Available online at www.sciencedirect.com
ScienceDirect
Journal of Operations Management 25 (2007) 1161–1183
JOURNAL OF OPERATIONS MANAGEMENT
www.elsevier.com/locate/jom

An analysis of decentralized collection and processing of end-of-life products

Ibrahim Karakayali [a], Hülya Emir-Farinas [b], Elif Akcali [c,1,*]

[a] Department of Industrial & Systems Engineering, University of Florida, Gainesville, FL 32611, USA
[b] IBM Software Group, 577 Airport Boulevard, Burlingame, CA 94010, USA
[c] Supply Chain and Logistics Engineering Center, Department of Industrial & Systems Engineering, University of Florida, Gainesville, FL 32611, USA

Available online 19 January 2007

Abstract

In this study, we analyze decentralized collection and processing operations for end-of-life products in durable goods industries. We consider a durable end-of-life product from which a particular part can be dismantled and remanufactured, and the remainder of the product can be further processed for part and/or material recovery. Both the quantity of end-of-life products available and the demand for remanufactured parts are price-sensitive. We develop models to determine the optimal acquisition price of the end-of-life products and the selling price of the remanufactured parts in centralized as well as remanufacturer- and collector-driven decentralized channels. We discuss how the decentralized channels can be coordinated to attain the end-of-life product collection rate that can be achieved in the centralized channel. In the presence of environmental regulations that require an original equipment manufacturer (OEM) of durable goods to collect and process its end-of-life products, we identify when and why the OEM would prefer a remanufacturer- or a collector-driven channel, i.e., outsource the processing or the collection activity, respectively. From a practical perspective, we show that the OEM should prefer a collector-driven channel to increase the collection rate, when end-of-life products are homogenous. However, we also show that the OEM would prefer a remanufacturer-driven channel under certain conditions. We also examine how the OEM can increase the quantity of used products collected, when the collection rate in the preferred channel setting falls short of the collection rate mandated by the environmental regulation. When end-of-life products are heterogeneous, we observe that the collection rate for all quality groups can be positive in a remanufacturer-driven channel, whereas the collection rate for some quality groups may be zero. This indicates that the OEM must pay more attention to its outsourcing decision in this case, if the environmental regulation in effect specifies target collection rates for individual quality groups.

Keywords: Operations strategy; Environmental issues; Product recovery

1. Introduction

Due to increased environmental pollution levels and reduced solid waste processing capacities, environmental regulations and take-back laws are being adopted in the nation and around the world (Toffel, 2003). One of the industries that is impacted by this development is the automotive industry, as Japan, Taiwan and the European Union enacted

* Corresponding author. Tel.: +1 352 392 1464x2041; fax: +1 352 392 3537.
E-mail addresses: ibrahimk@ufl.edu (I. Karakayali), farinas@us.ibm.com (H. Emir-Farinas), akcali@ise.ufl.edu (E. Akcali).
[1] Tel.: +1 352 392 1464x2005; fax: 1 352 392 3537.

0272-6963/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.jom.2007.01.017

directives to regulate the collection and processing of end-of-life vehicles in these countries (Johnson and Wang, 2002; Lee, 1997). Although these directives identify specific recovery and recycling targets for an original equipment manufacturer (OEM) in the automotive industry, not all of them prescribe how the OEM should manage the necessary collection and processing activities.

For the effective management of end-of-life vehicle collection and processing, the OEMs need to improve their understanding of the practice and the economics of these activities. To this end, several European and Japanese manufacturers carried out in-house pilot dismantling studies, and decided to outsource these operations (Recycling Today Online, 2004; Volkswagen, 2003). Ford noticed the potential economic benefit associated with end-of-life vehicle processing, and purchased several automotive salvage yards and parts recycling companies in North America and Europe to enter the business (Autoparts, 2002; BBC News, 1999; McCann, 2003; Recycling Today Online, 2002). Many observers' predictions that ''Ford's inexperience in the specialized world of automotive salvage would be a hindrance'' were validated when Ford admitted that entering automotive recycling ''was a poor business decision'' (Recycling Today Online, 2002), and abandoned the vehicle recycling business to ''redirect resources to automaking'' (Autoparts, 2002; BBC News, 2002; Collision Repair Industry INSIGHT, 2002; McCann, 2003). Therefore, the collective experience in the industry indicates that the OEMs are likely to outsource the processing of end-of-life vehicles to other agents. Although the OEMs do not want to process the end-of-life vehicles themselves (due to Ford's disappointing experience), they may still participate in take-back operations by collecting the end-of-life vehicles from final users and sell them to these agents to ensure that the vehicles are collected, and recovery and recycling targets are met.

Motivated by these developments in the automotive industry, which may soon expand to other durable product classes, we develop models to analyze the collection and processing of end-of-life products with remanufacturable parts. More specifically, we consider a durable, used product that has some parts that can be remanufactured and sold as service parts (Fleischmann et al., 2004). We focus on a setting where there is a collector and a remanufacturer. The collector specifies the acquisition price for the used (i.e., end-of-life) products and acquires them from the final users. The remanufacturer pays the wholesale (or transfer) price to buy the used products from the collector, decides the quantity of parts to be dismantled and remanufactured, and specifies the selling price for the remanufactured parts. The remainder of the product that is not recovered by the remanufacturer can be sold for further part and/or material recovery. The material flows and the agents are depicted in Fig. 1.

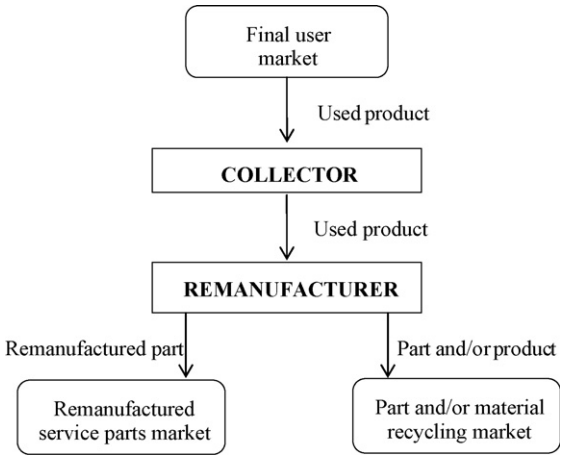

Fig. 1. System conceptualization.

As the collection and processing activities may or may not be performed by the same agent, we consider three channel settings in our study. First, we consider a collecting remanufacturer, who performs both the collection and remanufacturing activities, and, refer to this benchmark setting as the *centralized channel*. We also consider two decentralized settings, where the collection and remanufacturing activities are performed by the *collector* and *remanufacturer*, respectively. We analyze these decentralized settings in a *Stackelberg game* framework, where one agent is the Stackelberg leader and the other is the follower. We first consider the decentralized setting, where the OEM outsources the remanufacturing activity, giving the remanufacturer the leadership role in the channel, and we refer to this setting as the *remanufacturer-driven channel*. We also consider the decentralized setting, where the OEM outsources the collection activity, giving the collector the leadership role in the channel, and we refer to this decentralized setting as the *collector-driven channel*. Stackelberg game framework is used widely in the literature for the analysis of similar business decisions (Savaskan et al., 2004). Moreover, when BMW outsourced the processing of end-of-life vehicles in Germany to a select set of dismantlers, these dismantlers obtained the proprietary right to process end-of-life BMW vehicles, and, hence the channel power. Therefore, depending on whether the collection