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Transportation Research Procedia 3 (2014) 651 – 659

Transportation Research Procedia

www.elsevier.com/locate/procedia

17th Meeting of the EURO Working Group on Transportation,

EWGT2014, 2-4 July 2014, Sevilla, Spain

Short-term rail rolling stock rostering and maintenance scheduling

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Abstract

This paper describes an optimization framework for railway rolling stock rostering and maintenance scheduling. A key problem in railway rostering planning requires covering a given set of services and maintenance works with limited rolling stock units. The problem is solved via a two-step approach that combines the scheduling tasks related to train services, short-term maintenance operations and empty runs. A commercial MIP solver is used for the development of a real-time decision support tool. A campaign of experiments on real-world scenarios from Trenitalia (Italian train operating company) illustrates the improvement achievable by the approach when compared to the practical solutions.

Selection and peer-review under responsibility of the Scientific Committee of EWGT2014

Keywords: Railway Planning and Policy · Transit Assignment · Rolling Stock Rostering · Maintenance Scheduling

1. Introduction

This work addresses identification and analysis of a framework for optimizing short-term maintenance planning and rolling stock rostering. Rolling Stock Management (RSM) is a main cost factor for Rail Undertakings. In order

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Selection and peer-review under responsibility of the Scientific Committee of EWGT2014
doi:10.1016/j.trpro.2014.10.044

to reduce the costs due to railway operations, every company should address the joint problem of rolling stock rostering and maintenance scheduling since they are strongly related parts of the same problem. Maintenance optimization can be a key factor to increase the productivity of railway companies. At the same time, in a competitive globalized and multimodal market, RSM is one of the competitiveness key factor because services quality level depends on it. The strategic relevance of RSM, in particular of maintenance scheduling, is thus due to the reduction of needs (such as platforms and human resources) and to the enhancement of quality standards (such as vehicle reliability and cleaning). The problem to cover a given set of train services and maintenance works is a key problem in railway planning process.

The main objective is typically the minimization of the number of rolling stock units, while secondary objectives are to minimize the number of empty runs and to maximize the distance travelled by each train between two maintenance operations of the same type. First, the rostering and maintenance optimization problems are formulated by a graph theoretical approaches that involve short-term maintenance operations, the scheduling tasks related to train services and empty runs are studied by Giacco et al. (2012). The constraints of the maintenance optimization problem require that the different types of maintenance operations must be carried out for each train periodically. The various maintenance tasks can only be done at a limited number of dedicated sites. Starting from the solutions of the rostering and maintenance optimization problems, another graph theoretical approach is adopted to optimize workshop management and in particular to minimize the number of drivers involved and to verify the feasibility of the maintenance plan at each site have been addressed by Giacco et al. (2012-2013-2014). For a set of timetables and rolling stock categories, flexible versus rigid plans are compared in terms of empty runs and train services defined in each timetable.

For different feasible frameworks and different kinds of timetables, we evaluate mixed-integer linear-programming (MIP) formulations for train rostering and maintenance scheduling problems. The following questions are addressed: “How can the timetable be executed by an efficient use of resources such that the overall railway company costs are reduced? Which is the maximal improvement that can be achieved? At which cost?". We give an answer to these questions by performing an assessment of key performance indicators.

The computational evaluation presents the efficiency of the new solutions compared to the practical solutions. Experimental results on real-world scenarios from Trenitalia show that the optimization approach can reduce significantly the number of trains and empty runs when compared with the current plan. We use a commercial MIP solver for developing a decision support tool that computes efficient schedules in a short time.

2. Literature review

The railway industry is huge source of problems that can be modeled and solved by using Operations Research techniques. Many of these are still handled without automation and optimization. Such problems exist in several forms and arise at different levels in the planning process for a railway company. The complete railway system managing is highly complex and it is often divided into a lot of sub-problems which are interconnected. Given an objective to achieve, a very difficult task is to understand what problems are involved and how they are related. Interesting surveys and research works on railway planning have been presented by Abbink et al. (2004), Alfieri et al. (2006), Ahuja et al. (2005), Cacchiani et al. (2010-2012), Caprara et al. (2011), Cordeau et al. (1998), Hansen and Pachl (2008), Huisman et al. (2005), and Lingaya et al. (2002). From our point of view, the literature is too focused on manufacturing setting in order to reduce the occurrence of a failure, while unfortunately the coordination of maintenance and rolling stock scheduling is still under investigated. We next discuss some relevant publications addressing the rolling stock rostering and railway maintenance planning problems.

2.1. Rolling stock rostering

Given the departure and arrival times as well as the expected numbers of passengers, rolling stock circulation deals with the assignment of locomotives and carriages to the timetable services, while rolling stock rostering focuses on the assignment of a roster to each individual train unit. The latter problem should include rolling stock maintenance operations in the roster. Several objective criteria can be considered that are related to operational costs, service quality and reliability of the railway system. The problem calls for determining for each trip the