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PROPOSAL OF METHODOLOGY FOR STABILITY EVALUATION OF TRAIN TIMETABLES FROM THE OPERATIONAL-INFRASTRUCTURAL POINT OF VIEW

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Abstract

The compilation of the periodic timetables in rail passenger transport is currently a new evolving trend that increases the efficiency of rail transport. However, for the development of transport science, it is necessary to constantly develop this system. The paper offers one way to contribute in this area and thus raise and improve this system of organizing rail transport. The aim of the contribution is to propose a methodology that evaluates the level of stability of periodic timetables based on operational and infrastructural factors. The methodology identifies operational-infrastructural factors that affect the stability and reliability of periodic timetables. Using scientific methods, it presents the method of their quantification and determination of the weights of these factors, which evaluate the line sections and transport points of the examined transport route. From a practical point of view, the methodology is generally applicable to other European railway networks. There is practical application of the proposed methodological procedure in the form of model examples for various transport routes in the final part of the paper.

Keywords: methodology, capacity, zones, stability level, stability evaluation

1 Introduction

The role of the railway infrastructure manager is not only to manage the railway infrastructure. He also has a full responsibility for the allocation of routes. In the complex process of capacity allocation, it is necessary to know the true value of railway infrastructure capacity as its qualitative indicator, while respecting the qualitative parameters of the traffic operation. Rail transport makes a significant contribution to meeting the company's needs by moving raw materials, semi-finished products and products from production sites to consumption sites as part of the production process and also providing passenger transport. In connection with the fulfilment of the above tasks, the issue of the railway technical base railway capacity comes into consideration, because the railway facilities or devices operate as serial lines of service. Important transport points, nodes or junctions and the railway line are basic technical facilities for which capacity options need to be examined, determined and assessed in order to efficiently plan and compile the timetables.
There are lots of publications, contributions and scientific outputs which deal with this issue. For example Andersson et al. [1] presented a way to quantitatively measure timetable robustness to identify emerging timetable shortcomings and thus provide a proposal for improvement. The train departure processes and their impact on the performance of the rail network are described in the publication by Lüthi [2]. Very useful and progressive outputs

on research into railway infrastructure capacity are described and analysed in publications [3-5]. Interesting information regarding modelling, simulation and optimization of railway infrastructure capacity in the context of railway lines or railway vehicles is mentioned in the articles [6] and [7]. However, there are still many unexplored areas in this area. Stability evaluation of clock schedules from the operational-infrastructural point of view has not yet been comprehensively addressed. Therefore, this paper offers a brief solution to this issue.
This article describes a proposal for a methodological procedure for assessing the stability of tact timetable in terms of operational and infrastructural factors. By researching and finding an effective way in the field of reliability of tact timetables, the authors sought to contribute to the optimization of railway capacity and to broaden the perception of the element of stability from another point of view.

2 Node capacity constraints

Today's modern trend in compiling timetables is the introduction of the clock scheduling or systematic timetable. Scheduling a tact timetable with regular connections to other connecting railway lines has proven to be one of the successful tools for providing quality transport services and thus for attracting and retaining public transport users. Such a timetable also has its disadvantages and risks. As it requires high reliability of running times, it is necessary to ensure its stability to maintain its quality. The daily timetabling is a stochastic process, and the occurrence of any unforeseen event can cause delays which subsequent spread, which can have a negative impact not only on the carrier but also on passengers. Railway stations and junctions are usually the most significant bottlenecks on the rail network, because the train paths connect, stop, start or end there. Passengers board, get off or change trains in these stations so it is necessary to arrange the platforms appropriately and determine the time of stay. All trains that pass through or stop at junctions must be properly scheduled to minimize conflicts of train stays, which may limit capacity utilization. Table 1 shows the capacity restrictions at the nodes of the rail network. These restrictions are divided into main simple and main difficult restrictions. Simple restrictions are operational constraints and difficult restrictions are connected with the railway infrastructure [8, 9].

Table 1 Node capacity constraits

NODE CAPACITY CONSTRAITS	
Main simple restrictions	Main difficult restrictions
Crossing	Track arrangement
Overtaking	Type of switches
Occupated track with platforms due to dwell time exceeded	Type and location of signals
Shunting movement	Number of platforms
Train switching	Platform length

3 Methodological procedure for evaluation of timetables stability

The proposed methodology can be used to evaluate the stability of the constructed tact timetable in terms of operational and infrastructure constraints. It is a more complex indicator of infrastructure-operational conditions, which in a relative relationship expresses the percentage risk of instability of the timetable or its ability to reduce the transmission of delays to successive trains. If the stability indicator is higher, the more stable systematic timetable is, which leads to its improved reliability.

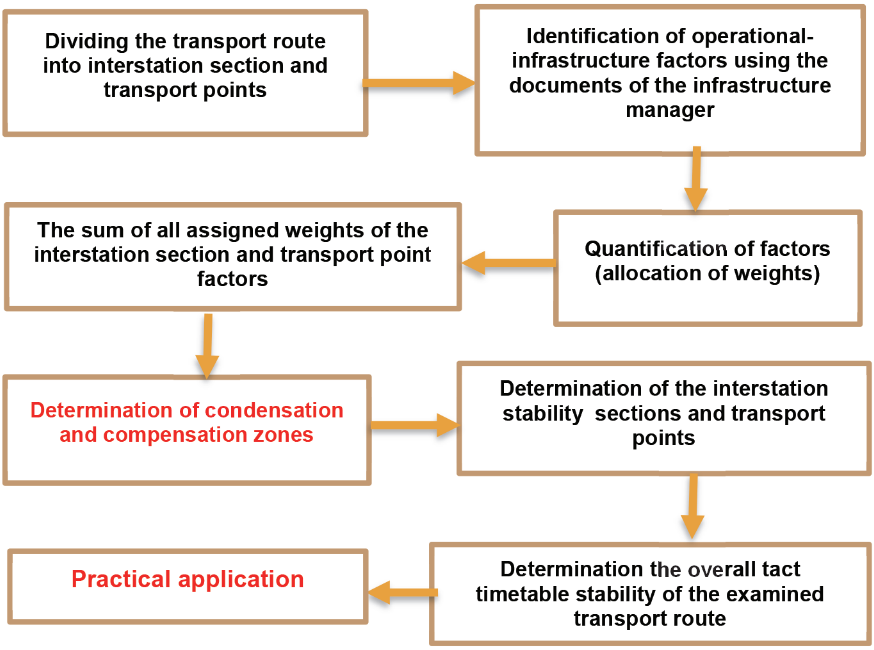

Figure 1 Particular steps of the methodological procedure

Stability assessment is based on the principle of comparing operational and infrastructural factors that affect the stability of tact timetable. An important part of this proposal is the correct quantification of the chosen factors that assess the timetable stability. The proposed methodology is quite extensive and contains eight partial steps, including a practical application. The particular steps follow each other and are mentioned in the methodological procedure in the figure 1. All these steps are very important for the correct setting of the methodology and they have been researched in the scientific and research activities of the authors [10]. This paper is focused on the steps 5 and 8 (determination of condensation and compensation zones and practical application – marked in red), because they can be considered as the most significant and decisive part of the methodological process.

3.1 Determination of condensation and compensation zones

It is necessary to correctly identify the condensation and compensation zones in step 5. Concept of the railway network dividing into condensation and compensation zones was developed to solve the problems with timetable planning [2]. Condensation zones are very sensitive to time and reliability. These are therefore mainly sections or transport points with a low ability to reduce the transmission of delays. These areas are characterized by short stopping time of a train, slow travel time, operating control point with a small number of running tracks or a low number of block sections, etc. Compensation zones serve to compensate for the time when the delay is created. They can also be used for overtaking and train crossing when organizing transport to reduce the risk of reduced travel times in condensation zones and thus ensure the reliability of tacts. Thus, these are zones that are the opposite of condensation zones. We can say that these zones serve as areas that provide time backup [11-13].

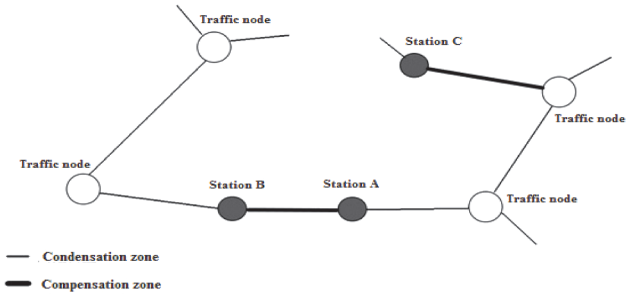

Figure 2 Railway net division into condensation and compensation zones [13]

Condensation zones are located near major junctions (stations) where available capacity is limited and therefore maximum speed is required from trains. On the other hand, train traffic is less dense in the compensation zones that connect the condensation zones. In this way, it is possible to introduce time reserves for train runs in compensation zones in order to increase the stability of the timetable. Each zone is then treated according to its specific properties. Figure 2 graphically shows the division of infrastructure into compensation and condensation zones [8].

The higher the number of compensation zones, the greater the stability of tact timetable. Due to the difference in operational-infrastructural factors, it is necessary to evaluate interstation sections and transport points separately for even and odd directions due to different stopping time of a train or directional and slope conditions, which affects the travel times of passenger trains. These zones can be determined as condensation zones, although we will not include them in the calculations of the evaluation of the stability of the transport route. Also, another exception in this methodological procedure is the turnouts. These specific transport points are mainly used for train crossing and overtaking of a train, thus acting as compensation zones. For this reason, turnouts are fixed as compensation zones as transport points. It is not necessary to assign weights to switches, but in formula (1) we calculate them for the calculation of tact timetable stability [13, 14].

$$\text{Stability level} = \frac{\text{Number of compensation zones}}{\text{Total number of zones}} \tag{1}$$

4 Practical application of the proposed methodology

This chapter presents a practical application of the proposed methodology. As an example, the railway line Humenné - Košice was selected. This is the railway line of the Eastern part of the Slovak Republic. It is shown in the figure 3.

The following tables contain the final values of the assigned weights of the transport point factors and stability level of the transport route Humenné – Košice.

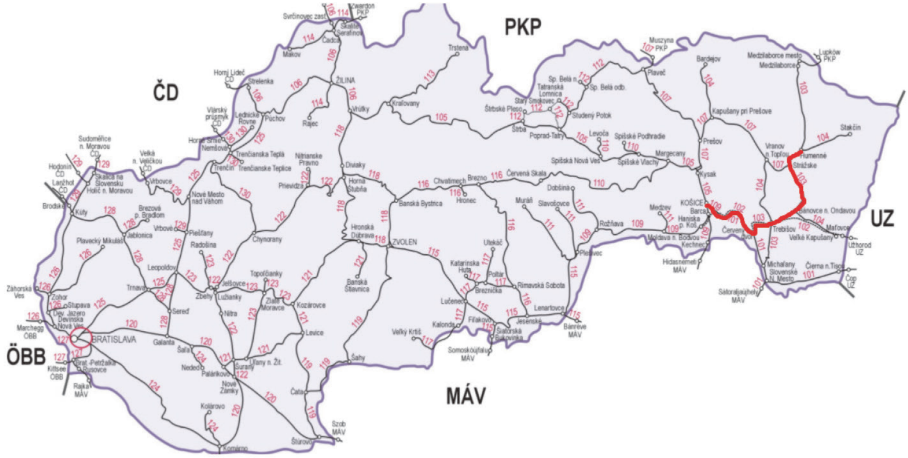

Figure 3 Map of the Slovak railways with the marked railway line Humenné – Košice

Table 2 The sum of the assigned weights of the transport point factors in the Humenné - Košice direction [13]

Name of operating control point/open line	Traffic point						
	Inter-locking system	Stopping time of a train	Number of platform edges	Coefficient of free capacity of the station	Coefficient of free capacity of running track	Number of connecting railway	Number of running track
Station Humenné	ORIGINATING STATION						
Humenné - Strážske							
Station Strážske	12,27						
Strážske - Petrovce n. Laborcom							
Overtaking station Petrovce n. Laborcom	TURN-OUT						
Petrovce n. Laborcom - Michalovce							
Station Michalovce	9,29						
Michalovce - Bánovce n. Ondavou							
Station Bánovce n. Ondavou	10,99						
Bánovce n. Ondavou - Hrinište							
Overtaking station Hrinište	TURN-OUT						
Hrinište - Trebišov							
Station Trebišov	12,87						
Trebišov - Čeľovce							
Overtaking station Čeľovce	5,91						
Čeľovce – Overtaking station Slivník							
Overtaking station Slivník	TURN-OUT						
Overtaking station Slivník - Slanec							
Station Slanec	11,26						
Slanec - Ruskov							
Station Ruskov	12,76						
Ruskov - Nižná Myšľa							
Station Nižná Myšľa	10,26						
Nižná Myšľa - Krásna n. Hornádom							
Station Krásna n. Hornádom	11,26						
Krásna n. Hornádom - Košice							
Station Košice	TERMINAL STATION						

Table 3 Calculation table of the level of stability of the transport route in the even direction, [13]

Interstation section	
The total sum of the weights of the criteria	61, 92
Total number of zones	13
Breakthrough value of zone determination	4, 76
Condensation zones	8
Compensation zones	5
Stability level	0, 38
Transport point	
The total sum of the weights of the criteria	96, 87
Total number of zones	12
Breakthrough value of zone determination	10, 76
Condensation zones	3
Compensation zones	9
Stability level	0, 75
Stability level transport route	0, 57

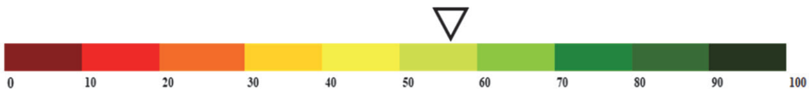

Figure 4 Graphic presentation of the stability of the Humenné - Košice transport route [13]

5 Conclusion

This paper presents the newly proposed methodology for stability evaluation of timetables from the operational-infrastructural point of view. The methodology consists of partial steps of a heuristic procedure. These proposals will gain importance in the field of tact timetable as well as integration of transport system, as it helps to compile complex timetables more efficiently. Thus they can serve as a guide for the infrastructure manager in the creation of various technological or construction and reconstruction measures. Further research in this area can lead to the quantification of infrastructure elements or operation elements, which need to be determined for a more detailed perception of this methodology [15].

Acknowledgement

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