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Coordinating a green reverse supply chain in pharmaceutical sector by negotiation

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ABSTRACT

This paper investigates the pharmaceutical reverse supply chain. For this industry, the reverse supply chain is usually not owned by a single company. A decentralized negotiation process is thus presented in order to coordinate the collection of unwanted medications at customer zones. Using a Lagrangian relaxation method, the model is solved for a real generic pharmaceutical company. Coordination efforts are required from the supply chain entities, facing environmental regulations, to collect and recycle unwanted medications. Therefore, a bonus sharing technique is also proposed based on each entity's investment in the coordination process. Some numerical results are presented and discussed for two case studies. It shows that up to 28% more products could be collected if companies coordinate their operations efficiently. Besides, future insights on the same network are highlighted.

1. Introduction

Alterations in the state of the environment, which result from industrial manufacturing activities, caused a quantum leap for the supply chain management (SCM) and business practices. Customer pressure and environmental legislations also raise the complexity for performance measurement of reverse supply chains (RSC). Up till now, most of RSC actions are market-driven; i.e. companies take the initiative to reduce costs by reusing the waste of unsold parts. However, in Europe some actions are legislation-driven to fulfill the obligatory regulations of collecting specific amounts of end-of-life products (return stream) in order to avoid penalties forced by governments (Beamon, 1999).

A good example is the pharmaceutical industry. In fact, this industrial field has developed at a very fast rate in the last decades. It is a rapidly growing market due to the increased rate of modern century diseases and the raised number of old-age nations. Likewise, the presence of pharmaceutical products as trace pollutants for environment has been firmly established. Knowing the potential severity of using expired or improper drugs, the recovery process of unsold or unwanted medications is essential (Bartelt-Hunt, Snow, Damon, Shockley, & Hoagland, 2009). A wide range of proactive actions is therefore necessary to reduce or minimize the introduction of pharmaceutical wastes to the environment. Pharmaceutical RSC is considered as one of the complicated supply chains because of the restricted percentages of chemicals in medications and the regulated conditions for distribution and storage. Furthermore, the zero-salvage value of returned medications hinders the development of RSC (Xie & Breen, 2012). In other words, it differs from other RSC, such as electronics industry RSC, where the salvage value of the returned products is significant.

This study focuses on tactical planning in the pharmaceutical RSC. In general, tactical level decisions include many actions, such as collection of waste materials, recycling, long-term RSC chain coordination contract drafting, recovery channels of reverse logistics, and recovery efforts designing (Shah, 2004; Xu, Zhang, Liu, & Zhao, 2012). Since pharmaceutical RSC activities fall outside core functions of a company, the majority of the activities are usually handled through third-party logistics (3PL) providers (Kumar, Dieveney, & Dieveney, 2009). Using 3PLs enables companies to focus more on their own core processes and reduce the associated costs. Moreover, 3PL providers usually update their information technology and techniques, which are more flexible than in-source logistics. Despite the aforementioned advantages, some companies might lose control inherent in outsourcing particular functions, due to the limited collaboration between the supply chain entities (Levi, Kaminsky, & Levi, 2003). For example, in our case, due to the lack of collaboration, a part of unsold/expired medications remains at customer zones.

In reality, supply chains are not typically owned by one company. They consist of facilities that are managed by different

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companies, like producers, retailers, and 3PLs. Hence decision-making system in such supply chains is bound to fail unless a coherent approach of coordination is utilized. Coordination in networks are either a centralized process that has a unique decision maker who possesses all information on the entire network, or a decentralized process that has multiple decision makers (Giannoccaro & Pontrandolfo, 2004). Product recovery problem is complex; i.e. many factors and constraints of information sharing are required for accurate modeling. For example, information are needed about collection volume, frequencies, locations, and cost associated with collection and disposal (Sbihi & Eglese, 2007). In the pharmaceutical industry, paucity of information may be observed as a result of the lack of trust between entities, hence, prohibiting the coordination of the RSC (Lin & Ho, 2014). This paper assumes a decentralized decision-making process and proposes a negotiation approach as a coordination mechanism in the RSC described herein.

We propose a coordination model for a real pharmaceutical RSC from the retailer point of view, who represents the producer company, *Generic PharmaX*. In the past, the producer policy did not include collecting the unsold items from outside the country because she believed that medications have a null salvage value. As a result, the company, through her retailer, used to send new items instead and ask the retailer to either burn or bury the unwanted drugs. This type of disposal harms the environment and the groundwater. As a result, the environmental reputation of the company was affected.

Under the new business context, the producer pays the retailer for collecting the unwanted or unused medications at customer zones (i.e. hospitals and pharmacies). The retailer is thus responsible for negotiation with 3PLs over quantities that must be collected, i.e. the retailer controls the reverse supply chain communication. The retailer next pays fees, i.e. *current collecting fees* to 3PLs, for collecting the discarded medications at customer zones, as well as sorting and delivering to sinks of the network. The sinks are governmental safe disposal and recycling facilities. Currently, the coordination between the retailer and 3PL companies is insufficient. In other words, about 20% to 40% of the unwanted medications remain uncollected.

Because the company used to pay penalties to governments for uncollected medications at customer zones, we suggest her to share that amount with RSC entities instead and green her reputation. In other words, to minimize the fees and penalties that she pays to governments, we suggest the producer to offer the retailer an extra fixed amount, i.e. a *bonus*, on top of the regular collecting fees. The bonus is paid if, and only if, all unwanted products at customer zones are collected. We believe that this extra income for RSC entities will motivate those who are eager to collaborate and participate in greening the network. Therefore, the retailer's objective is to ensure that all unwanted products are collected. As a result, the retailer has to pay adequate collecting fees for 3PL companies to collect more products. Moreover, the retailer needs to share the predictable bonus with the 3PLs to guarantee a complete collection of products at customer zones. The reason is that the 3PLs objective is to maximize the individual profit from collecting products and from recycling some of returned products.

This paper, as a first research on the pharmaceutical RSC coordination, contributes to the available literature by modeling this RSC in order to meet environmental legislations and reduce the amount of wastes. It is a challenging RSC because the recovered products have almost no economical values to recyclers or to producers. Using data from a real case study, a single period tactical planning model is developed. The producer has to fulfill the regulations and improve her green image among competitors and customers. The RSC model considered herein consists of one retailer, four third-party logistics, and four recyclers. A coordination approach based on a negotiation mechanism is applied to handle the communication within the network. With the aid of Lagrangian relaxation, four sub-problems are solved for small-case and large-case problems. In addition, an appropriate method to share the network gain from an improved coordination is suggested, which shares the savings based on each entity's effort. Moreover, the effect of the proposed coordination method on the performance of the RSC is analyzed.

The reminder of this paper is organized as follows. A literature review regarding RSC and coordination mechanisms is first proposed. A brief description of the case study context and the pharmaceutical RSC tactical planning model are next given in Section 3. Also, Section 3 covers the proposed negotiation methodology to solve the model and the suggested profit sharing technique. Some numerical results and discussions for the real case study are given in Section 4. Finally, some concluding remarks are provided in Section 5.

2. Literature review

There is a growing stream of literature on product recovery and RSC. However, the available literature on the pharmaceutical RSC is still limited and the existence research is scant. Detailed reviews on RSC models can be found in Akcali, Cetinkaya, and Uster (2009) and Aras, Boyaci, Verter, Ferguson, and Souza (2010). Blackburn, Guide, Souza, and Van Wassenhove (2004) highlighted the growing interest in RSC in today's business. As the large body of literature on RSC planning shows, mixed integer programming (MIP) models are the common models for the quantitative planning of many case studies (Fleischmann, Beullens, Bloemhof-Ruwaard, & Wassenhove, 2001; Fleischmann et al., 1997). However, most of the discussed models are for single facility problems. Very recently, Brandenburg, Govindan, Sarkis, and Seuring (2014) presented a holistic review of the available literature prior to 2014 on quantitative models for SCM including RSC. Lambert, Riopel, and Abdul-Kader (2011) proposed a conceptual framework for RSC including generic process decisions, economic aspects, and performance measures with respect to the tactical level decisions. Sbihi and Eglese (2007) focused on combinatorial optimization problems in a network with waste management and reverse logistics. Hoshino, Yura, and Hitomi (1995) constructed a linear goal programming model to maximize the total profit and recycling rate for recycle-oriented manufacturing systems. Likewise, Karakayalı, Emir-Farinas, and Akçalı (2010) investigated the pricing and recovery planning problem in a single-period setting. By using a target rebate-punish contract, Yan and Sun (2012) modeled a multi-echelon RSC for a scrap recycling. Their results on a steel RSC, involving a manufacturer and multi- 3PLs companies, revealed that the target rebate-punish may coordinate the RSC under certain conditions.

Regarding the literature on pharmaceutical RSC, few works can be found. Shih and Lin (2003) presented a multiple criteria optimization approach to minimize the cost for collection system planning for medical waste. Recently, Kumar, Dieveney, and Dieveney (2009) proposed a framework to state each party's responsibility in the pharmaceutical RSCs. They suggested the usage of consistent information systems and carriers to streamline the supply chain. The absence of collaboration in their model with 3PLs draws into question the ability of the model in tracking the products. In addition, the study ignored the criterion of sharing any possible benefits of using this technology as well as sharing the implementation cost among the entities. Lately, Xie and Breen (2012) designed a green pharmaceutical supply chain model to reduce preventable pharmaceutical waste and to dispose inevitable waste. The study revealed that the RSC is not really utilized in the pharmaceutical