Disassembly Scheduling with Capacity Constraints, Safety stocks and Lost Component

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Abstract

This paper considers a disassembly scheduling problem in which we determine the optimal quantity of ordering the end-of-life products to fulfill the demands of individual disassembled parts over a given planning horizon. Our objective is to minimize the sum of setup, inventory holding, purchase of parts/components, the safety stock deficit and penalty costs for overloading disassembly capacity in each period. In this paper, an integer programming model of the two-level capacitated disassembly scheduling problem is suggested to represent and optimally solve the problem.

In fact, several previous research articles have been published on the disassembly scheduling problem. Overall, they can be divided into incapacitated and capacitated models although most of which do not consider the resource capacity constraints. For the incapacitated or capacitated models, the literature can be classified according to the structure level (two and multiple), the number of product types (single and multiple) and with and without the parts commonality. As stated earlier, most previous research is concerned with the incapacitated version of the problem. (Kim et al.2006). Therefore, we are interested in this research to a structure of two-level, a single type of product by taking into account the constraint of disassembly time capacity and the overtimes.

In most studies, the authors considered that the disassembled components are all in a perfect condition besides and their state satisfies the demand, however, in the industrial reality, these components can be defective. In these circumstances, the requests may not be satisfied, very few studies have dealt with the integration of disposal decision into the disassembly scheduling problem.

For this reason, it seems interesting for us to build a good example of component loss decision by taking into account the disassembly scheduling problem in which the role of safety stock is studied in order to avoid breaks on requests.

Often, one of the decision maker's objectives is to have a stock profile above a threshold called a safety stock. The latter makes it possible to face unforeseen events (to have defective parts, increase requests, late delivery) besides, it serves to avoid breaks on requests. Since it may happen that we cannot reach this threshold, we can speak of a situation of deficit on the safety stock. These deficits are modeled by a unit penalty in the objective function, where the cost of unit deficit is associated for each component and for each period.

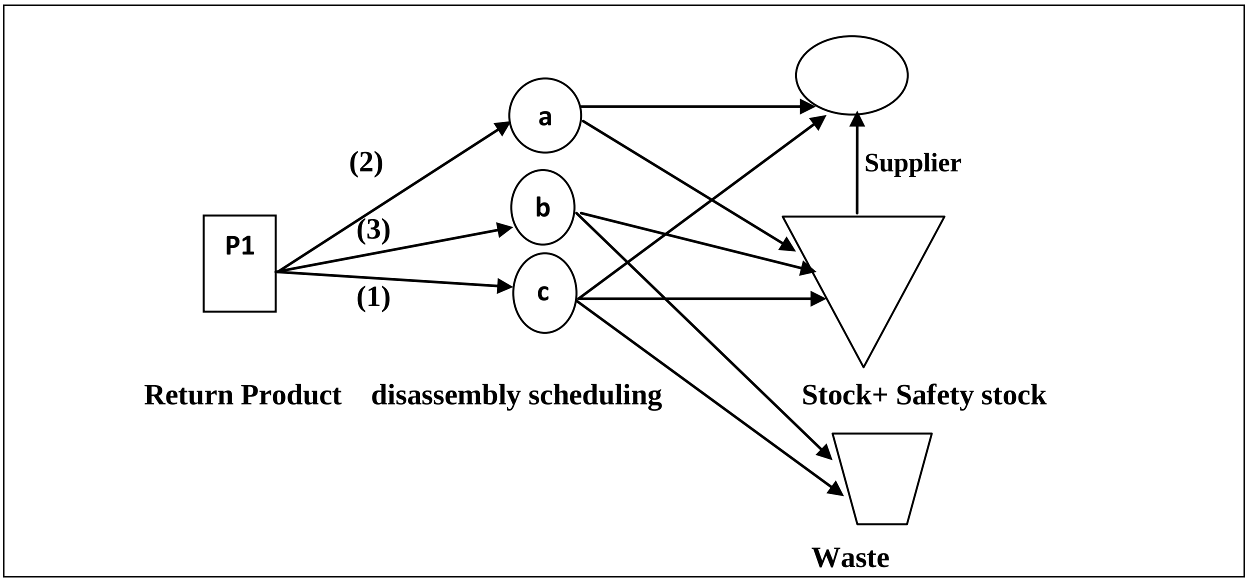

Figure 1. *Conceptual model*

Disassembly process can be selective (only a selection of a leaf item in the product is disassembled) or complete (all leaf items of the product are disassembled). In addition, it can be non-destructive (focusing on components rather than subsets) or destructive (focusing on subsets rather than components).(Gupta .1996).

We were interested in this research to a complete and non-destructive disassembly where the components are sold, disposed, or stored for a future use. Figure.1 displays an example of the disassembly structure for a product with three leaf items and presents a schematic representation of the model proposed for this research work. The operation disassembly of root item P1 extracts 2 leaf items of type a, 3 leaf items of type b and 1 leaf items of type c. The demand is defined for the leaf item only. The yield is the number of leaf items contains in the product

Two of the originalities of disassembly scheduling issues discussed in this research are:

- ✓ Considering the decision to dispose of defective parts.
- ✓ Resolving the problem of non-satisfaction of requests by taking into account the safety stock and /or by purchasing the components from a recipient.

To the best of the our knowledge, no one has addressed the optimization of capacitated disassembly scheduling problem with lost leaf item, safety stock and leaf item purchasing. The problem can be formulated as an integer linear programming with a discrete horizon decomposed into discrete periods. The model provides a solution to plan the recovery of components from the end-of-life products. The objective of the proposed model is to determine the optimal size of the end-of-life products to be disassembled in order to meet the demand of the components while balancing between the different costs (setup, inventory holding, and purchase of components, safety stock deficit and penalty cost for overloading disassembly capacity in each period). Therefore, the assumption can be summarized as follows:

- The demands of the components are deterministic.
- The cost parameters are assumed to be constant.
- All the demand must be satisfied in each period.
- No break or delay of the demand is accepted.
- The initial inventory of the components in the first period of the horizon is zero.
- The components obtained may not all be in good condition to meet the demand and subsequently can be eliminated.
- There is no storage for the end-of-life products since products can be obtained once they are requested.
- The demand not satisfied by the disassembly operation can be satisfied by the safety stock and / or the purchase of components from a recipient.

To show the effectiveness of the integer programming model suggested in this paper, we generated 90 problem 10 of which were randomly generated for each combination of three levels of the number of components (10, 20, 30) and three levels of that of the periods (10, 20, and 30) . In the disassembly structures, the yield was generated from DU (2, 5). Here, DU (a,b) is the discrete uniform distribution with [a,b]. The costs of inventories were generated from DU (5, 10) while that of the deficit on the safety stock was generated from DU (15, 20). The capacity per period was fixed at 480. The Disassembly time was generated from DU (1, 4). The demand was generated from DU (0,150) and the safety stock was generated from DU(20,50).

The CPLEX 12.6 commercial software package was used to solve the integer programs. Actually, the program, which generates integer programming formulations, was coded in C and the test was carried out on a personal computer with an Intel® Pentium (R) processor CPU2020@2.4MHz 2.4 GHZ.

Table 1 summarizes the CPU seconds to obtain the optimal solutions required by CPLEX 12.5, which shows that most small-to-medium size test problems can be resolved in a reasonable amount of time.

The test results show that the integer programming model performance is getting worse as the number of leaf item and the number of periods increase. However, the performance depends greatly on the structure of the disassembly product.

It can be seen from this table that the problems can be solved within a reasonable number of computation times although there are some variances, depending on the problem data.

Table 1: Performance tests

(a) Problem with 10 leaf item

	Number of periods		
	10	20	30
Problem			
1	0.218	1.607	2.340
2	0.484	1.591	2.730
3	0.234	1.669	1.966
4	0.250	1.685	3.372
5	0.156	1.747	3.324
6	0.218	1.622	2.324
7	0.140	1.716	3.463
8	0.187	1.404	3.198
9	0.172	1.248	2.075
10	0.499	1.529	2.574
Average	**0.255**	**0.978**	**2.736**

(b) Problem with 20 leaf item

	Number of periods		
	10	20	30
Problem			
1	0.343	1.420	3.136
2	0.437	1.014	2.543
3	0.328	1.622	2.231
4	0.374	1.404	1.700
5	0.390	1.139	2.855
6	0.359	1.825	2.917
7	0.328	1.435	3.089
8	0.452	1.054	2.512
9	0.218	1.404	3.385
10	0.374	1.716	2.558
Average	**0.360**	**1.403**	**2.692**

(c) Problem with leaf 30 item

	Number of periods		
	10	20	30
Problem			
1	0.406	1.856	4.243
2	0.406	1.404	3.416
3	0.390	1.683	3.978
4	0.546	1.778	3.167
5	0.515	1.747	3.978
6	0.452	2.044	3.448
7	0.577	1.903	3.728
8	0.530	1.888	3.869
9	0.343	1.607	4.228
10	0.484	2.106	3.635
Average	**0.464**	**1.801**	**3.769**

Keywords: Reverse logistic, capacitated Disassembly scheduling, safety stock, Lost Component.