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Remanufacturing In Vehicle Maintenance: Logistic Challenge And Constraint Or Opportunity For Increasing Sustainability

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The research discussed in this manuscript focuses on modeling and optimizing maintenance policies for industrial vehicles. In recent years, industrial vehicle manufacturers have recognized the pivotal role of after-sales services in their income sources. Consequently, the development of innovative maintenance services for customers has become crucial. The primary goal is to offer clients cutting-edge services, leveraging the increasing availability of data on vehicles to maximize productivity and availability while adhering to customer constraints. Customer expectations have evolved beyond simple breakdown or abnormal degradation alerts; they now seek comprehensive solutions and recommendations including maintenance, usage guidelines, and operational procedures to fully keep their vehicles operational. Within this context, manufacturers aim to ensure the availability of the customer's operational tools, emphasizing the importance of mastering and optimizing vehicle maintenance. Effective maintenance management is equally critical for customers, enabling them to ensure the availability of their trucks in good condition and guarantee the profitability of their businesses.

The maintenance of components and vehicles can be managed in two different ways: preventive maintenance or predictive maintenance based on monitoring data of the degradation level. Predictive maintenance uses predictive models based on vehicle data to estimate degradation and anticipate potential failures. However, decisions regarding maintenance dates are not fully optimized and are often made without the assistance of decision-making tools by customer service representatives responsible for the workshop maintenance schedule, making it challenging to consider numerous constraints in establishing an optimal calendar. The upcoming industrial goal is to optimize the schedule by integrating both preventive and predictive maintenance while addressing operational constraints.

One of the challenges in implementing advanced maintenance policies is the integration of diverse field constraints into the optimization of maintenance decisions. The motivation behind the work presented in this paper is to contribute to the development of dynamic maintenance models that take into account a range of operational constraints. These models seek to quantify the performance of maintenance policies and serve as decision support tools for informed maintenance decision-making.

The constraints to consider fall into three main categories:

- logistic and resource constraints: include the availability of spare parts, workshops, and maintenance teams;
- circularity constraints: the choice between replacing the faulty component with a new or remanufactured part, including the potential reuse of a replaced component in different usage contexts;
- customer constraints: customer constraints involve managing the overall fleet impact during maintenance-induced downtime and ensuring continuous fleet availability, considering potential regulatory constraints.

The analysis of the state of the art in maintenance modeling, particularly in predictive maintenance of systems, reveals that existing work and models do not always take into consideration entirely all constraints, and the maintenance problem is often simplified compared to reality. In particular, “circularity constraints” are taken into account in few works. The aim of this work is to investigate how these rather novel constraints can be integrated with the maintenance optimization, to assess their impact on the maintenance performance, and to examine whether considering circularity (i.e., using remanufactured spare parts) simply imposes additional constraints in the maintenance decision-making process, or opens new opportunities.

In our methodology, we start the research by critically analyzing the prior work on remanufacturing. This initial step includes defining the concept of remanufacturing and establishing its main objectives, aiming to prepare the foundation for an effective integration into a maintenance model. Building upon this analysis, we will propose a comprehensive maintenance model that explicitly incorporates remanufacturing. This involves defining the remanufacturing policy as part of the maintenance strategy seeking to effectively tackle this constraint.

By exploring the potential benefits, such as enhanced sustainability and more efficient resource management, we will emphasize different opportunities arising from this integration.

Simultaneously, we will examine the challenges posed by this approach, particularly focusing on logistical limitations associated with processing used components and the potential increase of implementation costs.

This critical analysis helps create a flexible maintenance model that includes operational constraints (mainly remanufacturing) and see whether maintenance decisions are improved and how does the possibility to use spare parts affect the performance of the maintenance model and plans.

Furthermore, our analysis will consider closely an important dilemma: the decision between frequent replacement with older, less available parts with a reduced carbon footprint or prioritizing less frequent replacements with new parts. These key questions will guide our analysis of the relevance of remanufacturing in the context of the maintenance model we are considering.

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