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Reducing the extraction of minerals: Reverse logistics in the machinery manufacturing industry sector in Brazil using ISM approach

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ABSTRACT

Mass consumption and shortening product lifecycles have increased worldwide production. Consequently, more raw materials such as minerals are used, and available landfills are filling up. Companies are urged to effectively incorporate sustainability issues such as End-of-life (EOL) management and Reverse Logistics (RL) practices to close the loop and diminish the amount of raw materials used in their production systems. However, implementing RL implies dealing with its barriers. The purpose of this article is to focus on the recovery of EOL products that use mostly raw materials from the mining and minerals industry by identifying and analyzing the interactions among the barriers that hinder RL development in Brazil. First, international peer-reviewed publications were considered to select the barriers and classify them into categories. In a second moment, an empirical research was conducted using the Multi-Criteria Decision Making (MCDM) tool named Interpretive Structural Modeling (ISM) to evaluate the relationship between the barrier categories. Logistics experts from machinery manufacturing industry sector in Brazil were consulted. The greater influence on all barrier categories is Policy related issues barrier category, which means that the lack of specific laws and lack of motivational legislation are still significant impediments to RL implementation in Brazil.

Introduction

Environmental issues from the extractive industries and particularly mining are prevalent and maleficent (Kusi-Sarpong et al., in press). Among the many environmental impacts this activity may cause, resource depletion emerges as a great concern. In this matter, companies are increasingly searching for solutions to close the loop of their supply chains by recovering materials or the entire product. Doing so, they progressively become less dependent on raw materials extraction and, at the same time, firms are able to reduce the environmental damage.

In this sense, reverse logistics (RL) has emerged as an important element for organizations to build their strategic advantage (Govindan et al., 2013a), since it is commonly related to social and environmental issues (Demajorovic et al., 2012). Reverse logistics is the process of moving goods from their typical final destination with the objective of capturing value or proper disposal. It is concerned with issues such as reclaiming, recycling, remanufacturing, reuse, take back, and disposal needs to be available for adequate service requirements (Govindan et al., 2012). Despite RL's apparent current relevance, a few prior works have addressed this topic (Van Der Wiel et al., 2012).

While companies are increasingly being pressured to engage RL for environmental, social and economic reasons, alongside, there are many barriers to the development of RL that limit their implementation (Kapetanopoulou and Tagaras, 2011). In general, RL is considered by firms as an undervalued part of the supply chain (SC) due to a variety of reasons such as: uncertain profitability, lack of personnel technical skills, difficulties with supply chain members and so forth (Abdulrahman et al., 2014). The profitability of RL is multidimensional because it depends on several aspects, such as: market price of the materials, technological innovation that could contribute to lowering the price of the recovery process, and the quantities of recovered materials (Van Der Wiel et al., 2012). In the domain of Green Supply Chain Management (GSCM), RL is considered as the most difficult initiative to implement when compared to design for environment and green purchasing (Hsu et al., 2013). Thus, RL has become an important topic of research in the GSCM domain (de Souza et al., 2012).

According to Abdulrahman et al. (2014), concerning the prior research on the barriers for RL implementation, little attention has been paid to emerging economies. As a BRIC country, Brazil is the largest Latin America economy, the seventh largest world economy

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and received the fourth largest mining investment in 2013 (Dolbear, 2014). RL is gaining importance in Brazil due to some factors: the new environmental policy, issued in 2010 (National Policy on Solid Waste – NPSW), economic issues as the recovery of the value of used products, improving social conditions and green marketing. However, at the same time, Brazilian organizations encounter the challenge of a poor logistics infrastructure (Arkader and Ferreira, 2004; da Rocha and Dib, 2002). Based on this, further research is needed to understand, analyze and overcome these barriers. In this matter, this article aims at identifying RL barriers in an international panorama and analyze their interaction in the Brazilian context. The proposed research framework includes a systematic literature review process and Interpretive Structural Modeling (ISM) for the interdependency analysis of barriers.

Theoretical background

This section presents an introduction on the mining and minerals industry in Brazil, RL practice, a literature review on RL barriers and a picture of emerging countries concerning product return.

The mining industry sector in Brazil

Brazil is among the G8 countries (Canada, France, Germany, Italy, Japan, Russia, United Kingdom, the United States, India, and China). These nations tend to have the greatest influence on the demand and supply of the minerals (Wellington and Mason, 2014). Mining in Brazil is centered on the extraction of iron, gold, niobium and copper. In 2011, 8870 mining companies were operating in Brazil (IBRAM, 2012b) and, in 2013, the mineral production of the country represented US$ 44 billion (IBRAM, 2014). The Brazilian government have forecasted a total of US$ 75 billion from private investment in the mining and minerals industry sector between 2012 and 2016 (IBRAM, 2012a).

In this scenario, the metal consumption from the machinery manufacturing industry sector in Brazil is highly significant. This sector employs 1.7 million people distributed in 52,000 companies in the country (SESI, 2011). Metal-mechanic products are a major contributor to Brazil's industrial Gross Domestic Product, together contributing over 32% of this GDP (FIERGS, 2011).

However, the country extraction and metal production magnitude has its drawbacks for the environment. In this sense, Kumar and Putnam (2008) have stated that as third world countries develop and consumption increases, raw materials will be in short supply (such as steel, copper, oil and aluminum). Resources depletion tendency have increased considerably commodity prices. For example, from 1910 to 2004, the aluminum price augmented 380%, copper price increased 1023% and for nickel the increment was even more significant: 15,675% (Calaes, 2009). Thus, new commodity markets are driven to develop the extraction of these materials from EOL products and hence practice RL. González-Torre et al. (2004) confirmed this, adding that the iron and steel industries are among the many industries practicing RL techniques.

For industrialization at least four metals are crucial: iron, aluminum, lead and copper (Johansson et al., 2014). The machinery industry sector uses widely these metals, hence this research focuses on the RL for the aforementioned industry sector for the recovery of these materials. In these connections, the next subsections defines and discuss RL practices.

Reverse logistics definition and practices

Reverse logistics is still considered as a new concept, even considering that it has recently received significant attention (Van Der Wiel et al., 2012). RL comprises all the activities involved in processing, managing, reducing, and disposing of hazardous or nonhazardous waste from production, packaging, and use of products (Govindan et al., 2013b; Rogers and Tibben-Lembke, 1999, 2001). Effective RL focuses on the backward flow of materials from customer to supplier – or alternate disposition – with the goals of maximizing value from the returned item or minimizing the total RL cost (Sasikumar and Kannan, 2008). RL is the joint responsibility of producers and consumers to minimize waste generation by means of reuse, remanufacturing, recycle and proper disposal of unwanted items in order to enhance the absorptive and regenerative capacity of the planet, contributing to sustainability and circular economy issues.

Due to the diversity of products in the reverse flow, there are various alternatives of RL activities, namely: reutilization, renovation, repair, reprocessing, recycling or cannibalization (Thierry et al., 1995). The majority of returned products undergoes practices such as resell "as is", refurbishment/remanufacturing, recycling, send to landfills, or repacking and sell as new. Rogers and Tibben-Lembke (2001) suggest further options: donations, sent to central processing facilities, sold to brokers or outlet stores. Fig. 1 brings the many flows in RL operations.

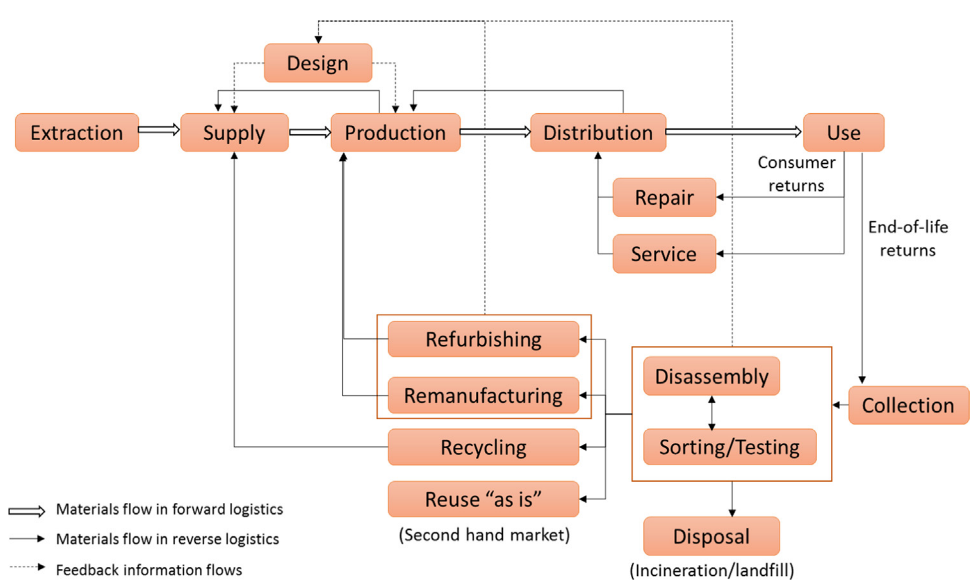

Fig. 1. Activities and flows in reverse logistics. *Source*: adapted from Kannan et al. (2010) and Lau and Wang (2009).