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Technical Paper

Decision evaluation process in end-of-life systems management☆

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ABSTRACT

In manufacturing sectors, firms are paying an increasing attention to sustainability concept with regard to their end-of-life products in order to respect environmental norms and satisfy the consumer sensitivity. This practise allows creating value by reintroducing dismantling and recovering parts and/or materials of end-of-life products into manufacturing process, or into maintenance process. Thus, deconstruction processes are developed in order to examine all activities addressing the end of life (EOL) systems to ensure its disposal according to environmental constraints when seeking an economic optimum. In this context, one of the first tasks to perform is to repatriate the EOL systems at lowest cost considering geographical optimization of treatment centers. Considering this point, the present paper proposes an evaluation and optimization approach for the withdrawal location process in the field of aircraft dismantling. Given the multitude and heterogeneity of characteristics to be taken into account, we propose to consider dismantling site location problem as multi-criteria/multi-objectives decision making problem and solve it using a new AHP-BOCR approach based on qualitative and quantitative evaluations. A bipolar structuring framework is considered to distinguish positive and negative aspects in the elicitation/evaluation process to avoid compensation and satisficing game theory is used as suitable mathematical tool for recommendation process. An experimental study is carried out to show the usefulness of the framework.

1. Introduction

Firms are increasingly interested in recovering used products due in particular to growing environmental awareness of population and increasing customer expectations of enterprises to dispose of manufactured products safely [1]. Considered as the best way for recovering some categories of end-of-life products [2,3], the EOL management becoming pervasive in socio-economic life, in order to consider questions dealing with the transport, reuse, refurbishment, recycling, disposal, secure storage, valorization, or, scrapped of EOL product [4,5]. These activities are included in the deconstruction process [6] which includes services of product returning, recycling, material substitution, reuse of materials, waste disposal, refurbishing, repair, and remanufacturing [7].

The deconstruction process is developed as part of the reverse logistics which discusses first, the planning process establishment to implement and control raw material flows, current inventory, finished goods from the point of use to the point of recovery. Reverse logistics also discusses the selection of proper disposal site and the optimization of the dismantling systems in order to reduce the negative impact of EOL products on the environment and to increase benefits of manufacturers thanks to recycling and recovery operations.

In the aerospace sector, increasing number of end-of-life planes requires to pay more attention to the elimination phase because EOL aircrafts contain valuable components and parts that can be reused and reintroduced in the aftermarket [8]. Moreover, the older fleet management and aircraft scrapping must face legislative pressure in terms of environmental protection laws and economic benefits [5] generated by policy of sustainable environment. These aspects are considered as critical factors in measuring the contribution of a firm to sustainable development. Thus, environmental, economic and social factors can be considered in reverse logistics to evaluate the efficiency of improvement actions. For example, economic factors can provide information on the benefits of adopting reverse logistics by manufacturers. Where cost saving and improving the corporate image allow to gain competitive advantage and to increase the environmental performance [9–12].

Among the issues addressed by the reverse logistics, the selection of proper disposal sites consists in aerospace sector to choose a withdrawal plan for the dismantling EOL aircraft. This issue

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requires optimizing some preference indicators such as, logistic costs, environmental effects, job creations, or economic enhancement. The withdrawal design phase allows to ensure geographical deployment reducing, long distance of EOL systems repatriation to the dismantling sites and limiting their storage needs or their processing capacity. This phase may take into account various parameters as: the complexity of the transport, the depth of disassembly (which products will be recycled?) and the sequencing of operations according to sustainable development (how to get the products while minimizing the time and cost of deconstruction, and maximizing the income generated by the products of the deconstruction?) [13]. An evaluation phase must then be realized to choose the best alternative among different existing deconstruction places. In fact, several sites can be candidates for the deconstruction operations which lead to many solutions in terms of logistics. In this context, the scrapped aircraft withdrawal plan location problem is considered in this paper. A new structured approach is proposed to resolve decision problem of the scrapped aircraft withdrawal plan location considering a new flexible bipolar context. A bipolar way is proposed to consider positive and negative aspects distinctly in order to identify the best alternative or the most satisficing one. The potential interaction of decision elements and the impact of human behavior on the final decision are taken into account. Given the large volume of data involved in solving the scrapped aircraft withdrawal plan location problem, this paper proposes to resolve it by using a multi-criteria/multi-objective decision approach based on AHP method which offers a robust hierarchical structure. The AHP process is adjusted to meet the needs and to minimize complications. BOCR analysis built upon the bipolar notion of supporting and rejecting that characterized relationships between attributes and objectives is demonstrating its power as a structuring tool for decision analysis, see for instance [65–69] for some modeling methods and applications based on this notion. The BOCR analysis considering benefit, opportunity, cost and risk factors is associated to AHP method in order to consider uncertainty aspect in adequate withdrawal plan identification. This approach allows distributing the data across four distinct factors thus forming less voluminous clusters reducing the number of pairwise comparison at the operational level. The potential interactions between problem characteristics are considered using Choquet integral. The proposed model allows alternatives to be characterized by heterogeneous criteria and manage incomparability between alternatives in terms of Pareto-equilibria using satisficing game theory in recommendation phase where a final selection is given according to positive and negative contribution.

1.1. Literature review of facility location problems

The facility location framework can consider different contexts involving multiproduct and multistage reverse logistics network problem for the return products [14], evaluating green supply chain alternatives [15,16], recovery planning like the determination of the disassembly level [17], or the elaboration of catalog distributors to reduce costs from returns processing [18]. The facility location problems including remanufacturing are frequently encountered in the literature and solved using several approaches going from optimization to multicriteria evaluation. For example, in [19], authors used p-median method to calculate the minimum weighted distance from p manufacturing/remanufacturing facilities to n demand locations considering the minimum efficient scale for environmental and economic performance. In [20], authors proposes a conceptual framework, an analytical model, and a three-stage algorithmic solution based on p-median approach. The objective was to determine the optimal number and location of receiving canters and the correct financial incentive in order to stimulate collection of used or unrecoverable products to a required degree. In order to locate recycling centers and to assign collection depots to those centers, authors in [21] propose 2-stage location set covering problem–p-median integrated model that obtains exact solutions using heuristic algorithms on the basis of set operations. The Mixed integer programming model [22–24] is another optimization approach used to capture, for example, component commonality among different products to have the flexibility to incorporate all plausible means in tackling product returns using a multi-commodity formulation and use a reverse bill of materials [25]. In some facility location problems, fuzzy context is considered [26–28] to take into account risk which influences the supply chain design and management and which can be related to uncertainty embedded in the model parameters (which affects the problem of balancing supply and demand) and/or, natural disasters, strikes and economic disruptions, or terroristic acts. The optimization methods offer complex technical resolution leading to a final 'optimal' solution characterizing the instruction given by the analyst once the resolution is complete. However, these methods are not always applicable and flexible for complex problems with a large volume of data. For p-median method for example, it is difficult to solve the instances of very large sizes and the associated classical linear relaxation to this problem. For mixed integer programming model using integer variables make an optimization problem non-convex and therefore far more difficult to solve. Memory and solution time may rise exponentially as more integer variables are added.

The multicriteria context is proposed as an alternative in some studies with fuzzy TOPSIS method [29], AHP approach [30,31], ELECTRE III method [32], or fuzzy compromise programming [33] to deal with the vagueness of human judgments and determine marginal utility function for each criteria to consider scaling and subjective weighting issues. It is argued that the selection of a facility location is a multi-criteria decision-making problem including both quantitative and qualitative criteria. This supports the use of multicriteria methods as those given above. However, some methods although easy to implement, can be restrictive, depending on the problem considered. For example, TOPSIS method based on ideal and non-ideal notion has the disadvantage of only considering cardinal criteria where preferences are fixed a priori and method provides the best action among the poor if all the alternatives are not satisfactory. For the AHP method based on hierarchical structure and linguistic scale, a large number of decision elements can increase the number of pairwise comparisons and a rank reversal problem can occur where two actions can view their order priority reversed after adding or deleting one or several actions. For outranking ELECTRE III method using a veto threshold, the complexity lies in the large number of technical parameters and in the interpretation which may be difficult. More generally, complex decision problem considering a multitude of objectives, a variety of conflicting and often heterogeneous criteria and multiple actors with different opinions and personalities, in a potentially uncertain environment make multicriteria modeling necessary to consider simultaneously all these aspects. Compromises are then required to achieve a response. However, the multicriteria modeling proposed in literature considers generally that elicitation of criteria is independent of alternatives and objectives, which is not always true in practice. On the other hand, aggregation methods are used to represent alternative with a unique value. This compensatory approach does not distinguish between the positive and negative aspects that alternatives present regarding objectives.

The remainder of this paper is organized as follows: Section 2 introduces the characteristics of deconstruction processes. Section 3 addresses the structured framework method for analysis development starting with an introduction of proposed AHP-BOCR approach and, detailed then the steps of aggregation phase and the basis of the satisficing game theory used on the recommendation phase. Section 4 provides an example of application.