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Dimensioning windows for railway infrastructure maintenance: Cost efficiency versus traffic impact

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ABSTRACT

The Swedish Transport Administration is introducing a new regime, called maintenance windows, for allocating train free slots reserved for maintenance tasks on the railway infrastructure. In this paper, a model for the assessment and the dimensioning of such maintenance windows is presented, which considers marginal effects on both the maintenance cost and the expected train traffic demand. The aim is to establish quantitative measures that can be used for comparing conflicting capacity requests from infrastructure maintenance and traffic operations on railway networks. The model is demonstrated in a cost benefit analysis for a real life case study on the Swedish Northern Main Line.

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 € annually on maintenance and renewals for a railway system consisting of about 300,000 km of track, giving an average of 70,000€ 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/or around the clock operation - especially when traffic demand and maintenance needs are increasing. This is the case in Sweden, where passenger and freight trains are mixed on the same infrastructure and a large increase in passenger traffic, both regional and inter-regional, have forced many freight trains to be run during night time, leaving very few opportunities for maintenance.

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 in the railway area. 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 more research. This is further accentuated by increasing needs for transportation regarding volumes, weights, speeds, safety and comfort, which, together with an ageing infrastructure, will increase the demands for maintenance and renewals. Historically, research about scheduling and planning has however focused more on train operation problems than on infrastructure maintenance. Specifically, the coordinated planning of infrastructure maintenance and train operations has received little attention. In such planning, with conflicting capacity

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requests that should be balanced, we need quantitative measures that can be used as evaluation criteria - which is the issue to be addressed here.

In this paper we present a model for evaluating the impact of different maintenance window designs on both train traffic and maintenance cost and apply it on railway lines with a homogeneous train traffic. The major contributions of this work are (a) an analytical model for calculating the maintenance cost depending on the available train free time, (b) a framework for quantifying and comparing conflicting capacity requests from maintenance and traffic on railway networks, and (c) demonstration of the approach on a real life case study. For the train operations we apply standard transport economy models on the detailed level of individual travel choices and transport service changes. Although we mainly will discuss single track situations, the models are applicable to any type of rail line.

The paper is organized as follows: In the next section we describe the background and motivation for the studied problem followed by a literature review in Section 3. The modelling approach is outlined in Section 4, followed by the mathematical formulations for assessing the effects on maintenance cost (Section 5) and traffic and transportation (Section 6). In Section 7 the use of these models on a real life case study is reported. Finally, we conclude with summary and discussion in Section 8. For better readability we consider a somewhat simplified case in Section 5 while the complete and detailed maintenance cost model is presented in Appendix A.

2. Problem description and assumptions

All non-train activities that require secure access to the railway infrastructure must obtain a (work) possession (RailNetEurope (2013)). Up to now, the planning regime adopted in Sweden has been to let the maintenance contractors apply for these work slots, which usually is done as late as possible. If no room is reserved for maintenance in the timetable it can be difficult to find suitable possessions, which forces the contractors to perform their work on odd times and/or divide the tasks into small chunks which leads to inefficiency and cost increases. If the work cannot be split into smaller tasks, then the timetable must be altered and train operations rescheduled. Statistics from 2012, regarding the Swedish main line network which is 14,700 km long, show that there were about 16,000 work possessions applied for during the timetable period. Several of these triggered train path and timetable changes, but the exact figures are not known. As an indication, the total amount of timetable changes in the same period were in the order of 20–30,000.

To increase the possibility for suitable work possessions, a new planning regime is now being introduced in Sweden, called maintenance windows, where the infrastructure manager will propose regular, 2–6 h train free slots *before* the timetable is constructed. Thus, the maintenance windows are given as a input to the yearly timetable process. In addition, the maintenance windows will be dimensioned and constructed before the procurement of maintenance contracts and will remain more or less unchanged during the contract period, giving stable planning and quotation conditions for the contractors. The goal is to perform almost all planned maintenance on work possessions within the stipulated maintenance windows. Note that maintenance windows are predetermined train free slots in the timetable, while possessions are the actual reservations for specific work tasks.

Hence, the basic idea is to go from a situation with many, small and fragmented work possessions squeezed into an already published timetable (which causes changes and disturbances for the train operations), to a situation with few, large and regular maintenance windows preplanned before the timetable is constructed and the maintenance contracts procured. The overall aim is to increase efficiency, reduce cost as well as planning burden and also to improve robustness and punctuality. We will not analyse all these aspects but will focus on the consequences for maintenance, train traffic and transportation demand. A more complete study of the pro's and con's when introducing maintenance windows must consider several other factors, like the long term unavailability of train capacity, network wide effects, planning efficiency etc.

The dimensioning and construction of maintenance window patterns is a long term planning problem of crucial importance, since it lays the foundation for both the maintenance work and the traffic operation. It must be based on reasonable predictions about the maintenance work volumes as well as the traffic demand for period lengths of 5–10 years (corresponding to the maintenance contract length – which is 5 + 2 years in Sweden).

Now we turn to the content and organization of the actual maintenance jobs. A maintenance work shift typically consists of three parts:

Preparation: Crew and equipment must be transported to the working site, where the resources will be organized, prepared and set up. The working area must be secured, by proper signalling and electrification measures which includes registration and acknowledgement from the traffic control centre(s).

Maintenance: The actual work task(s) can be of varying type, where some tasks (e.g. inspection and vegetation clearance) require short times, say 1/2 – 1 h, while others (e.g. welding, switch machine work) take longer to finish, say 2–6 h.

Termination: When the maintenance task has been finished, the site must be cleared, resources and safety measures removed and finally the responsibility handed back to the traffic control centre(s).

We will label preparation and termination as *overhead* time, while the actual maintenance job is called *task* time. Together they form the *shift* time and the sum of all shifts is called *work* time. Our basic assumption is that the tasks are divisible such that, e.g. a 2 h task can be performed on two possessions. The overhead time, on the other hand, is directly proportional to the number of possessions. Further we will consider that some part of the overhead time can be performed *outside* the track possessions, while the rest must be done *inside* it. This terminology is illustrated in Fig. 1, which also shows the three different window size cases discussed below and exemplified in Table 1.