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A hybrid multiple criteria decision making approach for measuring comprehensive performance of reverse logistics enterprises

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ABSTRACT

The area of reverse logistics has recently received considerable attention and is an important business policy. The performance measurement of reverse logistics is seldom studied due to the complexity and uncertainty of its operations. This paper provides a multi-criteria performance measurement model to assess the reverse logistics enterprise's performance by considering performance attributes such as product lifecycle stages, strategies, processes, capabilities, and perspectives and measures. In developing the performance measurement model, a hybrid multi-criteria approach combining DEMATEL, fuzzy ANP and AHP methods are applied. Furthermore, the relative importance of these attributes and their criteria with respect to each other and their contribution to the overall performance are affected by the competitive outlook considered by the reverse logistics enterprises. The performance evaluation model developed in this paper incorporates relevant attributes and achieves a more realistic representation of the enterprise's performance by calculating the overall comprehensive performance index. This study provides decision makers a basis for improving the reverse logistics enterprise performance.

1. Introduction

Recently the interest for reverse logistics (RL) has increased since many enterprises have realized the various advantages for their operations. Rogers and Tibben-Lembke (1999) define RL as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal. According to Alvarezgil, Berrone, Husillos, and Lado (2007) the RL operations support enterprises with reduction of costs due to the low prices of raw materials and spare parts, and also generate revenues by reselling materials and products after being scrapped. In a survey conducted by Pollock (2010), 87% of organizations indicated that the effective management of the RL was either 'extremely important' or 'very important' to their operational and financial performance. Further, Skjott-Larsen, Schary, Mikkola, and Kotzab (2007) presented that within the RL there are challenges; however, an important one would be the lack of performance measurement (PM) for return process efficiency. The PM system is a process to allocate responsibilities and decision making, set the targets of performance, and give out the result by analyzing the achievement of the target (Cliville et al., 2006; Lee & Yang, 2011). In the literature, various integrated PM systems have been developed to use as performance controlling and improvement tools within RL. In the management of RL enterprise, one wants to not only know which attributes affect performance and which of their criteria affect these attributes, but also understand the degree of influence of each attribute. This requirement is satisfied by applying multi-criteria approaches (Babic & Plazibat, 1998). Multi-criteria approaches are widely used in the literature for various purposes, including PM of enterprises in terms of profitability and efficiency. There are many criteria and attributes that impact the performance of RL enterprises. These criteria and attributes can be summarized and classified into different constructs and act as an effective reference for PM and decision-making. In the next paragraphs, we present the literature of various multi-criteria decision making methods (MCDM) applied for PM in RL.

Ravi, Shankar, and Tiwari (2005) propose a combination of balanced scorecard and analytic network process (ANP) based approach for piloting RL operations for end-of-life computers. In another research, Yellepeddi (2006) presents a quantitative methodology for reverse supply chain performance. It is based on balanced scorecard and fuzzy ANP method for PM of RL in electronics industry. On the other hand, Jianhua, Lidong, and Zhangang (2009) discuss performance evaluation of reverse supply chain by modifying the balanced scorecard and applying fuzzy analytic hierarchy process (FAHP). Conversely, Huang et al. (2011) propose five assessment dimensions: financial performance, operational procedure, learning and growth, reverse relationship and flexibility and utilize ANP method for RL performance

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evaluation of recycled computers. A framework for a comprehensive and integrated approach of PM of RL enterprises is presented in Shaik and Abdul-Kader (2012). Their input-output model applied AHP for the prioritization and integrated the balanced scorecard and performance prism. Recently, Shaik and Abdul-Kader (2014) present a comprehensive PM and decision making model for RL enterprise and utilize DEMATEL method for understanding the influencing criteria of performance attributes. Their paper presents the logic of development of framework, various performance attributes such as product life cycle, strategies, processes, capabilities, and perspectives are described and the inner relationships of performance criteria of various performance attributes. In another study, Bansia, Jayson, Varkey, and Agrawal (2014) apply the balanced scorecard and fuzzy AHP for the development of a PM system of RL for a battery manufacturer. Khalili-Damghani and Najmodin (2014) present a conceptual model which measures PM of RL by identifying and classifying the most important factors in an auto industry. The model is verified by structural modeling method and fit statistics that exhibit the influential factors and their significance for PM of RL. Guimaraes and Salomon (2015) propose a few aspects for the evaluation of RL in footwear industry and applied ANP to understand the interrelation among the aspects. Using a quantitative analysis, Yogi (2015) presents an approach for PM for RL considering inventory indicators, flexibility measures and cylinder utilization indicators in a case study for Liquid Propane Gas (LPG) Agency. Maulida, David, and Regina (2016) present a mathematical model of PM in a carpet reverse supply chain, particularly on carpet recycling and refurbishing facilities. The performance metric is the 'cost' of return product flow. The objective of the model is to minimize cost and they considered the sum of all the costs associated with the RL process such as, holding cost for returned products at the recovery centre warehouse, disassembly cost, refurbishment cost, transportation cost to manufacture, transportation cost to landfill, transportation cost from manufacture plant to distributor, holding cost for parts at the manufacturing plant warehouse, new part cost from a supplier, production cost and new product holding cost at manufacture plant warehouse. Roxana, Behrouz, and Mahdi (2016) propose assessing of dairy organization's performance in the RL area by integrating balanced scorecard and data envelopment analysis, and further using fuzzy AHP for ranking weights. They considered five perspectives including innovation and growth, internal and external process, costumer, environmental, and financial. Steffen, Sebastian, Matthias, and Rolf (2017) develop the holistic approach for PM system to assess international reverse supply chains based on the balanced scorecard and apply AHP to calculate the performance index from citizenship and legislation, financial, stakeholder, process, innovation and growth and flexibility perspectives.

From the above review of literature, it is evident that the PM of RL is presented by utilizing established performance frameworks such as balanced scorecard, modified balanced scorecard and examining several various factors which contribute to RL performance. All the above-mentioned research works have applied only one of the MCDM methods for PM of RL. The evidence of only one MCDM method is also confirmed by a systematic study on MCDM methods and applications (Rezaei, 2015). So, the reason for a hybrid method is a pressing need for a comprehensive PM that clearly contributes to the existing literature for PM of RL. In the literature, we find hybrid or a combination of MCDM methods is applied in different areas. Alam-Tabriz, Rajabani, and Farrokh (2014) apply hybrid MCDM consisting of DEMATEL, ANP and TOPSIS for supplier selection problem. Uygun, Tekez, Kacamak, and Simsir (2014) utilize hybrid DEMATEL, ANP and TOPSIS MCDM methods for evaluating and ranking projects. For the analysis of PESTEL (political, economic, socio-cultural, technological, environment and legal) factors, Yuksel (2012) present a combined model of AHP, ANP and DEMATEL methods. Yang and Tzeng (2011) illustrate the best vendor selection by applying hybrid DEMATEL and ANP methods. Although the combined use of DEMATEL and ANP is used in different areas, to the best of our knowledge, this is the first time it is used for PM of RL.

In this study for the RL performance, it is important to identify and understand the performance attributes and their criteria, whether they are interdependent of one another or they relate one to another only implicitly. To understand the relationships among the performance attributes and their criteria, this paper considers all the basic and various relations among the performance attributes. Accordingly, the paper proposes an analytic modeling and measurement process to operationalize the relationships by applying hybrid MCDM method. The proposed hybrid MCDM method integrates DEMATEL, fuzzy ANP and AHP MCDM methods. The proposed research work further augments the previous study by Shaik and Abdul-Kader (2014), by addressing the following: (1) To describe the performance attributes and their criteria; (2) To develop a network to understand the inter and inner dependent relationships of the various criteria within the performance attributes; (3) To propose a decision making model by applying the hybrid MCDM methods; and (4) To present the PM and performance index for strategic planning by outlining the improvement and success of RL operations.

The remainder of this paper now builds upon the understanding and literature review from Section 1 and is further organized as follows: Section 2 provides the basic characteristics of the PM model and MCDM methods; Section 3 discusses the development of the comprehensive PM model and methodology; Section 4 presents a numerical example study. Section 5 provides results and discussions and finally, conclusions are presented.

2. Basic characteristics of the proposed comprehensive performance measurement model

The proposed comprehensive PM model for RL enterprise combines two different approaches: integrated PM systems and MCDM methods. In this section, we present the basic characteristics of the PM framework for RL enterprises consisting of attributes and criteria for the framework and MCDM methods applied for the understanding the relationships among the attributes of the PM framework.

2.1. Performance measurement framework with attributes and criteria

The PM is useful in benchmarking or setting standards for comparison with best practices in other enterprises. The long-term success is the logical consequence of successfully managing operations, by including the critical areas into the performance model of an enterprise accurately (Kaplan & Norton, 1992; Letza, 1996).

The PM system model of RL developed here is applied in the following steps: (1) presentation of the areas of success; i.e., performance attributes, their criteria and performance measures, which are used to measure the performance level as described by Shaik and Abdul-Kader (2014); (2) calculation of the relative weights of the inner dependent and interdependent relationships of criteria and attributes of success by using the hybrid model (DEMATEL and fuzzy ANP and AHP methods); and (3) rating the RL performance in each performance measure and computing the overall performance score of the enterprise. These steps are further developed in the following sections; and a numerical example is provided to illustrate the applicability of the comprehensive PM model for RL enterprise.

Per the first step, the comprehensive PM of RL enterprise is identified by the performance attributes such as product lifecycle, strategies, operational processes, enterprise capabilities, performance perspectives with their criteria and key performance measures. The performance attribute 'product life cycle' is considered, since the RL requirements are affected by various forms during the lifecycle of the product. The five criteria of product lifecycle considered are: introduction (INT) phase; growth (GRO) phase; maturity (MAT) phase; decline (DEC) phase; and obsolete (OBS) phase (Yellepeddi, 2006). In the introduction phase, RL can play an important role in fixing quality problems due to warranty by collecting information on returned products, looking for