Rolling stock maintenance scheduling with logistic and resource constraints

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1 Introduction

The scheduling of preventive maintenance activities is becoming a key issue in many industries. In the case of rolling stock maintenance, preventive activities play a crucial role. On the one hand, the consequences of failures are enormous, as they have an impact on the entire rail network. On the other hand, since these are assets with a high utilisation rate, performing too many maintenance activities means reducing the utilisation rate of these assets and increasing the time they are not productive.
According to the work of [5], there are two approaches to consider maintenance activities into the rolling stock circulation plan. First, the rostering allows to treat maintenance activities as tasks to be performed by each train unit. These activities are considered together with the regular service tasks to define the rolling stock circulation plan [1]. Second, in maintenance routing, the circulation plan is considered as an input to the problem and the objective is to find the moment in which train units can reach maintenance centers without affecting transport services [3]. In all previous approaches, maintenance activities are only an input of the problem, without considering the possibility of defining maintenance dates according to the state of assets degradation. Therefore, maintenance is treated as a constraint rather than an optimisation problem.
Broadening the field of research, many studies in the literature analyse the problem of scheduling preventive maintenance activities. Linear and non-linear optimisation models are proposed with the purpose of minimising the overall maintenance cost over, namely the cost of preventive activities and the cost of non-predicted breakdowns [4]. In the field of rolling stock preventive maintenance scheduling, the work presented in [2] proposed a non-linear model that tries to reasonably reduce the maintenance frequency while ensuring safe operations.
In our research the problem of scheduling preventive maintenance activities for a fleet of train units is studied. The aim is to define a preventive maintenance plan considering the failure behaviours of components and the actual possibility of carrying out the activities in a given day by taking into account resource availability at different maintenance work centers.

2 Problem Description

Train units are subject to regular preventive maintenance activities, defined by the manufacturer and regulated by law. Basically, the problem of scheduling preventive maintenance activities for rolling stock deals with the determination of the optimal date when a given train unit goes from the operational state, i.e. when it ensures transport services, to a maintenance center to perform maintenance activities.
Therefore, we consider a set of train units, each with a given set of cyclic preventive maintenance activities to be performed. Each maintenance activity must be scheduled within a

planning horizon consisting of a certain number of time slots without affecting the transport service. In other words, it must be ensured that a certain number of railway units are available to perform the transport service. In addition, for contractual reasons, there is a maximum number of railway units that can be in maintenance status at the same time.
Maintenance activities can be scheduled in different maintenance work centers depending on the availability of the necessary resources. Therefore, we consider a set of different work centers and a set of resource types, e.g. rails, spare parts or available manpower. Each activity needs a certain amount of different types of resources and in each work center there are different available resources.
For each maintenance activity, we consider a deadline which is actually the end of the preventive maintenance cycle. If the train unit is not maintained before the deadline, it cannot run. Regarding each activity separately, the optimal time to maintain it is the deadline otherwise some of the available time is wasted.
The optimization problem is therefore to define the time slot and the work centers where every maintenance activity holds, for each train unit while respecting operational constraints. The objective function is to minimise the cost of the shift between the optimal maintenance date defined a priori and the planned maintenance date. The cost parameter used in our optimisation model is the maintenance cost per unit time of a given cycle which is a reliability parameter. This parameter takes into account both the cost of maintenance activities and the indirect cost of unforeseen failures, allowing us to balance excess maintenance, the cost of unforeseen failures, and the unavailability of assets due to failure to meet the maintenance deadline. Using this parameter, our objective is to take into account the reliability aspect of the assets to be maintained while keeping the problem linear. The problem is modelled as an integer binary programming model.

3 Conclusion and perspectives

We have proposed a Mixed Integer Linear Programming model (MILP) to solve the considered problem. Computational experiments have been carried out to assess the performances of the proposed MILP using CPLEX 20.1.0. These experiments are run on a 2020 Macbook Pro with a 3.2 GHz (Apple M1 processor) and 8 GB RAM. The model is coded in Java and tested on randomly generated instances consisting of 50, 100, 150 or 200 tasks with 60 time slots. All these instances are solved in less than one minute. The next step in our research is to consider cyclic preventive maintenance activities for each system in each train.

Références

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