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Electronic Notes in DISCRETE MATHEMATICS

Electronic Notes in Discrete Mathematics 47 (2015) 141–148 www.elsevier.com/locate/endm

Variable Neighborhood Search for Integrated Timetable Based Design of Railway Infrastructure

Igor Grujičić [a,1] Günther Raidl [a,2] Andreas Schöbel [b,3]

[a] *Institute of Computer Graphics and Algorithms, Vienna University of Technology, Vienna, Austria*

[b] *Institute of Transportation, Research Centre for Railway Engineering, Vienna University of Technology, Vienna, Austria*

Abstract

In this paper we deal with the problem of building new or extending an existing railway infrastructure. The goal is to determine a minimum cost infrastructure fulfilling the requirements defined by an integrated timetable and the operation of the railway system. We first model this planning task as a combinatorial network optimization problem, capturing the essential aspects. We then present a metaheuristic solution method based on general variable neighborhood search that makes use of a dynamic programming procedure for realizing individual connections. Computational experiments indicate that the suggested approach is promising and the analysis of obtained results gives useful hints for future work in this area.

Keywords: Railway Infrastructure Design, Integrated Timetables, Dynamic Programming, Variable Neighborhood Search.

[1] Email: grujicic@ads.tuwien.ac.at

[2] Email: raidl@ads.tuwien.ac.at

[3] Email: andreas.schoebel@tuwien.ac.at

http://dx.doi.org/10.1016/j.endm.2014.11.019

1 Introduction

The design of new railway infrastructure is nowadays strongly guided by the prespecified integrated timetables that have been derived from expected traffic to be served [4]. Integrated timetables synchronize the traffic in major nodes (hubs, e.g., main railway stations in major cities) at regular time intervals, ensuring connectivity between different lines with minimum waiting times at those hubs, and allowing passengers to easily remember the regular departure and arrival times.

The Timetable Based Design of Railway Infrastructure (TTBDRI) problem can be summarized as follows: The aim is to extend an existing or to build a new railway infrastructure in such a way that all scheduled connections can be realized according to the given (integrated) timetable and costs are as low as possible. Implementing the concept of integrated timetables imposes major challenges and constraints, see e.g. [1]. Computational complexity of TTBDRI is discussed in [6].

In this paper we present a concrete combinatorial approach for modeling the basic problem which builds upon our former work [2]. It considers already existing railway infrastructure as well as extension possibilities in a fine-grained way. We then suggest a variable neighborhood search algorithm for approximately solving this problem, which makes use of a dynamic programming procedure for realizing individual connections locally optimal.

2 Problem Definition

We are given the following input data.

- An undirected graph $G = (V, E)$ represents the existing railway infrastructure plus all possible extensions. The node set V contains different types of nodes, first of all the following *infrastructure nodes* corresponding to real objects:
  - **track segment nodes** representing physical, simple track segments of a certain length, they always have at most degree two;
  - **switch nodes** representing classical switches, they have degree three (or possibly higher if more complex switches are modeled by single nodes);
  - **crossing nodes** representing crossings of two lines, which always have degree four;
  - **signal position nodes** representing signaling stations; they always have degree two.

  To model mutually exclusive alternatives for infrastructure extensions, we