route for admission to the second station
3	τ_3	The time it takes to prepare the route from the second station to the shipment
4	τ_4	The time it takes to prepare the route for admission to the third station

Table 7. Check the station's terms of accepting or dispatching the train.

№	T_i	Multiple positions
1	t_1	Check the condition of sending the train from the first station to the second station
2	t_2	Check the condition of the second station to accept the train departing from the first station
3	t_3	Check the condition of sending the train from the second station to the third station
4	t_4	Check the condition of the third station to accept the train departing from the second station

According to the matrix method of Petri Nets mathematics, j – is the intersection of rows and ε – is the intersection of columns $i_{j\varepsilon}$ equal to the element, if p_ε If there is an arc at the top of the ground and t_j at the top of the transition, it is equal to it, otherwise it is zero. j - row and ε – standing at the intersection of the columns $o_{j\varepsilon}$ element t_j if there is an arc at the top of the p_ε from the top of the transition, it will be equal if t_j is zero without an arc. If t_j - from p_ε – to the bow, Petri Nets will not be available [24-26]. The mathematics of the Petri Nets can be written in the form of expressions (2) - entry, (3) - exit conditions for checking the condition and priority of trains in the process of creating trains for receiving or sending trains at stations:

$$I = \left|i_{j\varepsilon}\right| = \begin{vmatrix} i_{11} & i_{12} & i_{13} & i_{14} \\ i_{21} & i_{22} & i_{23} & i_{24} \\ i_{31} & i_{32} & i_{33} & i_{34} \\ i_{41} & i_{42} & i_{43} & i_{44} \end{vmatrix} \tag{2}$$

$$i_{j\varepsilon} = \begin{cases} 1, if \rightarrow p_\varepsilon \in P^I t_j \cup t_j \in T^0 p_\varepsilon, \\ 0, if \rightarrow p_\varepsilon \notin P^I t_j \cap t_j \notin T^0 p_\varepsilon. \end{cases}$$

$$O = \left| o_{j\varepsilon} \right| = \begin{vmatrix} o_{11} & o_{12} & o_{13} & o_{14} \\ o_{21} & o_{22} & o_{23} & o_{24} \\ o_{31} & o_{32} & o_{33} & o_{34} \\ o_{41} & o_{42} & o_{43} & o_{44} \end{vmatrix} \tag{3}$$

$$o_{j\varepsilon} = \begin{cases} 1, if \rightarrow p_{\varepsilon} \in P^{0} t_{j} \cup t_{j} \in T^{I} p_{\varepsilon}, \\ 0, if \rightarrow p_{\varepsilon} \notin P^{0} t_{j} \cap t_{j} \notin T^{I} p_{\varepsilon}. \end{cases}$$

3 Results

The routes that can be installed at the stations are modeled using Petri Nets mathematics according to the route preparation modes at the stations shown in Figure 1 (Figure 2). The preparation of routes at the stations shown in Figure 1 shows the preparation of routes in accordance with the schedule of high-speed trains.

How to set up an automatic route on the train dispatcher section:

The high-speed train dispatcher sends information about {Z} to all stations on the train section that are about to depart from the first station on the moving section. If positive data S_1 and P_1 are received from the first station, then t_1 is comparable to the difference between z_1 and δ_1.

If condition z_1-δ_1>τ_1 is met, the second station checks the information about the acceptance of the train, otherwise the train S_1 will not be sent from the first station.

If t_1 the condition is satisfied, the second station sends the information P_2 and y_1 on the reception of the train S_1 to the condition t_2.

If y_1 and P_2 are positive, then t_2 is comparable to the difference between, z_2 and δ_2 τ_2.

If z_2-δ_2>τ_2 the condition is met, the S_1 train will be sent from the first station and accepted to the second station, otherwise the S_1 train will not be sent from the first station.

If the S_1 train has to leave the section, then the possibility of passing the train without stopping at the second station will be checked. If positive data P_2 and S_1 come from the second station, then t_3 is compared to the difference between z_3 and d_3.

If the condition z_3-δ_3>τ_3 is met, the third station checks the information about the acceptance of the train, otherwise the train S_1 will not be sent from the second station.

If t_3 the condition is satisfied, the data P_3 and y_2 on the acceptance of the third station S_1 train will be sent to the condition t_4.

If y_2 are positive, then t_4 is comparable to the difference between, z_4 and δ_4.

If z_4-δ_4>τ_4 the condition is met, the train S_1 from the second station will be sent without stopping and will be accepted to the third station, otherwise the train S_1 will not be sent from the second station.

The same route will be prepared by the train dispatcher at the remaining stations where high-speed trains run.

4 Conclusion

In conclusion, the method discussed in the article is used in the preparation of routes for high-speed trains to organize the movement of ordinary trains on the moving part of a single train dispatcher section. The train traffic control method discussed in this article is modeled using Petrie network mathematics. The Petri Nets was obtained on the basis of the analysis of the correlation conditions of the mathematical parameters and the compatibility of the automation and telemechanics devices at the station. This compares the time it takes to prepare a route for high-speed trains after the entry / exit routes that can be installed at the stations.

References

1. A.B. Nikitin, Boltaev, T. Sunnatillo, A.M. Glybovskiy, Proceedings of Petersburg Transport University **13(2)**, 215–228 (2016) DOI: https://doi.org/10.20295/1815-588x-2016-2-115-128
2. A. Nikitin, A. Manakov, S. Boltayev, Bulletin of Scientific Research Results **(1)**, 132–142 (2018) DOI: https://doi.org/10.20295/2223-9987-2018-1-132-142
3. A. Nikitin, A. Manakov, I. Kushpil, A. Kostrominov, A. Osminin, Institute of Electrical and Electronics Engineers Inc. (2020) DOI: https://doi.org/10.1109/EWDTS50664.2020.9224707
4. D. Nikitin, A. Nikitin, A. Manakov, P. Popov, A. Kotenko, *Automatic locomotive signalization system modification with weight-based sum codes 2017 IEEE East-West Design & Test Symposium (EWDTS)* (Novi Sad, Serbia, 2017) DOI: 10.1109/EWDTS.2017.8110099
5. M.V. Gofman, A.A. Kornienko, E.T. Mironchikov, A.B. Nikitin, *Digital watermarking of audio signals for robust hidden audio communication via air audio channel* (SPIIRAS Proceedings, 2017) DOI: 10.15622/sp.55.8
6. A.M. Kostrominov, O.N. Tyulyandin, A.B. Nikitin, M.N. Vasilenko, A.T. Osminin, Proceedings. Institute of Electrical and Electronics Engineers Inc. (2020) DOI: https://doi.org/10.1109/EWDTS50664.2020.9225125
7. A.B. Nikitin, I.V. Kushpil' Automation on Transport **6(4)**, 411–434 (2020) DOI: https://doi.org/10.20295/2412-9186-2020-6-4-411-434
8. A. Nikitin, I. Kushpil, Automation on Transport **5(1)**, 45-61 (2019)
9. H. Shigeto, Quarterly Report of RTRI **53(1)**, 1–6 (2012)
10. W. Wu, J. Yin, F. Pu, S. Su, T. Tang, ITSC Institute of Electrical and Electronics Engineers, 2368–2373 (2021) DOI: https://doi.org/10.1109/ITSC48978.2021.9564794
11. A. D'Ariano, D. Pacciarelli, M. Pranzo, European Journal of Operational Research **183(2)**, 643–657 (2007) DOI: https://doi.org/10.1016/j.ejor.2006.10.034
12. J. Yin, L. Yang, T. Tang, et al., Transportation Research Part B: Methodological **97**, 182–213 (2017) DOI: https://doi.org/10.1016/j.trb.2017.01.001
13. J. Yin, T. Tang, L. Yang, et al., *Research and development of automatic train operation for railway transportation systems: A survey. Transportation Research Part C* Emerging Technologies, Elsevier Ltd., 2017) DOI: https://doi.org/10.1016/j.trc.2017.09.009
14. D. Zhang, J. Zhao, Y. Zhang, Q. Zhang, Journal of Systems and Control Engineering **236(5)**, 975–988 (2022) DOI: https://doi.org/10.1177/09596518211064799
15. E. Khmelnitsky, IEEE Transactions on Automatic Control **45(7)**, 1257–1266 (2000) DOI: https://doi.org/10.1109/9.867018
16. N. ZHAO, *Railway traffic flow optimisation with differing control systems* (N. ZHAO doctor of philosophy, 2013)

17. A. Ferrari, G. Magnani, D. Grasso, A. Fantechi, *Model checking interlocking control tables. In: FORMS/FORMAT 2010* (Springer, Berlin, 2011)
18. U. Khan, J. Ahmad, T. Saeed, S.H. Mirza, Complex Adaptive Systems Modeling **4(1)** (2016) DOI: https://doi.org/10.1186/s40294-016-0028-5
19. J. Mocki, Railway Interlocking Process: *A Formal Method for Documenting and Evaluating Railway Junction Signalling and Interlocking* (2015) DOI: https://doi.org/10.25904/1912/3702
20. D. Emery, Advanced train control systems, Southamp-ton:WIT Press, 113- 122 (2010)
21. B. Ning, T. Tang, K. Qiu, et al., In Advances in Transport **15**, 393–399 (2004) DOI: https://doi.org/10.2495/978-1-84564-494-9/01
22. W. Shangguan, X.H. Yan, B.G. Cai, J. Wang, IEEE Transactions on Intelligent Transportation Systems **16(4)**, 2215–2225 (2015) DOI: https://doi.org/10.1109/TITS.2015.2402160
23. Y. Wang, B. Yu, J. Yong, W. Wang, ICCSE 2019 Institute of Electrical and Electronics Engineers Inc., 585–589 (2019) DOI: https://doi.org/10.1109/ICCSE.2019.8845521
24. ITM Web of Conferences **24**, 02007 (2019) AMCSE 2018 DOI: https://doi.org/10.1051/itmconf/20192402007
25. Jorg Desel, Javier Esparza, *Free choice Petri Nets. Cambridge Tracts in Theoretical Computer Science* (Cambridge University Press 1995)
26. T. Murata, Proceedings of the IEEE **77(4)**, 541–580 (1989) DOI: https://doi.org/10.1109/5.24143
27. S. Vanit-Anunchai, Including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics **6116**, 137–151 (2010) DOI: https://doi.org/10.1007/978-3-642-13414-2_10
28. S. Vanit-Anunchai, International Journal on Software Tools for Technology Transfer **20(3)**, 243–262 (2018) DOI: https://doi.org/10.1007/s10009-018-0482-9
29. A. Ferrari, G. Magnani, D. Grasso, A. Fantechi, *Model checking interlocking control tables. In FORMS/FORMAT 2010 - Formal Methods for Automation and Safety in Railway and Automotive Systems* (Kluwer Academic Publishers, 2011) DOI: https://doi.org/10.1007/978-3-642-14261-1_11
30. S. Vanit-Anunchai, Springer Verlag. **9933**, 214–230 (2016) DOI: https://doi.org/10.1007/978-3-319-45943-1_15
31. M.S. Durmus, U. Yildirim, M.T. Soylemez, Pamukkale University Journal of Engineering Sciences **19(5)**, 216–223 (2013) DOI: https://doi.org/10.5505/pajes.2013.14633
32. M.S. Durmus, S. Takai, SICE Journal of Control, Measurement, and System Integration **6(6)**, 403–410 (2013) DOI: https://doi.org/10.9746/jcmsi.6.403
33. M.S. Durmuş, S. Takai, M.T. Söylemez, IEEJ Transactions on Electrical and Electronic Engineering **10(2)**, 186–194 (2015) DOI: https://doi.org/10.1002/tee.22052
34. I. Mutlu, U. Yildirim, M.S. Durmuş, M.T. Söylemez, In IFAC Proceedings Volumes (IFAC-PapersOnline) **1**, 55–59 (2013) IFAC Secretariat DOI: https://doi.org/10.3182/20130916-2-tr-4042.00035