A Disassemble-to-Order Heuristic for Use with Constrained Disassembly Capacities

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1 Introduction

Due to the increasing environmental awareness of their customers, manufacturing firms have to incorporate an ecological aspect in their corporate identity to remain competitive. In several cases these firms offer an option for their customers to return the product to them after its end-of-use or alternatively its end-of-life. The field of reverse logistics presents an overall approach on how these backward flows of products can be handled efficiently. Therefore, it expands the original focus of logistics to a closed-loop supply chain perspective.

Remanufacturing is one of the manifold options to deal with the returned products [2]. Within this process the returned products (which we will refer to as cores) are disassembled to obtain functional components (which we will refer to as leaves) that can be reassembled into "good-as-new" products afterwards. Before reassembly these components must be cleaned, inspected and if necessary reworked to ensure full functionality. A part of the embedded economic value of those reused "good-as-new" leaves can thus be saved with this procedure. For those components that cannot be reused, newly produced parts have to be availed. The remanufacturing of engines gives a practical example for this process where "good-as-new" engines are offered to the customers in exchange for broken ones. Since reworked components are used, both the environment because of reduced landfilling and the customers because of cheaper spare parts are satisfied.

A known demand for the remanufactured products leads by a bill-of-materials explosion to an individual demand for each leaf. This demand can either be fulfilled by procuring the leaves or by disassembling a specific amount of cores. The so called disassemble-to-order problem seeks to find a solution for this challenging planning task. Since an optimal solution for realistic problem sizes can hardly be found within a reasonable time, as can be seen in section 2, the use of heuristics can be motivated. Prior work on heuristics for the disassemble-to-order problem (see e.g. [1]) has neglected restricted disassembly capacities. However, our experience with several engine remanufacturers has shown that an unrestricted disassembly capacity does not portray reality. As not every desired core can be disassembled with restricted capacities, a more expensive planning results because several leaves

have to be procured instead of being obtained through the usually cheaper option of disassembly.

Following this short introduction, an integer programming model to solve this problem to optimality is presented. After that, a heuristic approach that can be applied to the disassemble-to-order problem with restricted disassembly capacities is introduced in section 3 and a numerical example is shown in section 4. Finally, a short conclusion and a brief outlook is given in the last section.

2 Exact Solution Method

We will now put forth an integer programming model which can be used to find the optimal solution to a disassemble-to-order problem. We can start by examining the underlying assumptions. All the data that is put into the model is of deterministic nature, which means that the demand, the yield rates (amount of leaves that is obtained through the disassembly of a core), the capacity absorption and the overall capacity are known with certainty. With respect to the capacity absorption factors it should be mentioned, that these are modelled as linear factors since the often manual process of disassembly is not significantly influenced by setup times. Further assumptions are that there is no disassembly lead time considered and that the number of cores that can be bought from the market is not constrained. The last assumption that should be mentioned here is that cores are completely disassembled down to their leaves.

A disassemble-to-order problem can be solved to optimality with the aid of an integer programming model. This section is dedicated to introduce all required variables of the problem setting. Starting with the indices, i represents a single core and I represents the set of considered cores. The index j represents a single leaf while J is the set of leaves. There is also the time index t, which indicates that a multiperiod problem of T periods is examined. The capacity absorption factors a_i represent the amount of capacity that is needed for disassembling a core i. The overall disassembly capacity in each period is called C_t. While the demand for each leaf in period t is described by D_{jt}, the deterministic yield rates are represented by n_{ij}. There are several cost parameters in this model, namely c_i^s which is the overall core cost (containing the costs of procuring, transporting and disassembling a core). c_j^p represents the cost for procuring a leaf j, while its disposal costs c_j^d and holding it for one period results in costs of c_j^h. Solving the integer program results in deciding on the amount of core i to be disassembled in period t, x_{it}^s, as well as the amount of leaf j to be procured and the amount of this leaf to be disposed of in period t, x_{jt}^p and x_{jt}^d, respectively, and the height of the inventory level at the end of period t, named y_{jt}. The starting inventory is denoted y_{j0}. The integer programming model is given as: