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Railway infrastructure maintenance - a survey of planning problems and conducted research

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Abstract

Railway infrastructure maintenance consumes very large budgets, is complicated to organize and has numerous challenging planning problems. Specifically, the coordination with train traffic operation is of crucial importance. Despite this, little work has been conducted in the operations research area regarding infrastructure maintenance as compared to train traffic operations.

The aim of this paper is to give a comprehensive overview of the railway infrastructure maintenance field, the planning problems it contains and the research that has been conducted so far. We present (i) a catalogue of planning problems, based on a series of interviews with experts and planners representing all major stake holders in Sweden and (ii) an extensive literature overview covering more than 60 research references published until 2014 regarding the use of mathematical methods and optimization for solving such planning problems. From this we extract some statistics and a mapping which identify the major lines of work as well as future research possibilities.

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Keywords: Maintenance planning; Operations research; Railway infrastructure

1. Introduction

Railway infrastructure maintenance is of crucial importance in order to obtain a well functioning transportation system. The actual maintenance work consists of a large amount of different activities, requiring considerable resources and large budgets. The European countries are reported to allocate 15 - 25 billion EUR annually on maintenance and renewals for a railway system consisting of about 300 000 km of track, half of which is electrified, giving an average of 70 000 EUR per km track and year (see EIM-EFRTC-CER Working Group (2012)).

There is however an inherent conflict in deciding how to assign maintenance work slots and train operation paths since these activities are mutually exclusive. This planning conflict becomes crucial on lines with high traffic density and especially when network traffic demand and maintenance needs are increasing.

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In addition, a far reaching deregulation has been going on since the 1980s in Europe, with the overall purpose of opening up for commercial competition. For infrastructure maintenance, this trend has extended the use of maintenance contractors, which raises more concerns regarding contractual forms, public procurement as well as planning.

All these factors - the large volumes, the interrelation between maintenance and traffic, the organizational aspects - motivate efficient and coordinated planning as well as further research. Historically, operations research has however focused more on train operation problems than on infrastructure maintenance activities.

To gain a better understanding of how railway maintenance is organized, planned and performed we have conducted a series of unstructured interviews with 15 experts and planners in Sweden, representing different organizations (infrastructure manager, contractors, operators), planning steps (from procurement to day-of-operations) and major technical activities (measurement, inspection, grinding, power system maintenance, etc). From this study we have identified and described the major planning and scheduling problems that must be solved. The result is presented as a catalogue of planning problems in Section 2. Further, we have conducted an extensive literature review to investigate which problem areas that have been studied scientifically. An overview of the publications found is presented in Section 3. Finally, we present some statistics and a mapping which shows which problem areas that so far have been addressed in the literature.

Scope. We focus on the planning and coordination of infrastructure maintenance and train traffic activities on a commonly used infrastructure. Hence, we are less concerned with the maintenance technique itself and the details of how to perform the actual work. Also we do not treat software tools for asset management and maintenance planning, which have been developed for railway infrastructure purposes over the years (e.g. REPOMAN, TRACS, MARPAS, ECOTRACK, SOG), instead referring interested readers to Guler (2013). Another type of work which we will not cover are simulation models for studying how network capacity, delays, etc, depend on the state of each track section, degradation, maintenance and train traffic (see for example Simson et al. (2000); Podofillini et al. (2005)). Finally, we will not include pure train traffic capacity and timetable work, planning of rolling stock maintenance and robustness of railway schedules in this study.

Infrastructure access and planning process. All activities that require secure access to the railway infrastructure must obtain a (work) **possession** (RailNetEurope (2013a,b). If the possession will be in conflict with or influence a train path we call it a “major possession”, while those not affecting the train operation are called “minor possessions”. The complete planning process for obtaining possessions and train operation slots in Sweden follow EU guidelines and consists of the following steps: (1) Freight corridor planning, where “prearranged paths” for international freight trains are established and coordinated with large major possessions; (2) Preparation and publishing of the network statement, which shall contain all major possessions that the train operating companies must adhere to; (3) Yearly timetable planning, where the basic timetable for all train paths are planned together with the major possessions; (4) Timetable revision planning, where the dated timetables are produced and final coordination of train paths and major possessions is done; (5) Planning of minor possessions, where work which do not affect any train paths are scheduled; (6) Operational planning and control, where the traffic control centers will make operative adjustments, authorize all possessions (including unplanned ones) and control all activities on the railway infrastructure. This process (where steps (1) - (5) is often labelled “capacity planning”), is representative for most European countries.

For further introductions to practical maintenance planning issues, we refer to Aspebakken et al. (1991), which describes a North American setting, and Ferreira (1997), which covers planning problems and aspects faced by a deregulated and timetable governed railway operation, such as those in Europe and Australia. We also refer to Lidén (2014) for a more complete description of railway infrastructure maintenance from a planning perspective.

2. A catalogue of planning and scheduling problems

In this section we list classes of planning and scheduling problems that have been established during our survey. Some of these problems have been identified in the interviews, while others have been recognized by comparison with other operations research fields.

We classify the problems as strategic, tactical or operational. In the strategic class we list problems concerning dimensioning, localization and organization, with time horizons of one to several years. Tactical problems include