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Priority rule-based planning approaches for regeneration processes

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Abstract

Regeneration comprises the maintenance, repair and overhaul (MRO) of complex capital goods such as jet engines, wind turbines and stationary gas turbines. Service providers of such regeneration processes face many challenges, including the variability of regeneration paths due to the availability of different repair procedures. In addition, conditions for regeneration processes are defined by the high requirements for logistical performance, e.g., short delivery times and strong adherence to delivery dates set by customers. To meet these requirements, it is essential to efficiently plan regeneration processes. If constraints are not met, regeneration service providers risk heavy penalties and a loss of customers. In this paper, we present methods that, with the aid of priority rules, provide support in planning regeneration processes. These priority rules can be applied to different steps within the planning process: on a higher planning level, priority rules can be implemented to sequence orders and thus to optimize logistical performance. On a more detailed planning level, priority rules can be used to decide on the regeneration path and to schedule the particular regeneration steps. Both successive planning approaches take into account customer requirements as well as targets set by the service provider.

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Keywords: regeneration; complex capital good; planning; priority rules

1. Introduction

Complex capital goods such as jet engines, wind turbines and stationary gas turbines consist of a multitude of components with extensive functional interdependencies [1,2]. Because these different components perish during a good's service, it is necessary to carry out maintenance, repair and overhaul (MRO) processes to restore or even improve the good's functionality at the end of its service life. MRO processes in the context of complex capital goods are referred to as regeneration.

Planning internal regeneration supply chains and processes is characterized by several challenges that distinguish the regeneration from common productions. The extent of necessary repair procedures differs due to the specific condition of the capital good. In addition, customers have a strong influence on the possible repair process based on their business model. Therefore, each regeneration order has the character of an individual project. For such a project, there are several possible regeneration paths due to the availability of different repair procedures for specific wear. This increases the degrees of freedom for the planning of regeneration processes. In addition, there are high logistical demands concerning the schedule reliability, short delivery times and strong adherence to delivery dates set by customers. Delay penalties caused by non-schedule compliance need to be avoided because the competitive pressure is very high. To avoid a loss of customers, regeneration service providers have to guarantee high customer satisfaction.

Taking those circumstances into account, our paper discusses methods for planning internal regeneration supply chains and processes. To guarantee a holistic planning approach, two different planning steps are considered. The first step is a rough planning of the order processing considering an efficient logistics process. The second planning step focuses on the determination of a detailed and

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resource-specific sequence of the particular activities that are associated with the orders. This approach allows us to take the concretion of information into account. In the first step, only vaguely estimated information is available. The extent of damage and therefore the workload is then determined during a diagnostic phase at the regeneration service provider's site and is considered in the second planning step.

2. State of the art

Figure 1 shows the regeneration process, which can be divided into different subsystems [3]. In addition to the processing, in which the actual refurbishment of the components takes place, the regeneration process includes a disassembly at the beginning and a reassembly at the end of the supply chain. During the disassembly, the partition into the different components takes place. At the beginning of the processing, the components are cleaned and diagnosed. After these steps, the workload and the possible regeneration paths are known for each order. The subsequent repair consists of different repairing jobs depending on the chosen regeneration path. After repairing, the good can be reassembled. A quality assurance at the end of the regeneration checks whether the reassembled good demonstrates the required functionality [4].

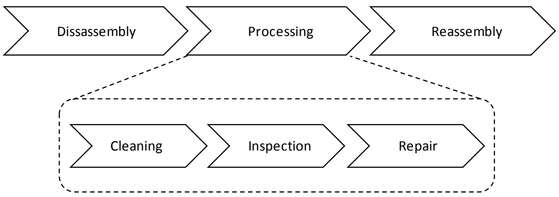

Figure 1 Subsystems of a regeneration process

A survey shows that 41% of the surveyed MRO service providers have problems to adhere the given delivery dates due to time delays within the procurement of components and the repairing processes [5]. This shows that the planning of the regeneration process in MRO companies has room for improvement by taking the specific requirements into account.

In our research, we focus on the configuration of the regeneration processes. The goal is to define in which sequence and in which regeneration mode orders and the corresponding jobs should be processed. Thereby, the competition of different orders for the existing resource capacities must be taken into account. A capacity is scarce if the sum of the overall workload of the orders that could be started at the considered point of time exceeds the available resource capacity.

Regeneration service provider should focus on minimizing turn-around times as well as the arising costs [6]. In our problem setting, the occurring costs consist of the job costs and possible delay cost. In case of missing the delivery date given by the customer, penalty costs for every delayed period arise. In addition, due to the varying repair jobs, each regeneration path is characterized by different costs.

Because of the high variability of the processes due to specific dispatching dates and unknown conditions of the goods accompanied with highly individual customer-oriented regeneration processes, classical planning approaches as, e.g., lot-sizing models are not sensible to solve this problem. Instead, each regeneration event should be interpreted as a project with individual requirements [7]. Due to the in advance uncertain information, it is reasonable to decide which of possible alternatives actually occurring should be chosen instead of forecasting all possible settings. For implementing such a method, one needs rules that prioritize the different alternatives under consideration of the problem setting's objective, so-called priority rules.

Based on the chosen priority rule, a priority value for each order is determined. This specific priority value is interpreted as a rating. Based on this rating, the processing sequence can be determined. Every priority rule embraces one or several criteria. Those criteria include, e.g., schedule-based, monetary or strategic key figures. Priority rules using just one criterion are the easiest way to decide on the sequence. A combination of multiple criteria leads to an advanced planning approach because for each schedulable order or repairing job, a more complex priority value must be calculated. A good overview of different priority rules is given by Browning and Yassine [8].

Admittedly, this usage of priority rules is heuristic, i.e., it is not assured that the optimal solution will be found. However, optimal solution methods like a branch and bound are not able to find a good solution for practical oriented problem sizes with such a high complexity in a reasonable time [9].

In our approach, we distinguish two subsequent planning steps where we apply priority rules. One planning step is to determine which regeneration orders should pass through the regeneration process at what time. The second step includes the fixation of the regeneration path of a specific order as well as the scheduling of the repairing jobs that have to be determined. These steps are described in the next two sections.

3. Priority rules within regeneration planning

Within the planning processes, decisions on the order release must be made at a certain time. In planning on a rough level, the specific resources of the three subsystems disassembly, processing and reassembly are not the focus; rather, the aggregated supply chain is considered. With that, the full internal regeneration supply chain is taken into account. For this reason, the order release should specify the access sequence on the first subsystem.

The goal of this planning step is to achieve high logistics efficiency by realizing the best possible ratio of logistics costs and logistics performance. In terms of logistics costs, minimizing inventory costs as well as minimizing logistics-related process costs are the main targets. For a high logistics performance, short throughput times, high resource availability and high reliability for customer delivery need to be achieved [10]. In general, there is a conflict of targets