Development of the Train Traffic Regulation Method for "Rail Baltica" Line Based on the Implementation of the European Train Traffic Control Systems

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Abstract. This article focuses on analyzing the systems and methods used for the interval regulation of train movement on "Rail Baltica" line in "Lithuanian Railways". The method discussed in the article can be viewed as a combination of several management automation solutions and it is based on the implementation of the European Railway Traffic Management System (ERTMS). As it is known, the ERTMS provides an interoperable European railway network. The primary objective is to improve the quality of train traffic and to make railway transport safer and more comfortable. In order to ensure new traffic prevision for Lithuanian Railways, new interval regulation methods and traction calculations must be used. This developed method is more useful than the previous methods as it allows to shape an efficiently automated and optimized scheduling process as well as to improve line capacity and efficiency. This paper proposes the development of a moving block train control system. The calculations were made using the intervals between trains. The interval and block-section borders are not fixed by traffic signs or traffic-lights. Instead, they move after the train in the front, creating a flexible interval regulation system. The results showed that the implementation of the method had a positive impact on the operators' performance and allowed to reduce energy consumption and to increase the speeds of train movement. The paper also presents a statistical figure portraying railway accidents and railway operation accident reports before and after the implementation of the ERTMS. The results of the analysis showed that the implementation of the European Train Traffic control systems and the interval regulation of train movement method will provide high throughput and carrying capacity, traffic safety and also increase the productivity of operation procedures.

Keywords: railway line, capacity, management automation solution, scheduling process, method of interval regulation.

Conference topic: Roads and railways.

Introduction

Along with the increasing speed of trains, the risk to make mistakes in the management of train traffic also increases. It is obvious that the human factor takes almost the first position in the list of risks. The current traffic management systems in Lithuania are not prepared for the management of trains faster than 160 km/h. Therefore, there has to be traffic management system updated along with the signalling system. Relevant engineering projects require a special accent for the integrity of the parts of the project (Stapelberg 2009). For instance, scientific studies constantly force to update the specifications of the European Railway Traffic Management System standards and improve the reliability in the contemporary systems of trains (Flammini *et al.* 2005). At the time of the analysis of transportation planning and modelling problems, transportation economic and social solutions (Ortuzar, Willumsen 2011), there are the most important transportation modelling methods, their practical importance and the selection of the most suitable modelling tools presented.

The use of the latest European carrier road is very relevant to the passengers. They are in need of fast communication which may be ensured only after the installation of the effective train traffic management system. If the ERTMS system were installed as fast as possible, the time of travelling of trains from Kaunas to Poland in the distance of 123 km would be shortened till 1 hour. ERTMS would also ensure the full functioning of the public logistics centre of Kaunas and already constructed "Rail Baltica" railway. This will allow to ensure the smooth, timely schedule of trains with no additional checks or settings by national compatible networks. ERTMS (ETCS+GSM-R) systems ensure a maximum effect for the smaller amount of investment costs in comparison with traditional signalling systems.   The general reply from European and other countries about installed the European Railway Traffic Management System is that so after the certain working time they reach a sufficient level of reliability, at least such as traditional signalling system. This may be achieved by intensive testing and improvement using programmes including both the manufacturers and managers of infrastructures. At the time of the study of the scientific works it is to be noticed that after the installation of ERTMS system in other railways of Europe, the indicators of reliability and safety would further increase. Organizations should provide the necessary training to their employees after Global System for Mobile Communication – Railways (GSMR-R) implementation in oder to maintain their operational capabilities. At the time of the

analysis of 74 events which took place in 14 European countries from 1998 till 2011 (Smith *et al.* 2013), there have been conclusions drawn that the obtained result indicates the positive effect of the GSM-R system. There has been only on event of the failure of GSM-R system from 11 events due to the fault of automatics, signalling and connections. The transition to a more automated traffic management system requires, among other things, changes to infrastructure, rolling stock, and operational procedures. The new systems will strengthen the safety in the railway crossings. It is essential to implement the projects of installation of the safety systems, based on the latest technologies. Despite the fact that the number of deaths in the rail road's amount only about 2 percent of the general number of deaths on the roads, but it amounts to 20–30 percent of all deaths on the rail roads (Gailienė *et al.* 2013). At the time of the increase of the intensity of the train traffic, it is vital to improve the permeability of the rail road lines (Sameni, Preston 2012). Therefore, there have been train permeability models and algorithms provided, which are suitable for the conclusion of the schedule of the train traffic (Li *et al.* 2013). Along with the introduction of automatic trains and ERMTS level 3 systems, the traffic interval adjustment algorithm optimizes and shows a higher level of exploitation efficiency. Centralised automatic control algorithms (Baranov *et al.* 2012) and imitation modelling establishes that their exploitation allow the decrease the number of unexpected stops in the inter station of the railway to the minimum, the outage of trains and the consumption of electricity to 3–9 percent. One of the main indicators of train traffic organisation is the permeability of the lines. Analysed methods of determination of the permeability is analytical (the determination of the necessary and current railway line) and iterative (by compaction of train traffic schedule when there are the methods of programming technology). Their comparison determines the fact that the automatized control of the traffic, the execution of the schedule and solution of conflict situations using the programming technologies, increase the permeability of the railway lines and ensure the requirements of the traffic safety (Valentinovič, Sivilevičius 2014).

Train scheduling is one of the most important and complex elements in the planning process for railway operation. The Two-stage hybrid method was presented (Jong *et al.* 2013). Experimental results demonstrated that this hybrid method not only improved the efficiency of the solution substantially but also provided better timetables compared with the current practice. In the process of train operation, the interaction between train wheels and railway track underneath leads to changes in track geometry. Changes in track geometry result in track irregularity. For managing the mean value of track irregularity is used track quality index (TQI) to quantify track irregularity of a unit track section. TQI is used for planning and scheduling railway track maintenance (Hu *et al.* 2011). The Time rescheduling algorithm based on Mixed Integer Programming was presented (Sato *et al.* 2013). The objective function is calculated on the positive difference between the inconveniences which each passenger suffers on his/her route in a rescheduled timetable and that in a planned timetable. Application of automatic fare collection data were investigated, with a focus on analysis of travel time reliability and estimation of passenger route choice behaviour (Sun, Xu 2012).

The "Rail Baltica" project aims to lay a new 1435 mm wide European standard railway line across the Baltic States, replacing the old 1520 mm Russian railway line and providing South-North oriented integration into Europe's railway infrastructure. One of the most important aspects of European 1520 mm rail systems is the high level of existing interoperability with third countries. The installations of new signaling system extend technical collaboration between railway specialists of Baltic States. All requirements are important and one of them is the regulation of train traffic.

The European Train Control System (ETCS), a train control standard, based on in cab equipment able to supervise train movements and to stop it according to the permitted speed at each line section, along with calculation and supervision of the maximum train speed at all times. Information is received from the ETCS equipment beside the track (Balises or radio) depending on the level of operation. The objective of Automatic Train Protection System (ATP) is to constantly monitor the train speed, and compare it to the maximum values that are sent by trackside signalling. This communication that is needed between onboard and trackside, will be provided by means of Balises or by Global System for Mobile Communication – Railways radio connection. GSM-R is the second ERTMS system, the European radio communications standard for railway operations. Based on GSM radio technology, GSM-R uses exclusive frequency bands to communicate the train with traffic control centres, devices beside the track. The analysis identified the factors that have the most significant influence on human performance in the conventional and upgraded railway systems. The analysis result showed that the implementation of GSM-R has had no negative influence on operator performance. In particular, no personal or personal dynamic railway performance-shaping factors were identified as contributing factors to railway accidents and incidents after the implementation of GSM-R (Smith *et al.* 2013).

Therefore, the European Railway Traffic Management System is the European standard for such an ATP that achieves interoperability throughout Europe. Indeed, it allows a train equipped with an ERTMS onboard device made by any supplier to run on track sections equipped with the European Railway Traffic Management System devices made by other suppliers. This also implies the ability for any onboard equipment installed on any train to behave in exactly the same way under the same circumstances. The European Railway Traffic Management System does not cover all traffic management functions.

European Union agency for railways has the following the ERTMS definitions. The European Rail Traffic Management System project has been set up to create a unique signalling and communication standard throughout Europe.

The Control – Command and Signalling Subsystem is defined as all the equipment necessary to ensure safety and to command and control movements of trains authorized to travel on the network. The Control Command and Signalling Subsystem is divided in to two parts: Onboard Assembly and Track side Assembly. The TSI Control Command

and Signalling specifies only those requirements which are necessary to assure the interoperability of the train European rail system and the compliance with the essential requirements. The Control Command and Signalling subsystem includes:

–   Train protection.
–   Radio communication.
–   Train detection.

Within each of the above items two classes are defined:

–   Class A: The unified Control-Command and Signalling functions, interfaces and performances, specified in this TSI.
–   Class B: Control-Command and Signalling functions, interfaces and performances existing before the entry in force of this TSI, under the responsibility of the corresponding Member State. The Class A train protection system is ERTMS/ETCS whilst the Class A radio system is GSM-R.

For Class A train detection, this TSI only specifies the requirements for the interface with other subsystems. For Class B train protection, Specific Transmission Modules (STMs) installed on board allow a train equipped with ERTMS/ETCS to operate on lines fitted with Class B train protection systems.

On-board ERTMS/ETCS functionality. The Basic Parameter for ERTMS/ETCS on board functionality describes all of the functions to run a train in a safe way. The primary function is to provide automatic train protection and cab signalling:

–   Setting the train characteristics (e.g., maximum train speed, braking performance).
–   Selecting the supervision mode on the basis of information from track-side.
–   Performing odometer functions.
–   Locating the train in a co-ordinate system based on Eurobalise locations.
–   Calculating the dynamic speed profile for its mission on the basis of train characteristics and of information from track-side.
–   Supervising the dynamic speed profile during the mission.
–   Providing the intervention function.

Moving block systems are able to increase line capacity and improve traffic fluidity, and thus, energy efficiency. In comparison with traditional fixed block systems, moving block systems are able to offer higher availability, reliability and safety in railway operations due to the distinctly different system configuration and component used in the approach (Wang *et al.* 2014).

There are reviewed Cab Signaling with Moving Block and Cab Signalling with Fixed Block sections. The main reason for having fixed block sections on lines with cab signaling is the need for the checking of the completeness of the trackside train. The main difference from a fixed block system with line side signals is the independence from the approach distance of the line side signal system, is the distance between the signal at the entrance of the block section and the signal in rear that provides the approach indication. The approach time is no longer the running time between these two signals but the running time within the real braking distance based on the supervision curves of the cab signal system. On the lines with Cab Signalling with Moving Block the length of the block sections is reduced to zero. It means that the running time between the block signals will be eliminated. But all other components of the blocking time can also be found in moving block. On most lines, the sum of these other components is much greater even then the part of the blocking time that can be eliminated by moving block. That is why, in comparison with fixed block operation with short block section, moving block will just lead to a moderate improvement of capacity.

The difference from a line with fixed block sections is that only the 'steps' of the blocking time stairway will be eliminated. The blocking time diagram will be transformed into a continuous time channel (see Fig. 1).
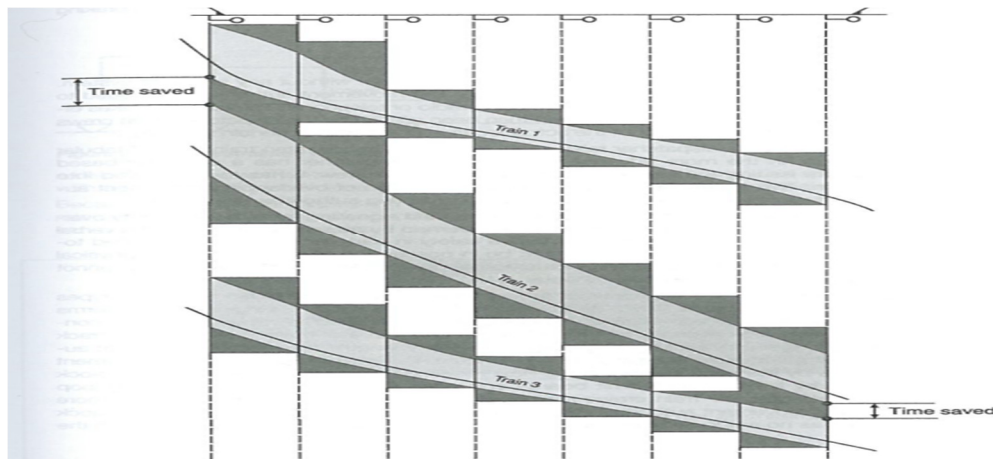

Fig. 1. Blocking time of moving block, in comparison with fixed block

One lines with mixed traffic of trains running at different speeds, the possible improvement is almost negligible.

Moving block, as explained above, is also called train separation in absolute braking distance. Relative braking distance means that the distance between two following trains equals the difference of the braking distances of the trains plus an additional safety distance. Therefore, the braking distance of both trains must be calculated with braking curves as a function of speed. Train separation in relative braking distance leads to a maximum of the line capacity (Theeg, Vlasenko 2009). Recently, along with the beginning of the integration of automatized traffic management systems, it has been noticed that the navigation systems, which automatically control the trains and centralised train traffic management allow the minimisation of the basic criterion of the exploitation of the resources: the breaking power, failures of signalling and fuel costs. It also improves the useage of recuperation, comfort of passengers, and increases the permeability of the lines and the comfort of passengers (Kondo 2010).

Innumerable studies have contributed to the energy efficiency in train control. The developed algorithm (Ozhigin 2016) of automated train control produces an intelligent control sequence which provides an energy efficient trip. The track profile inclines are taken into account, consumed and recuperated energy is computed. The design of the autopilot with a feature of energy optimality is under discussion and consideration for now. Rough theoretical estimations have shown savings of consumed energy up to 14.5% as opposed to manual driving. One of the main part of the ERTMS is the Global System for Mobile Communications-Railway. GSM-R is a telecommunications system specific to railways, endorsed by the International Union of Railways and specified through functional and system requirements (UIC 2016).

Traction calculation, methods and analysis

The new signaling systems are set new objectives, such as railroad traffic organization, railroad traffic schedule optimization, and maximum exploitation of railroad infrastructure. In existing system we could review implementing traction calculations and arrangement of three-aspect automatic block signals in section Šiauliai-Klaipėda, the following train categories are used as main:

- Loaded cargo trains, with a speed up to 80 km/h, weight norm 6000 t.
- Suburban and passenger trains with the speed up to 120 km/h, weight 1000 t.

Examination of block section length, when there is three-aspect automatic block system, was implemented according to the conditions of safe train run, regarding the calculations of braking distances of above mentioned train categories.

When calculating braking distances of proposed train categories, the minimum brake press is planned for each 100 tone of train weight in section Šiauliai-Klaipėda, calculating for cast-iron slippers, set according to norm of train movement schedule of the year 2000–2001. Calculation auto block intervals between trains are 8 min. and cargo trains are considered as a calculation object.

The setting of interval between trains is executed regarding the limits of train in the same direction:

- In line side – by three block sections and protective section.
- Leaving the station, also in stop areas (stations and platforms) – by two block sections and protective section.

The separation scheme of trains in order to set intervals between trains when there is three-aspect auto block system with protective sections. Interval between trains according to the time is 0, 3 min. when setting intervals between trains leaving the station, also in stop areas. It is compulsory in:

- Station – because of aspect change acceptance in exit signal and movement start of a train.
- Line side stop areas – because of line side signals acceptance and because of train running unevenness.

In addition, when setting intervals between trains for intercity trains in stop areas, interval includes intercity train stops at the platform.

Traction calculation is executed according to traction calculation rules for train operation of two train run modes on the even track profile:

- Rational (optimal) – because of setting of movement time in line side and auto block intervals between trains.
- Forces (maximal) – because of braking distances in block sections examination with maximal calculated speed.

The length of each block section shouldn't be shorter than braking distance during the complete ordinary brake and running in maximal speed. Also, block section shouldn't be shorter than braking distance during the sudden brake with indicated speed.

After the implementation new signalization in the "Rail Baltica" line, previous braking systems calculation should be changed. The railroad vehicles must be equipped with a group of components: onboard computers, special hardware and software. ETCS onboard computer must predict the decrease of the train speed in the future, from a mathematical model of the train bracing dynamics and of the track characteristics ahead. This prediction of the speed decrease versus distance is called a braking curve. From this prediction, the ETCS on-board computer calculates in real time braking distances, which will also be used to assist the driver and to allow him to drive comfortably, by maintaining the speed of the train within the appropriate limits. The European Union Agency for Railways proposes documents which are

mainly intended to give a high level description of the ETCS braking curves to people outside the ETCS community. The "Lithuanian Railways" systems integrates to the European railways system and a number of strategies and technologies have been implemented or and being developed to reduce the risk. ETCS braking systems have never described in an existing system in Lithuania. So, preliminary methodology is developed to estimate frequently asked questions: how is to fully harmonize the ETCS braking curves and why it has been so difficult and controversial. The main reason is the clear split of responsibility between the Railway Undertaking and the Infrastructure Manager, which has been enforced by EU directives. The braking curve related to the speed decrease due to the emergency brake is called Emergency Brake Deceleration (EBD) curve.

From the EBD and the measured train speed, the ETCS computer calculates in real time, several times per second, the distance necessary to stop the train from the time the ETCS on-board would command the intervention of the emergency brake. To do so, it is necessary to make worst case assumption:

– On the train dynamics during the lapse of time before the full emergency brake effort is developed (emergency brake build up time), by taking into account the measured acceleration.

– On the actual speed of the train, by taking into account the inaccuracies of the speed measurement.

This distance determines a location called the EBI (Emergency Brake Intervention) supervision limit, i.e. the point beyond which ETCS will bypass the human in charge (see Fig. 2) (ERA 2016).
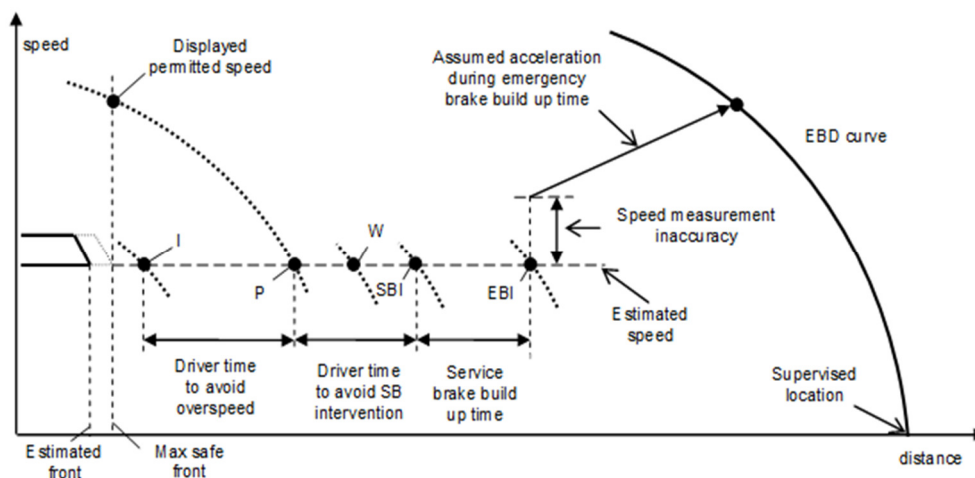

Fig. 2. Overview of the EBD bracking curve and its related supervision limits

Difference between systems

It is possible to use optimization model and maximal speed of train depends from the dislocations of the train in the front. What is the difference between Russian 1520 mm and European 1435 mm gauge systems? Why is it important comparer before ERTMS implementation? ERTMS level 2 or level 3? All this questions will be very important. In the railway traffic system, there are two kinds of signaling systems for safe operations of trains, that is, the fixed-block signalling system and the moving-block signalling systems. As a traditional control method, the fixed-block signalling system, in which the rail line will be divided into different physical segment by signal lights, has been employed more than one hundred years on almost all railways. Trains travel on the rail line according to the following operation strategies. That is, if a train arrives at a signal light and its previous train has not left the second previous segment, then this train must stop before the signal light to avoid the possible occurrence of conflicts; otherwise, the train is allowed to enter the next segment. In the moving-block signalling system the safe headway is guaranteed by checking the distance between adjacent trains in real time and then controlling the following train on the basis of its actual headway. Systems of automatic block system of the Russian 1520 mm are based on rail tracks. The line sections are divided on rail tracks of different lengths. To each of sections sends a signal to the Automatic Locomotive Signalisation (ALS) allowable speed of the train. This system is effective to use on Metro line.

ERTMS level 3 is capable of delivering further infrastructure cost reductions of around 25% on top of the 40% already identified by the ERTMS Programme Team as available for Level 2 without line side signals. The additional cost savings offered by level 3 would be offset to some extent by an increase in the cost of radio communications equipment. The level 3 capacity can be approached by optimizing the level 2 block layouts in line with infrastructure capability. The level 3 environment additional capacity requires no additional trackside hardware. There are lots of benefits, but in another works we can see the opposite side. For example: safety, development risk. The industry associates these risks primarily with block-less ("moving block") operation and the driver perspective.

However, discussions with some experienced operational personnel and drivers suggest that these concerns may be overstated. In any case, they do not impact safety because in normal operation train movement will be protected by the system. From the driver perspective, a moving block system differs from fixed block working in that train may be given a supervised movement authority to any point on the route. This may cause performance problems because the driver may be unfamiliar with stopping the train at that location and starting it again, as compared with a fixed block system where stops occur always at the same points on the line. Some opinions are that ERTMS does not yet exist; it is nothing more than a misleading marketing pitch.

Analytical estimation of the distance between trains

In ERTMS level 3, traffic is controlled by so called moving block that is associated with the distance between subsequent trains. The difficulties can be grouped in loss of time at the boundaries. The possibilities of frequent update of movement authority through radio transmission enables trains to run closer together and the line capacity been increased by significantly (moving blocks). There are lots of methods to calculate railways line capacity (Landex *et al.* 2007). One is the next formulas:

$$q = \frac{1}{T} = \frac{v}{\delta} \; ; \tag{1}$$

$$C = q_{max} = \frac{1}{T_{min}} = \frac{v^*}{\delta_{min}} \, , \tag{2}$$

where: T – train headway (temporal train spacing between two following trains); V – train speed; v^* – critical train speed (the highest speed allowed with the given braking distance); δ – distance spacing (between two following trains); $\delta_{min} = d + L_t + f$, where L_t – train length; f – safety margin; d – the minimum distance between two trains that allows the one behind to run not being slowed by the one ahead.

The static moving block keeps a safety distance between trains with an absolute braking distance. The dnamic moving block takes into account the fact that the train ahead has a minimum emergency braking distance and uses this as separation distance to allow the train following to stop in safety. For interval regulation, we can consider fixed and moving blocks. In existing system with signals each block distance between trains is considered by the equation:

$$L_{b.tr} = 0,5\, l_{tr} + l_{b11} + l_{b12} + 0,5 l_{tr}, \tag{3}$$

where: $L_{b.tr}$ – the distance between trains; l_{tr} – train length; l_b – block length between signals in block line.

In moving block, the running distance between two trains is reduced to the space needed to the train in rear to completely stop from the actual speed. This space represented by the coefficient η:

$$\eta = k\frac{v^2}{2\gamma} \, , \tag{4}$$

where: v – train speed; γ – deceleration rate (assumed constant); k – safety coefficient (normally equal to 1.1).

So the throughput can be expressed by:

$$q = \frac{v}{k\dfrac{v^2}{2\gamma} + L_t + f}. \tag{5}$$

Numerical simulation

Numerical simulation is one of the main development trains traffic process and tools (Vale *et al.* 2012). Opportunities are arising with the implementation of simulation:
- – Quality improvements;
- – Cost savings;
- – Increase in productivity;
- – Higher quality of drafts;
- – Better design control;
- – Less iteration.

Along with the introduction of the automatically controlled trains and ERTMS level 3 systems, the traffic interval adjustment algorithm optimizes and indicates a higher level of exploitation.

As the ERTMS level 3 system has not been yet introduced, we can made simulation of optimizing the speed profile with parallel computing techniques in order to demonstrate the advantage of computation time and possibility of applying to the distance between trains:

$$T_{xj}^{*}[k-1] = T_{xj}^{*g}[k-1] + TV_{xj}^{*}[k-1], \qquad (6)$$

where: $T_{xj}^{*}[k-1]$ – the rescheduling time; $T_{xj}^{*g}[k-1]$ – the scheduling time; $TV_{xj}^{*}[k-1]$ – time variable.

So, this interval regulation of train movement provides high throughput and carrying capacity. Flexible train regulation system can enhance the global natural resources saving. Significant advances have been made to improve the efficiency of the train motion: minimization of resistant forces, construction improvements, recuperation capabilities (Kondo 2010). For optimal control problem is it possible to use basic Dynamic Programming. One can obtain discretized linearized state equation (2) and (3) using first-order Taylor expansion and trapezoidal rule for approximation of integral.

$$\psi_k = \left(I - \frac{A\Delta t}{2}\right)^{-1}\left(I + \frac{A\Delta t}{2}\right)\psi_{k-1} + \left(I - \frac{A\Delta t}{2}\right)^{-1}Bf_0\Delta t; \qquad (7)$$

$$J_k = J_{k-1} + \xi(u)m\frac{\Delta t}{2}\left(f(u,u_k)v_k + f(u,u_{k-1})v_{k-1}\right), \qquad (8)$$

where: $A = \begin{pmatrix} 0 & 1 \\ \alpha & \beta \end{pmatrix}$; $B = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$; $\psi = \begin{pmatrix} x \\ v \end{pmatrix}$; $f_0 = f(u_{k-1}, v_{k-1}) - r(x_{k-1}, v_{k-1}) - \alpha v_{k-1} + \beta x_{k-1}$;

$\alpha = f_v(u_{k-1}, v_{k-1}) - r_v(x_{k-1}, v_{k-1})$; $\beta = -r_v(x_{k-1}, v_{k-1})$.

After the transform terminal boundary conditions to penalty function:

$$\varnothing(x(T), v(T)) = \lambda_1(x(T) - L)^2 + \lambda_2(v(T))^2. \qquad (9)$$

Thus, optimal problem is approximately converted into the following N-stage decision process without terminal boundary conditions:

$$\min_{\{u_k\}_{k=1}^{N}}\left\{J + \varnothing(\psi_N)\right\}, \qquad (10)$$

A penalty value $(\varnothing(x_N, v_N))$ is given for each lattice point on the N-th phase, the phase k is set to N-1, and the forward search is done from an origin along the trajectory already created by the backward-search procedure described above (see Fig. 3).
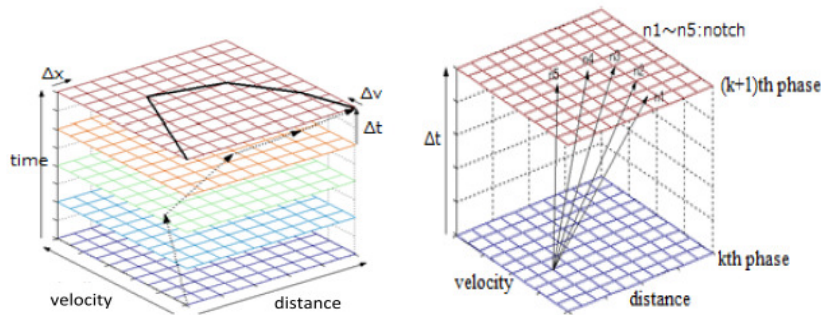

Fig. 3. Spatial and time discreditation. Finding the optimal control input at each lattice point

Here, it is possible to combine track conditions, such as discontinuity of multistage notches, velocity limitation, and gradient resistance, which are difficult to be combined as solution method into simulations easily. Even if the actual trajectory becomes away from the optimal one due to some disturbances by signaling and so on, it is able to recover the trajectory to the optimal one. If the closest lattice point from the point which can detect its position and velocity can be given as primary value and notch value which optimizes cost function can be read out. Here, notch value gives command for powering and brake in the case of train operation (Matsuura, Miyatake 2014).

The one of main role in line capacity plays stochatic disturbance (Yang *et al.* 2010). To show the different dinamic characteristics of the movements of train, two kinds of traffic flow were used (see Fig. 4).
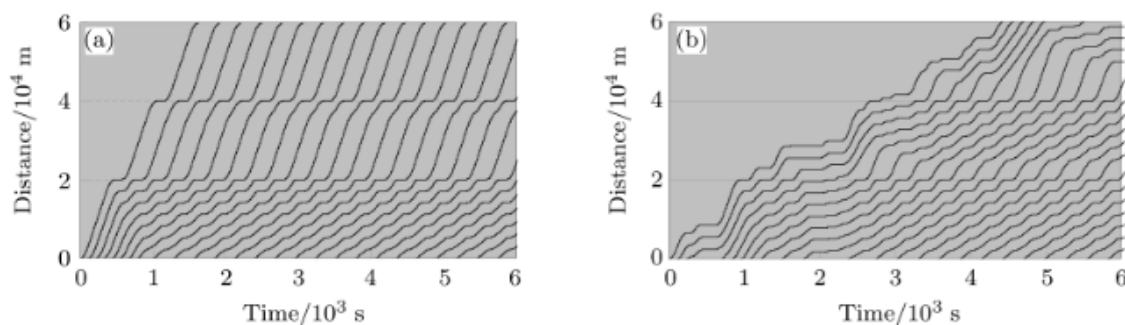
Fig. 4. The train traffic flow

Figure 4 (a) shows that without the stochastic disturbance, the minimal safe headway between adjacent trains can generally be quaranteed since the dwelling time at stations 2 and 3 is large enough. In Figure 4 (b), for analysing the dynamic characteristics of train traffic flow conviently, there was only the stochastic disturbance acting on the head train considered. It is easy to see that all trains will dwell at stations 2 and 3 for 100 seconds for unloading and loading passengers. Before each station, each train will bracke for entering the station and then dwell at it for 100 seconds. In order to keep a safe distance from the previous train, the following train has to brake and stop before the station until the previous train leaves the station. In real time, if the delay time of a train on railway line is too large, it can be considered to be rescheduled. However, when the stochastic disturbance occurs, the acceleration of the train will change. When the acceleration is positive, the train is performing the traction operation. If the acceleration is negative, the train is performing the braking operation. If the acceleration equals zero, then the train is stopping or moving with a uniform speed. From this it follows that the main task of the simulation to determine the minimal safe headway between the adjacent trains.

Conclusions

This paper gives recommendation value of the design the ERTMS level 3 in Lithuanian Railways. First of all, the implemented system should be safe. Also, during the performance, the new system should be observed in case of maintenance in the future.

This paper proposes positive impact for the development of moving block train control system. Although, the fixed-block signalling system can guarantee safe operations of trains, the traffic capacity of the rail line cannot be utilized sufficiently. With the development of communication techniques, more and more railways will be equipped with the moving-blocking systems to utilize the railway traffic sources more efficiently. Different from fixed block systems, moving block train control systems permit to reduce the distance between trains up break distance with safety coefficient.

Before implementation of new signalling system, it is needed to use numerical simulation for showing how will be changed discrete-time dynamic model when stochastic disturbance occurs. The results will show that the stochastic disturbance can not only decrease the traffic capacity of the rail line but also make more delays in the train traffic flow. The application of this methodology will contribute to bridging the gap between traditional, highly abstracted formal methods. Theoretically, this method can be a suitable candidate for moving block train control system development. The proposed method can be extended to develop existing Lithuanian Railways system used in railway signalling, such as improving line capacity in moving block train control system. Moreover, a moving block system could be an interesting study, for example, using new methods of Numerical simulation, optimization methods.

The dynamic characteristics of train traffic flow with particular dates can be investigated in the future researches during the ERTMS system implementation in "Lithuanian Railways".

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