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CALCULATION OF THE THROUGHPUT RAILWAY OF THE TRACK SECTION AS AN ELEMENT OF THE CRITICAL INFRASTRUCTURE

1. Introduction

The transport infrastructure and railway transport play an important role in the critical infrastructure of the state. However, the railway transport is extraordinarily vulnerable. Due to an emergency it can be disrupted or interrupted. When the continuity of the transport process is disrupted, it is necessary to implement such an organisation of work in the critical section which will ensure the required transport output. Any preliminary verification of the assumed technology in practice is practically impossible. The classical calculations or computer simulation according to the changed transport and transportation conditions are the only possibility. The simulation enables accepting general conclusions and to prepare such measures in advance which will minimise the negative impacts of the crisis phenomena on the transport performance.

2. Options for calculating the throughput railway of the track sections in the critical transport infrastructure of the Slovak Republic

Classical Methods for Testing the Performance Efficiency of Railway Tracks

The throughput railway in the railway transport gives a number of actions (especially the train ride) which can be realised in the given section or another track element for a stated computing time. The computing time is a selected time which is most frequently a period of 1,440 minutes, i.e. one day. In the railway transport we meet the throughput of the following elements most frequently:

- the throughput of the track rail, track section or the whole railway track,
- the throughput of the railway stations,
- the throughput of the track leads in the railway stations.[1]

Furthermor, we divide the throughput to the maximal throughput and practical throughput. The reality, however, is better expressed by the practical throughput ***n*** which includes the traffic closures and limiting handling and also reflects the stochastic character of the railway transport when the individual steps do not follow each other (i.e. the trains do not go mathematically accurately but according to the demands of the customers and carriers). The formula for an orientation calculation of the practical throughput railway (all time in minutes) is as follows:

[1] I. Milata, L. Novák, Z. Dvořák, E. Sventeková, *Program ASTRA – simulácia vlakovej dopravy v krízových situáciách*. [in:] TRANSFER. II. ročník. 1/2010. s. 20-21. I. Milata, L. Novák, V. Kašpar, *Vliv stochastičnosti na organizaci vlakové dopravy v krizových situacích.* [in:] Zborník z 5. vedecko-odbornej konferencie s medzinárodnou účasťou „LOGVD – 2002 – Logistika v doprave“. Žilina, FŠI ŽU 2001, s. 83-87; 60%; L. Novák, *Možnosti simulácie premávky v traťovom úseku na základe minimálnej doby jazdy úsekom*. [in:] Zborník z 9. Medzinárodnej vedeckej konferencie VŠDS. Žilina, VŠDS 1993, s. 65-72.

$$n = \frac{T - (T_{v\acute{y}l} + T_{st\acute{a}l})}{t_{obs} + t_{dod} + t_{ru\check{s}}} \quad (1)$$

where

n = the practical throughput railway of the equipment or its element,

T = the computing time (as a rule 1,440 minutes),

$T_{v\acute{y}l}$ = the time for which the given element is excluded from operation due to the in advance known reasons (e.g. regular checks, planned reconstruction, etc.),

$T_{st\acute{a}l}$ = the time of permanent handlings during which the equipment is occupied by other activities,

t_{obs} = the technological time of equipment's occupation the throughput is detected for,

t_{dod} = the average time of one action which consists of:

- the time by which it is necessary to prolong the occupation time of the given equipment (element) due to the fact that when we release it, it stops occupying another equipment (element),
- the time for balancing the irregularities and delays.

t_{rus} = the average time of the total time of the probable mutual cancellation of the operations which develops on the equipment (elements) because it is impossible to carry out the operations on the given element at the same time (e.g. it is impossible for two trains to pass the station gridiron at the same time).[2]

Utilising the Theory of the Bulk Service for Testing the Performance Efficiency of the Railroad Tracks

The railway transport in the track sections can be understood (with a certain simplification) as a system of bulk service in which the track rail is considered the line of service. It is a system designated as M/M/1 where the conditions are unlimited, the stations of service limited (in our case it is one station of service) and with waiting for requirements on service. The time of service is the period for which the trains occupy the track rail (see the figure 1).

Until now the consideration is correct. However, there is a problem of assessing the input stream of requirements – the trains - because we can speak about the bulk service system only if the input stream of requirements is random. In the organisation of the railway transport we cannot speak about a clearly random entrance of the trains into the track section. The trains do not emerge, they do not arise coincidentally but their creation is a result of an organised activity in the marshalling yards according to the in advance stated plan – the train diagram. The possible disruptions are systematically liquidated by the dispatching staff.[3]

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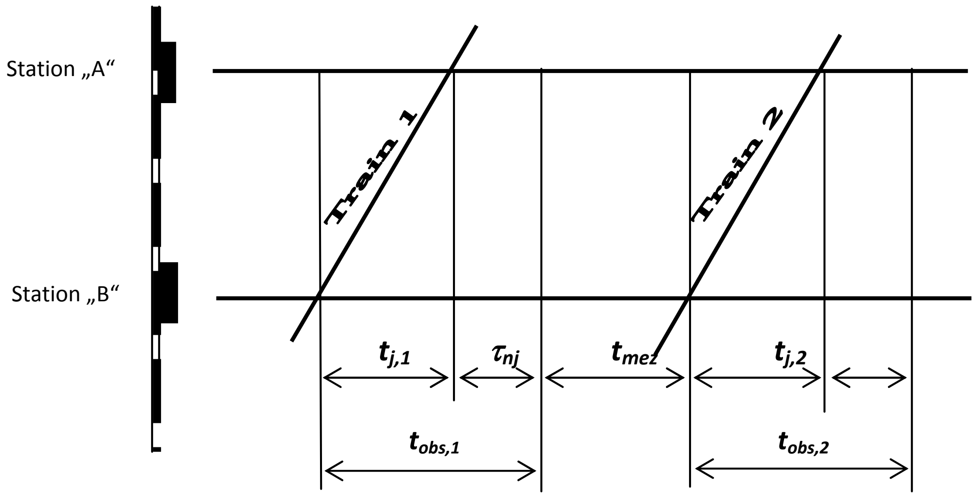
[2] L. Novák, *Možnosti simulácie premávky v traťovom úseku na základe minimálnej doby jazdy úsekom*. [in:] Zborník z 9. Medzinárodnej vedeckej konferencie VŠDS. Žilina, VŠDS 1993, s. 65-72; L. Novák, *Modelovanie a matematická simulácia železničnej premávky – nástroj práce krízového manažmentu ŽSR*. [in:] Zborník z 4. vedecko-odbornej konferencie s medzinárodnou účasťou „LOG VD – m 2001 – Logistika vo vojenskej doprave na prahu 21. storočia". Žilina, FŠI ŽU 2001, s. 68-74

[3] L. Novák, *Vplyvy náhodných javov na železničnú premávku*. In: CD z 5. medzinárodnej vedeckej konferencie „Nové trendy v rozvoji letectva", Košice, VLA gen. MRŠ 2002, s. 5

Figure 1: *Occupation of the track section by the train ride*



The individual quantities in the figure 1 express the following values:

$t_{j,1}$ – the duration of the ride across the track section,

τ_{nj} – the interval of the following ride after passing of which another ride can follow,

t_{mez} – the time gap until the ride of the next train,

$t_{obs,1}$ – the time of track section occupation by the first train,

$t_{obs,2}$ – the time of track section occupation by the second train.

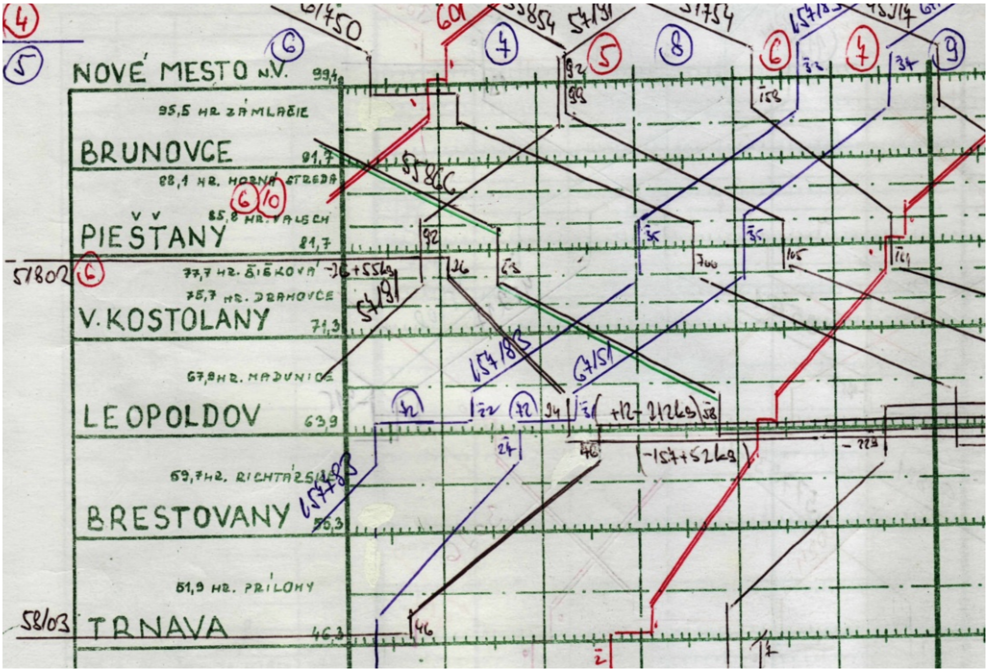
For the situation not be that simple, we have to bear in mind that also irregularities developing during the rides of the trains can be affected by the dispatcher staff in the framework of the operative management and also their impacts can be partially eliminated. With reference to the previous considerations we consider therefore the basic problem to describe mathematically the input stream of requirements – the trains and detecting the type of the random variable which defines this stream in the best way.[4]

Possibilities of Simulating the Railway Transport in the Track Sections

The main assumption of the mathematical simulation's accuracy is to state the deployment of all activities we consider to be stochastic correctly. In the case of the railway transport in the track sections the time of the train ride in the individual track sections which can be assessed from the historical data about the train rides (see the figure 2) is the decisive random quantity.

[4] L. Novák, R. Soušek, *Modifications Erlang' s distribution of random variable*. In: Механика, Транспорт, Комуникация. № 2/2005. София 2005. *http://mtc-aj.com/php/welcome.php?lang=bg*

Figure 2: *Manual record of the realised train diagram of the railway transport*



Based on the statistical assessment it is possible to test what classification of the random variable describes the activity being assessed in the best way. In the case of the railway transport it shows that the Erlang classification which is the most flexible out of all classifications suits best. This classification has three parameters and therefore it is very flexible and thus it can be used very well. The utilisation of suitable parameters can replace almost all classifications. Through using the rule *3δ* it can be also easily defined. The distribution function of the Erlang classification has the following form:

$$F(y) = \int_{y_0}^{y} \frac{b^a (y - y_0)^{a-1}}{(a-1)!} e^{[-b(y-y_0)]} dy \qquad (2)$$

where

a,b,y_0 = parameters of classification,
a = natural (integer) number > 0,
b = number > 0,
y0 = shift against the point [x=0, y=0].

In the case of parameters ***a* = 1, *b* = 1** this classification transfers to the exponential classification, at smaller values of the ***a*** parameter it seems as inclined on the left, at higher values of the ***a*** parameter it is getting closer to the normal classification.[5]

[5] L. Novák, R. Soušek, *Modifications Erlang' s distribution of random variable*. [in:] Механика, Транспорт, Комуникация. № 2/2005. София 2005. *http://mtc- aj.com/php/welcome.php?lang=bg*;

Furthermore, it is necessary to state the **algorithm** through which the computer will generate the pseudo-random distribution of the same type. Mathematically, the work of the system of the bulk service is described by the so called **events –** as a matter of fact they are the changes which developed in the system. The change of the system, i.e. the event that develops, when the requirement enters the system, when it joins the queue or quits its stay there, when it starts to be served or when the service ends, etc. The programme algorithm registers these events and records the state of each system segment at these moments. The **mathematical simulations** can be given an algorithm form in two ways – synchronously or asynchronously.

Possibilities of Simulating the Railway Transport in the Cascade of Track Sections

When assessing the throughput railway of the track sections we do not have in mind only the section between two neighbouring railway stations but a longer track section between two large railway stations. The trains go through individual partial sections which can be considered subsequent lines of the bulk service. The aforementioned considerations are valid for the first track section. The random phenomena which affected the ride across this section transfer to the next section. The outputs of the trains from the previous section are actually the inputs to the adjacent section. This fact is a decisive factor for the possibilities of modelling and simulation of the traffic in the track sections. It is possible to use the stream of trains leaving the previous section as an input stream of requirements – the trains – to the adjacent track sections. In this case only the time of the trains´ ride in individual partial track sections becomes the random variable.[6]

Software Application in Practice

The software application ASTRA which simulates the train transport in the real track sections of the Slovak railways using the aforementioned assumptions was created at the Faculty of Special Engineering of the University of Žilina in the framework of the project Critical Infrastructure Protection in Sector of Transport. Through changing the input parameters it is possible to model and simulate the railway transport and to detect in a simple way the throughput railway of the current and disrupted track sections or those ones that are being renewed.[7]

L. Simak, Z. Dvorak, L. Gaspierik, K. Kampova, J. Reitspis, M. Seidl, J. Svetlik, *Ochrana kritickej infraštruktúry v sektore dopravy* [Critical infrastructure protection in sector transport] Monograph. 180 p. 1st ed. Zilina, Slovakia: University of Zilina 2012

[6] L. novák, *Vplyvy náhodných javov na železničnú...,* op. cit., s. 5; R. Valkov, *Transport Staff Training for Activities under Crisis Conditions*. In: Zborník 7. vedeckej konferencie Riešenie krízových situácií v špecifickom prostredí. FŠI ŽU, Žilina 2002, s. 257-262

[7] D. Vidrikova, K. Boc, 2013. *Ochrana kritickej infraštruktúry I. časť* [Critical infrastruture protection, 1 st part] 1st ed. Žilina, Slovakia, University of Zilina. 2013, p. 164; D. Vidrikova, K. Boc, 2013. Ochrana kritickej infraštruktúry II. časť, [Critical infrastruture protection, 2nd part] 1st ed. Žilina, Slovakia, University of Zilina. 2013, p. 178; web page of project No 0471-10 *http://fsi.uniza.sk/ kritinf/aktuality.html;* Zákon NR SR č. 45 z 8. februára 2011o kritickej infraštruktúre

3. Conclusion

The stochastic methods of the operation analysis, especially the mathematical simulation show currently to be the most advantageous methods for planning the activities of complicated systems, especially of those which cannot be verified by an experiment, e.g. the natural disasters, sabotages, diversion, armed conflicts, etc. This fact is unambiguously valid also for testing the throughput railway of the track sections in form of the train transport simulation. We consider the method of bulk service of random character. The intervention of the human factor into the train transport is so serious that it even challenges the essence of the bulk service theory.

Streszczenia

Transport kolejowy i jego poszczególne elementy, zwłaszcza tory kolejowe, to istotny podsektor infrastruktury krytycznej Republiki Słowacji. W przypadku zakłóceń w tym obszarze może wystąpić zmniejszenie przepustowości kolejowej ze skutkami dla całego procesu transport i gospodarki kraju. Przepustowość kolejowa jest też decydującym kryterium przy projektowaniu odnowy uszkodzonych torów kolejowych. Do jej obliczeń mogą być użyte znane metody deterministyczne oraz metody analizy operacji i symulacji.

Summary

The railway transport and its individual elements especially the railway tracks are an important sub-sector of the critical infrastructure of the Slovak Republic. After their disruption a significant reduction of the throughput railway with a secondary impact on the transport processes and the whole economy of the country can arise. The throughput railway of the railway track is also a decisive criterion when designing the renewal of the damaged railway track sections. The known deterministic methods as well as the methods of operation analysis and simulation can be used for calculating the throughput railway.

References

1. Milata I., Novák L., Dvořák Z., Sventeková E., *Program ASTRA – simulácia vlakovej dopravy v krízových situáciách*. In: TRANSFER. II. ročník. 1/2010
2. Milata I., Novák L, Kašpar V., *Vliv stochastičnosti na organizaci vlakové dopravy v krizových situacích.* [in:] Zborník z 5. vedecko-odbornej konferencie s medzinárodnou účasťou „LOGVD – 2002 – Logistika v doprave". Žilina, FŠI ŽU 2001
3. Novák L., Soušek R., *Modifications Erlang' s distribution of random variable*. (in:) Механика, Транспорт, Комуникация. № 2/2005. София 2005. *http://mtc- aj.com/php/welcome.php?lang=bg*
4. Novák L., *Vplyvy náhodných javov na železničnú premávku*. (in:) CD z 5. medzinárodnej vedeckej konferencie „Nové trendy v rozvoji letectva", Košice, VLA gen. MRŠ 2002
5. Novák L: *Modelovanie a matematická simulácia železničnej premávky – nástroj práce krízového manažmentu ŽSR*. (in:) Zborník z 4. vedecko-odbornej konferencie s medzinárodnou účasťou „LOG VD – 2001 – Logistika vo vojenskej doprave na prahu 21. storočia". Žilina, FŠI ŽU 2001

6. Novák L., *Možnosti simulácie premávky v traťovom úseku na základe minimálnej doby jazdy úsekom*. (in:) Zborník z 9. Medzinárodnej vedeckej konferencie VŠDS. Žilina, VŠDS 1993
7. Simak L., Dvorak Z., Gaspierik L., Kampova K., Reitspis J., Seidl M., Svetlik J., *Ochrana kritickej infraštruktúry v sektore dopravy* [Critical infrastructure protection in sector transport] Monograph. 180 p. 1st ed. Zilina, Slovakia: University of Zilina 2012
8. Valkov R., *Transport Staff Training for Activities under Crisis Conditions*. (in:) Zborník 7. vedeckej konferencie Riešenie krízových situácií v špecifickom prostredí. FŠI ŽU, Žilina 2002
9. Vidrikova D., Boc K., *Ochrana kritickej infraštruktúry I. časť* [Critical infrastruture protection, 1st part] 1st ed. Žilina, Slovakia, University of Zilina 2013
10. Vidrikova D., Boc K., *Ochrana kritickej infraštruktúry II. časť,* [Critical infrastruture protection, 2nd part] 1st ed. Žilina, Slovakia, University of Zilina 2013
11. web page of project No 0471-10 *http://fsi.uniza.sk/kritinf/aktuality.html*
12. Zákon NR SR č. 45 z 8. februára 2011o kritickej infraštruktúre.

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