Rolling Horizon Approach for Rolling Stock TBM scheduling

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1 Introduction

The role of Time-Based Maintenance (TBM) remains critical, especially in addressing known issues, ensuring compliance, and adopting a proactive approach for critical components and equipment. However, scheduling TBM activities for rolling stock is challenging due to the high demand for transportation service and the need to comply with safety requirements. Balancing compliance and ensuring a high degree of asset availability for service operations poses a complex task. Additionally, the evolving needs of rolling stock over its lifecycle necessitate adaptable maintenance cycles, as the initially outlined activities may not be suitable for later stages.

The Periodic Maintenance Problem (PMP), proposed by [4], was developed for scheduling cyclic maintenance activities, but is constrained to scheduling one activity per time slot. The Opportunistic Replacement Problem (ORP) [1] explores the notion of opportunistically executing maintenance tasks, wherein the completion of one task is leveraged to perform additional activities. This approach enables the grouping of tasks, effectively minimizing the downtime of an asset. A flow formulation is proposed in the Preventive Maintenance Scheduling Problem with Interval Cost (PMSPIC) [5]. Maintenance activities are scheduled based on a cost parameter that is a function of interval length. When scheduling maintenance tasks, it is crucial to conduct a thorough evaluation of the overall maintenance costs. This evaluation includes not only the direct costs associated with performing maintenance activities but also the probabilistic costs linked to potential failures, which incorporate the implications of non-production periods. To address this, one approach is to integrate the failure rate function of assets into the objective function alongside the activity cost [6]. However, it's worth noting that this approach may introduce non-linearity, given that the failure rate of components often exhibits non-linear behavior [2], thereby contributing to challenges in solving such problems.

The objective of this study is to enhance the planning of TBM activities for rolling stock, with a focus on optimizing overall maintenance costs while accounting for operational and resource constraints. We develop a rolling horizon algorithm as a continuation of our research in the field of preventive maintenance scheduling for rolling stock [3].

2 Problem Description

This paper addresses the optimization of scheduled maintenance tasks for a fleet of rolling stock, with a focus on TBM activities. These activities are scheduled periodically based on an optimal maintenance cycle but may deviate from the schedule due to resource availability and their impact on regular transportation operations. The goal is to optimize the scheduling of TBM activities by evaluating overall maintenance costs, considering activity costs, and the minimum repair cost dependent on component failure rates influenced by the actual maintenance cycle duration.

We consider a set of train units each with a set of TBM tasks to be performed. Each activity is assigned an optimal maintenance date, acting as both a deadline and the ideal initiation time.

TBM activities must be scheduled across geographically dispersed maintenance depots with varying resources. This scheduling is done within a planning horizon defined by a set of time slots. We consider a set of resource typologies and each TBM activity may require specific quantities of each of these resources. Each task has got a not negligible duration expressed in number of time slots necessary to perform the activity in which resources are occupied.

To align with the practicalities of a rail transport network, we establish a minimum count of available train units. A train unit can be unavailable in two situations : first, when a task is underway, and second, when at least one task is not completed by the end of its interval. While surpassing the interval is not explicitly prohibited, it does affect the number of available train units, which is a strong constraint.

To accommodate the cyclical nature of TBM activities, we employ a rolling horizon approach. This method introduces new instances of maintenance dates in successive optimization horizons, enabling us to effectively schedule recurring TBM maintenance activities.

3 Conclusion and Perspectives

We developed a Rolling Horizon algorithm which iteratively solve a Mixed Integer Linear Programming (MILP) model for scheduling the next occurrence of Time-Based Maintenance (TBM) activities for a fleet of rolling stock. Our key contributions to the maintenance scheduling scientific literature involve the capacity to schedule recurring activities while taking into account the overall maintenance cost. We ran computational experiments on instances with up to 350 activities and 90 time slots to evaluate the performance of MILP, using a 2.00 GHz Intel Xeon CPU E7-4820 R910 server (2 processors) with 256 GB of RAM. Our next research step involves integrating the TBM scheduling problem with the train assignment problem.

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