ARTICLE IN PRESS

Journal of Rail Transport Planning & Management xxx (2017) 1–16

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

Solving large-scale train timetable adjustment problems under infrastructure maintenance possessions

Sander Van Aken [a, b, *], Nikola Bešinović [a], Rob M.P. Goverde [a]

[a] Department of Transport and Planning, Delft University of Technology, P.O. Box 5048, 2600 GA Delft, The Netherlands
[b] KU Leuven, Leuven Mobility Research Center — CIB, Celestijnenlaan 300, Box 2422, 3001 Leuven, Belgium

A R T I C L E I N F O

Article history:
Received 14 June 2017
Accepted 25 June 2017
Available online xxx

Keywords:
Railway timetable
Maintenance
Possessions
Train Timetable Adjustment Problem (TTAP)
Periodic Event Scheduling Problem (PESP)

A B S T R A C T

During infrastructure maintenance possessions, commonly not all trains can operate, and the original timetable may have to be adjusted accordingly. To deliver the best service to passengers, operators have to coordinate adjustment measures dealing with multiple possessions at the network level. In this paper, we consider the Train Timetable Adjustment Problem (TTAP) and present a mixed integer programming (MIP) model for solving TTAP. In order to solve large-scale problems, such as national Dutch network, and design high-quality solutions, modelling extensions are needed. First, we apply three network aggregation techniques to decrease the problem size, which enables to solve instances on the complete Dutch network within satisfactory computation times. Second, we model turnaround activities for short-turned trains and test different strategies. Third, we introduce flexible short-turning possibilities to the MIP to possibly reduce the number of cancelled train lines. We test the proposed model on real-life cases of Netherlands Railways (NS) and assess the effect on computation times and solution quality. Also, we identify differences with current planners' practice. Planners were positive about the quality of generated solutions and the computation speed. The current model can also be used to decide on combinations of time windows for possessions.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

High-capacity railway transport is one of the main drivers of public transport and often forms the backbone of a wider network. In the Netherlands, main operator Netherlands Railways (NS) and infrastructure manager ProRail are front-runners in using mathematical models for various planning problems (Kroon et al., 2009), aiming at providing a high level of service. The problem of designing a timetable is known as the Train Timetabling Problem (TTP). Two types of models can be distinguished: macroscopic models consider stations as nodes and tracks as arcs between them, with given capacities, while microscopic models incorporate details such as block sections and signalling constraints. On the macroscopic level, a timetable includes arrival, departure and through times at stations and some other important locations such as junctions. For networks with dense railway traffic, a timetable is often defined on a periodic basis. Serafini and Ukovich (1989) introduced the Periodic Event Scheduling Problem (PESP), which is used in operations research-based tool *Designer of Network Schedules* (DONS) to generate the original macroscopic timetable of NS.

* Corresponding author. Department of Transport and Planning, Delft University of Technology, P.O. Box 5048, 2600 GA Delft, The Netherlands.
E-mail address: sander.vanaken@outlook.com (S. Van Aken).

http://dx.doi.org/10.1016/j.jrtpm.2017.06.003
2210-9706/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Van Aken, S., et al., Solving large-scale train timetable adjustment problems under infrastructure maintenance possessions, Journal of Rail Transport Planning & Management (2017), http://dx.doi.org/10.1016/j.jrtpm.2017.06.003

However, an increased number of train services results in a higher need for maintenance, which induces a range of additional planning challenges. Conducting infrastructure maintenance requires *possessions*, which are defined as “non-availability of part of the rail network for full use by trains during a period reserved for the carrying out of works” (RailNetEurope, 2015). The reduced available capacity may make the original timetable impossible to operate. In the Netherlands, traffic planners need about 14 weeks to generate a feasible solution for one day of operation, mostly based on experience (Engel, 2016). Thus, mathematical models could significantly speed up this process and generate more efficient solutions.

Lidén (2015) examined the possible maintenance activities, the involved planning problems and the mathematical models that have been developed for those problems. Adjusting the timetable to preventive possessions, i.e., the ones known long in advance, fits within the tactical planning level. Van Aken et al. (2017) defined the Train Timetable Adjustment Problem (TTAP) to generate an alternative timetable for a given set of long possessions, i.e., lasting one or more days, whilst minimizing the deviation from the original one. They presented a macroscopic PESP-based model to solve the macroscopic periodic TTAP, which considers complete open-track possessions, and station track possessions. However, bigger instances like a complete national network are still too large to be solved by the model presented in Van Aken et al. (2017). Currently, each planner at NS considers only a small part of the network and the relevant possessions, based on his own experience. This may lead to measures conflicting with those of other planners, resulting in the need for multiple iterations. The additional value of a macroscopic model is the possibility to coordinate adjustment measures to deal with possessions for a complete network.

In this paper, we extend the previous work on solving TTAP by making it applicable to large-scale instances, and by including more real-life constraints into the model. First, we apply three network aggregation techniques to reduce the size of the problem while maintaining a required level of detail, and study the effect of different aggregation levels on the solution quality and the computation speed. Second, we implement the additional turnaround activities for short-turned trains to prevent possible station capacity violations. To this purpose, we introduce and evaluate different short-turning strategies and consider the integration of these turnarounds both in the preprocessing and postprocessing, resulting in four different procedures. Third, we present a flexible short-turning procedure as alternative for the fixed preprocessing step in Van Aken et al. (2017). Finally, we test the model for solving TTAP on a real case and compare our solutions with the ones obtained by planners, explaining differences, thereby identifying possibilities for future research.

The remainder of this paper is structured as follows. Section 2 presents previous work relevant to possession scheduling, network aggregation, and the TTAP; and distinguishes our research. Section 3 summarizes the model developed in Van Aken et al. (2017), which serves as basis for our current work. The applied network aggregation techniques and procedures for turnarounds of short-turned trains are described in Sections 4 and 5, respectively. Additionally, the latter introduces the flexible short-turning concept. Section 6 presents three case studies and evaluates effects of different levels of network aggregation, and the different procedures, in terms of computation speed and solution quality. Furthermore, it discusses a real-life case study and its conclusions. Section 7 gives an overview of results and indicates directions for future research.

2. Literature review

Lidén (2015) presented a survey on the possible maintenance possessions, the involved planning problems and the mathematical models that have been developed for those problems. The scheduling of infrastructure maintenance actions is important on all levels of planning: strategic, tactical and operational. Depending on its time of planning, a possession can be categorized as either preventive or corrective. The former are defined as “maintenance that can be planned long in advance” (Forsgren et al., 2013), such as renewal and replacements of existing tracks (Budai-Balke, 2009). Lidén (2015) also distinguished between two types of possessions: major ones, which cause conflicts with scheduled trains paths; and minor ones, which do not interfere with train operations. In addition, a train path is “the infrastructure capacity needed to run a train between two places over a given period” (RailNetEurope, 2015). We consider major preventive possessions on a tactical level, and in particular, possessions that take one or more days to be completed. Examples of such possessions are renewal works of the station platform, which may cause possession of neighbouring tracks up to several weeks, or repairing signals along the track between two stations taking the whole working day. Since we consider major possessions, adjustments to a timetable are necessary. We distinguish three approaches to tackle the problem regarding major possessions: (a) scheduling only maintenance windows without changing the timetable, which can also be considered as a strategic problem, (b) adjusting timetables for given maintenance possessions, and (c) scheduling train traffic and track possessions simultaneously.

Lidén and Joborn (2015) presented a model for the first approach, where they assessed and dimensioned maintenance windows before a timetable is generated. Kidd et al. (2016) and Vansteenwegen et al. (2016) proposed a train routing model for adjusting a timetable and corresponding train routes due to given possessions, which corresponds to the second approach. The former was tested on the Copenhagen Metro line, and latter on the network around Brussels Central station. Arenas et al. (2017) formulated a MILP model to delay and reroute trains, close to operations, for a given possession, and considered scheduling additional train paths for maintenance trains. Without considering train cancellation, most of the generated timetables were feasible on the microscopic level. Albrecht et al. (2013) and Forsgren et al. (2013) tackled the third approach and both papers solved a scheduling problem for small cases with at most one or two given possessions. Albrecht et al. (2013) proposed a heuristic to solve the problem, while Forsgren et al. (2013) used an exact approach. Also, Luan et al. (2017) developed an integrated MILP model by considering maintenance possessions as virtual trains. For the other trains, the deviation from a given timetable was minimized. They used a cumulative variable approach to model track capacity, thereby

Download English Version:

https://daneshyari.com/en/article/6752009

Download Persian Version:

https://daneshyari.com/article/6752009

Daneshyari.com