



STATE OF THE ART REPORT ON TRAIN AND TRAFFIC CONTROL ON COMMUTER LINES

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Abstract

Railway operation on commuter lines is mostly characterized by high traffic density. Thus, any disruption of railway traffic may cause instability to the system with lower service quality and higher operating costs. Therefore, conflicts have to be identified at an early stage to allow their immediate solution. To achieve this functionality, various operation control systems have been developed and are currently used by several infrastructure managers. Due to very high density and complexity of mixed railway traffic on main lines used by commuter trains, there is a necessity for centralization of train and traffic control. The key role in the control process belongs to dispatchers, who should be supported by adaptable and adequately designed decision support and control systems. This requires the usage of special computer programs as decision support tools for dispatchers. Special attention in the development of such systems is dedicated to improvement of algorithms for railway timetable rescheduling and train running optimization process. Improvements are attempted in terms of realization of dispatchers' decisions in real traffic conditions, with respect to appliance of automatic train control. Special attention is given to the development of automatic route setting and automatic train operation systems. According to this, there is a trend of reduction of track side equipment for train control and upgrading of onboard systems. The development of new models of train and traffic control systems is aimed at improving railway timetable stability with respect to energy-efficient train driving. The objective of this paper is to give an overview of recent research in train and traffic control systems on commuter lines around the globe.

Keywords: Train and traffic control, commuter lines, railway traffic optimization

1 Introduction

Commuter railway traffic plays an important role in daily migration of population in large metropolitan areas. Thus its quality has a big influence on the life quality of citizens who live in suburban part of metropolitan area. Congestion of road traffic cause an increase of demand for commuter railway services in peak times. This requires more suburban and regional trains during the day especially during rush hour, where a higher level of line capacity is needed. Under these circumstances, tolerance for running times and headways between two trains is reduced and thus stability and robustness of railway timetable could be lower. This means that an increase of passengers can cause overload of railway system if it isn't adequately adapted. In that sense, special attention is given to train and traffic control system which should be able to ensure quality of railway services and reliability of timetable realization. Today there are many examples of railway systems with limited capacity for commuter lines. Since there is no possibility for construction of new track in many cases, the only way to meet this

problem is development of new models of management systems which are considering the implementation of special systems for train driver assistance and decision support in traffic control process. This kind of managing the railway traffic on commuter lines should be able to reach the aim of high timetable stability and therefore provide a high quality of railway services.

2 Timetable construction and robustness

Real-time railway operations are influenced by stochastic disturbances. Most of these disturbances cause both directly and indirectly delays in the railway traffic. There are many different factors causing disturbances, most of them are of technical and organizational art. The delays caused by a certain disturbance can be divided into primary and secondary delays. The primary delays are a direct effect of the actual disturbance, while the secondary are the delays of the trains that interact with the primary delayed trains. The train dispatcher, who plans from a train traffic control centre, supervises, and controls the movements of the trains cause only a diminutive part of the total quantity of primary delays, but has a key role regarding the secondary delays. This phenomenon occurs at the moment when, due to the operation of a certain train, the parallel operation of other trains according to in-advance planned schedule is prevented, because they claim at the same time period, the same line section, which regarding safety reasons leaves the possibility of parallel operation of only one of the trains. This may lead to the delay of the mentioned trains, which in turn may cause continued propagation of this phenomenon to other trains in the network [1]. It is well known that consecutive delay is a more relevant issue on the high density lines e.g. commuter lines. Therefore, relevant operational process times, especially station dwell times which can be prolonged due to unexpected increase of passenger number, can easily exceeded planned values. This led to delays and might cause netwide operational instability. Accurate estimation of station dwell time is critical for timetable realization. The importance of this issue is going along with the improvement of timetable stability and network efficiency, while serving more passengers and different types of transport services [2]. However, a railway timetable is a deterministic plan and regarding the fact that a timetable should be designed in such a way that it is able to deal with the stochastic disturbances. Therefore it should contain buffer times between trains and supplements in train running and dwell times according to UIC leaflet 451-1. Namely, railway timetables are based on deterministic running, dwell and headway times between stations. These times are mostly scaled in minutes and refer to a virtual stopping point at the stations. Small variations of the service times are compensated by standard running time and dwell time supplements, as well as margins between the train paths. The amount of time supplements and margins applied for scheduling, however, is mainly based on rules of thumb, sometimes checked by simulation, and only seldom derived from statistical analysis of real-world operations data [3]. Planning of train schedules is usually divided in several stages that have to be completed before a train schedule can be created. These stages usually are network planning, line planning, train schedule planning and planning of stock and crew. The general goal is to construct a robust timetable which should cope with unexpected disturbances without significant modification. Namely, modification of timetable is not desirable to prevent propagation of train delay. Predicting the robustness of a timetable will be a critical issue for the railway timetabling in the future [4]. In that sense, a significant effort is currently focused on developing of an algorithm for robust rescheduling plans production. Quality of timetable mainly depends on precise running and realistic recovery times, as well as optimal headway and buffer times. The currently used methods and tools for railway timetable design enable a high precision of the estimated travel times, headway times and time margins in order to achieve high-quality and robust railway timetables. Analytic models and micro-simulation are used for estimation of waiting times, while combinatorial models and stability analysis by means of max-plus algebra technique are suitable for network timetable optimization [3]. Railway operations quality can be modeled by micro-simulation which can be made in e.g.

“OpenTrack” railway micro-simulation tool [5]. Such tools allow analyzing railway operation in a kind of virtual laboratory in a short time. Of course the quality of the output depends on the quality of the input. So only if the model is calibrated in detail, it is possible to use results for local decisions. A limit of today’s tools is that especially for the usage on commuter lines, they do not consider increase of dwell time in case of disturbance of the given interval. This issue needs to be included to receive more realistic results also for this case of usage

3 Improvement of Traffic Control Process by Implementation of Decision-Support System

The centralized control of rail suburban traffic is an extremely complex process. It requires great experience and full concentration on the work of the dispatcher who monitors the events in rail traffic and based on this makes timely decisions on further traffic continuation. Based on such decisions the train control system acts on trains and thus determines the planned method of their movement. Regarding the density of train traffic, and its influence on the dispatcher’s workload, the rail track network has been divided into a number of control areas so that the work scope of a single dispatcher covers a single control area. The dispatcher’s task is to make decisions in order to optimize the train traffic flow, with the aim of maximum realization of the planned schedule with a minimum of delays. Based on the dispatcher’s decisions regarding the train traffic sequence, undesired events may be avoided, that may cause failure to realize the planned and published train schedule. Apart from some unforeseen factors that may influence the regular rail traffic flow, such as weather conditions, traffic accidents, and various malfunctions on the line side and onboard equipment. Most of these disturbances cause both directly and indirectly delays in the railway traffic. There are many different factors causing disturbances, most of them are of technical and organizational art. The delays caused by a certain disturbance can be divided into primary and secondary delays. The primary delays are a direct effect of the actual disturbance, while the secondary are the delays of the trains that interact with the primary delayed trains. The train dispatcher, who plans from a train traffic control centre, supervises, and controls the movements of the trains cause only a diminutive part of the total quantity of primary delays, but has a key role regarding the secondary delays. This phenomenon occurs at the moment when, due to the operation of a certain train, the parallel operation of other trains according to in-advance planned schedule is neglected, because they claim for the same time slot or the same line section in some part of the route, which is prevented due to safety reasons by interlockings. This may lead to the delay of involved trains, which in turn may cause continued propagation of this phenomenon to other trains in the network [1]. By making changes in the original timetable the dispatcher tries to handle the effects of the disturbances, i.e. by changing the times and locations for the train crossings and overtakes. This re-scheduling process is a demand due to the great complexity of the system [6].

Modern solutions of the train traffic control system allow timely collection of a large number of data on the traffic condition that the dispatcher may use in a very useful way to make decisions regarding further method of traffic control. Today, dispatchers have essentially reached the limits of maintaining rail network productivity and quality on heavily used dense railroad networks essentially through human judgment and minimized interference. In the future, new more advanced traffic control systems will be necessary to develop, implement and communicate new real-time schedules quickly and accurately. Regarding the relatively large number of the provided process data, and sometimes very complicated traffic situations that need to be solved in such a way as to foresee with maximum precision the future development of the traffic events, there is increasing emphasis on the need to apply the expert systems in order to improve the dispatcher’s cognitive ergonomics in the decision-making process during rail traffic control [7]. In the planning process of this system it is very important to define a man-machine interface concerning e.g. workload, situation awareness and automated cognitive

processes, limitations in human memory capacity, cognitive work environment problems, human error performance and dynamic decision processes [8].

A special attention in present research is given to capability of dispatcher to control traffic in case of high usage of commuter lines' capacity where even smaller deviations from defined timetable can seriously violate its stability and thus decrease quality of railway services. Significant number of scientific research regarding the improvement of dispatching efficiency was done, especially in sense of decision support during the traffic optimization process. It was shown that efficiency of dispatching operations can be improved by usage of decision support system where the dispatcher's workload can be reduced significantly [6], [9]. The quality of such system mainly depends on the used algorithms for traffic control and type of train control system. Therefore, there is an effort to develop new concepts of managing railway traffic which imply rescheduling procedures [5], [7], [8]. Algorithms for conflict detection and solution during timetable realization process are developed [10], [11], [12]. Regarding number of possible train conflicts and thus complexity of calculation process railway traffic optimization on single track lines represents a NP-Hard [13]. This means that there are no known algorithms for finding an optimal timetable solution in polynomial time and impose the need for appliance of heuristic methods which can efficiently solve these problems and find satisfactory solutions.

4 Development of Train Control Systems and Low Energy Consumption Train Driving

Train control system (TCS) represents an essential part of railway traffic management system. Its role is to enable trains to effectively and safely move through the railway network with respect to traffic control system decisions. Today many different types of TCS around the world exist. In Europe e.g. a significant effort is currently focused on technical harmonization and unification of train control systems within the ERTMS/ETCS project, with the aim of interoperability on European railway network achieving. The implementation of ETCS is not enough for the purpose of optimization of traffic flow but the given functionality of ETCS may help to realize an additional tool for optimization. The key for optimization is an active dispatching which should allow at least preventing unplanned stops or breakings of single trains.

Some research on train control systems are based on development of new algorithms for optimization of running profile of a train. With the aim of achieving the most efficient realization of timetable solution given by the traffic control system, as a part of train control system an additional algorithm should generate suitable speed profiles for all involved trains. In that sense, an important role plays the train driving strategy, which is also aimed on minimization of energy consumption. Those strategies are especially important for commuter trains which are specific because they have a great number of acceleration and deceleration phases during the ride and therefore the energy saving effects are more pronounced [14], [15], [16]. Regarding to this, special systems for train driver assistance are developed. Such system represents an interface between traffic control system and train driver, and its purpose is decision support for the train driver during the trip with the aim of effective timetable realization with rationalization of energy consumption. Conflicts are solved on the level of running characteristics with the aim to prevent unplanned stops in railway operation. This concept is one possibility to reduce the complexity of the optimization problem by setting boundary conditions. The algorithm seems to be suitable only for small or medium delays because the optimization is only working in the frame of seconds.

There is a significant effort in development of automatic train operation system as a part of train control automation process which has a great potential in saving energy [17]. Furthermore, significant improvement in train control can be achieved by development of new algorithms for train movement prediction in some short period of future. Those predictions can be very useful for decision making in traffic control process because they offer a possibility for se-

lection of the most appropriate train driving strategy, considering the real and most possible future traffic conditions and represent a basis for anticipated train control [18], [19].

5 Conclusion

Due to very high density and complexity of mixed railway traffic on main lines used by commuter trains the necessity arises for centralization of train and traffic control. The key role in the control process belongs to dispatchers who are responsible for timetable realization in case of any kind of disturbances. Due to complexity of their work there is a need for decreasing the dispatcher's workload in train and traffic control processes. In this sense, modern train and traffic control systems imply the usage of computer systems as decision support in the dispatching process. In the development of such systems, special attention is given to the improvement of timetable rescheduling and of train running algorithms. Improvements are attempted in terms of realization of dispatchers' decisions in real traffic conditions, with respect to appliance of automatic train control. The existing train and traffic control systems should be improved by developing of new algorithms to handle timetable rescheduling processes and to improve therefore train running profiles. By using the mentioned algorithms, an increase of the timetable stability and energy-efficient driving of suburban trains can be obtained.

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