Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 10 (2015) 524 – 533

Transportation Research Procedia

www.elsevier.com/locate/procedia

18th Euro Working Group on Transportation, EWGT 2015, 14-16 July 2015, Delft, The Netherlands

Maintenance scheduling in rolling stock circulations in rapid transit networks

Javier Andrés[a], Luis Cadarso[b], Ángel Marín[a]*

[a] Polyt. Univ. of Madrid. ETS Aeronautical and Space Engineering. Pl. Cardenal Cisneros, 3, Madrid 28040, Spain
[b]Rey Juan Carlos University, Departamental III Building, Camino del Molino s/n, Fuenlabrada 28943, Spain

Abstract

The railway routing problem determines specific paths for each individual train, given its type and composition and considering possible maintenance locations and durations. The objective is to minimize operating costs and penalties related to waiting times and maintenance all while considering train scheduling and maintenance constraints. The model is solved using Branch and Bound and Column Generation approaches. In the paper the different approaches are compared for different planning horizons and model parameter settings. The computational tests have been run in a real RENFE network.

Keywords: routing; maintenance; branch and bound: column generation.

1. Introduction

Before solving the rolling stock routing problem, network design, line service, timetable and rolling stock assignment have been addressed. Designing a rail network is vital to reduce traffic congestion, passenger travel time and pollution in any major city. The main goal of this design is to decide the least costly station locations that provide maximum coverage of the demand for the new network.

The next logical step is train scheduling. Traditionally, train scheduling has been decomposed into sequential steps. The first one is line planning, at tactical planning, in which planners determine the appropriate service frequency for each line, such that all travel demands are satisfied and certain objectives are met, e.g. maximization of quality of service for passengers and minimization of operating costs of the railway system. The second one is

* Corresponding author. Tel.:+34-91-3366323, ext 105; fax:+34-91-3366324.
E-mail address: angel.marin@upm.es

doi:10.1016/j.trpro.2015.09.006

timetable development, in which planners place the purposed train services throughout the day, subject to network considerations and other constraints. The result of timetable development is a series of train trips, which will be determined by the departure and arrival times from/at depot stations. Next, in the Rolling Stock (RS) assignment problem, train types and compositions of a given fleet are assigned to these trips ensuring that train capacity matches closely with demand and fleet cost is minimized.

This paper deals with the next step, where the railway network is redefined according to the previously established rolling stock assignment. Each train trip has a particular type and composition assigned to it; the goal of this step is to assign individual rolling stock units (trains) to those trips. This assignment is performed considering capacity, cost and maintenance requirements.

This problem determines the actual routes taken by the individual rolling stock units. It is usually called Rolling Stock Routing or, when maintenance is taken into account, Rolling Stock Maintenance Routing or simply, Maintenance Routing (MR). At this level, maintenance is key, as its requirements (and of course, network flow constraints) usually predominate over the rest of the constraints when defining the optimal route for each train. In this routing process, operating and maintenance costs are minimized, while each scheduled trip must be covered by exactly one train. Also, train flow conservation and depot capacity constraints must be satisfied at each network node. As a result, the final route performed by each train is composed by trips, storage at depots and maintenance checks, in a way that all the aforementioned requirements are met.

1.1. State of the Art

The paper of Cordeau et al. (1998) is an excellent survey of existing locomotive planning models and algorithms for the Train Scheduling. Cadarso and Marín (2010) study robust RS and routing of rapid transit rolling stock, but they do not consider maintenance restrictions. A comprehensive locomotive planning model is due to Ahuja et al. (2005).

Mellouli (2001) studies the routing and maintenance of trains and aircraft including the vehicle and crew scheduling. Maróti and Kroon (2005) consider the problem of routing locomotive units that require maintenance in the next one to three days and propose a “transition” multi-commodity flow model to solve this problem. The same authors develop the interchange model in Maróti and Kroon (2007) dedicated to regular maintenance routing of a few days, but considering preventive maintenance of about a month. However, small and frequent maintenance checks of only one or two days are not considered. They try to avoid empty trains forced by urgent maintenance tasks and are mainly interested in feasible solutions, given that in practice plans must be consulted with the local shunting crew. Other authors, Hong et al (2009), consider maintenance routing of uniform trains within a weekly train timetable in the High-Speed Railway (HSR) of Korea, covering the timetable with the minimum number of trains. As a second objective, the total working days of the train fleet is minimized. Typically, the MR is formulated in the literature as a multicommodity network flow problem or a set partitioning problem (Klabjan, 2005). The multicommodity flow network has a polynomial space complexity tractable by commercial solvers. The set partitioning formulation yields a tighter representation but involves an implicit enumeration of exponentially many paths and thus requires more complex solution techniques.

The idea behind this initial paper is developing a model suitable for the integration of maintenance routing with previous planning steps, consisting of timetable planning and rolling stock assignment. This future integrated model, with the necessary adaptations, can be used in a recovery planning scheme. In this way, some interesting reports may be mentioned: Borndörfer et al. (2012a, 2012b), Giacco et al. (2014), Wagenaar et al. (2015). The same ideas are being developed by Haahr et al. (2015) considering the integration to study the rescheduling during disruptions.

In this paper a detailed maintenance routing model is defined to deal with rapid transit network problems. The model approach is adapted to solve those problems, but considering the integration of the maintenance routing problem train scheduling planning stages. The paper is focused on maintenance routing but the intention to use it in an integrated recovery scheme, with the necessary adaptations. In contrast to the flow-based approaches to the same