Real-life Decision Support for the Locomotive Assignment Problem with Heterogeneous Consists

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1 Introduction

Arising from a practical problem in European rail freight transport we present a decision support system for the locomotive assignment problem (LAP) with heterogeneous consists (i. e. combinations of locomotives). Based on a preplanned train schedule, a set of locomotives (or consists) has to be assigned to a number of trains at minimal costs. Hence, the goal is to find an optimal schedule for each vehicle under consideration of several real-world requirements. Among these are a realistic modeling of consist busting processes (i. e. the process of dissolving and forming consists), regional limitations for running certain types of locomotives and requirements of each train regarding a minimum engine power of the assigned consists. Furthermore, the predefined route of each train can be divided into several route segments. Each segment can be covered by a different consist taking (dis-)connecting processes into

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account. Since most issues have been studied only with special assumptions or simplifications so far, a realistic decision support is not ensured in practice.

One of the first works considering heterogeneous consist was published by Florian et al (1976). As more recent papers modeling this problem Ziarati et al (1997) and Ahuja et al (2005) are noteworthy. Since the locomotive assignment is integrated in a higher-level planning process, there are also simultaneous approaches with up- and downstream processes, e.g. Cordeau et al (2001) and Godwin et al (2006). Nevertheless, to the best of our knowledge no suitable algorithms have been proposed that regard specific characteristics of European rail freight transport for the studied LAP. For a detailed literature overview we refer to Piu and Speranza (2014).

2 Modeling and Complexity

Usually the LAP is modeled as a commodity flow problem. We use a mixed integer formulation based on Ahuja et al (2005). In general, complexity of this problem is driven by three major factors. The first one is the number of possible consists. By predefining consists as artificial locomotives the model can be solved heuristically as simple LAP with heterogeneous locomotives (see Vaidyanathan et al (2008)). But defining a set of suitable consists becomes more difficult by increasing the number of locomotive types. Hence, strategies to create consists efficiently are necessary. Piu et al (2015) introduce several ideas for a preliminary consist selection. The second and third complexity driver arise from the underlying space-time network. Obviously, modeling each route segment as single train results in a very large problem. Especially, in European railway networks with relatively short distances this problem arises more frequently compared to, for example, American networks. The complexity can be scaled down significantly if the fact that each train consists of several route segments is ignored. However, this leads to a loss of optimization potential. Therefore, heuristic solutions can be achieved by using informations about trains and segments, and therewith, making the problem scalable. The last complexity driver is that locomotives are able to change their locations almost at any time between pulling two trains (light-traveling). This problem can be encountered by choosing a set of suitable light-traveling connections for gaining heuristic solutions.

3 Decision Support

Based on the complexity drivers we design a decision support system using a Locomotive Flow Formulation (LFF; Ahuja et al, 2005) and a Consist Flow Formulation (CFF; Vaidyanathan et al, 2008). Figure 1 illustrates the underlying structure of such a system. Each subproblem is given by a combination of used consists/locomotives and a reduced/complete network. The basic idea is using a heuristic solution generated by CFF as initial solution for LFF. Since

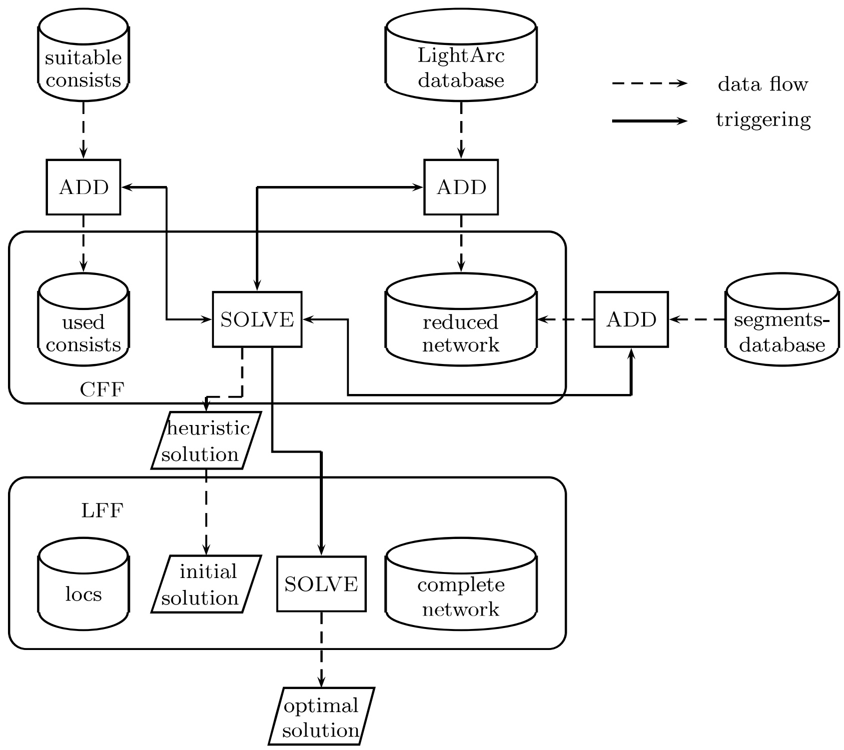

Fig. 1 Decision Support System for solving large LAP

CFF can be solved very efficiently, we present an iterative procedure for solving and adding suitable consists, light-traveling connections (LightArcs) and segments to improve the solution quality of CFF. We discuss several strategies of predefining a set of suitable consists as well as choosing distinct consists for adding to the model. Adding LightArcs is based on a combination of two decisions: first, a relation between stations has to be determined and, secondly, one or more time slots may be released. The latter can be chosen in relation to the given train schedule or can be distributed evenly over the planning horizon. Analogously, we compare the strategies of, on the one hand, dividing trains into a parametrized number of segments and, on the other hand, using schedule related information for choosing segments that are suitable to each other. Finally, creating a feasible initial state for CFF and a running order for solving and adding is presented. For very large instances finding an optimal solution in reasonable time can be assumed as unrealistic. Hence, providing a heuristic solution by introducing intelligent stopping criteria is suggested.

The resulting decision support system is implemented in `C#` programming language and tested on real world data as well as on self-generated instances using Gurobi for solving MIP. The improved heuristic is proven to be suitable for solving locomotive assignment problem with heterogeneous consists and integrated practical requirements of European rail freight transport.

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