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Modeling reverse logistics process in the agro-industrial sector: The case of the palm oil supply chain

Edgar H. Alfonso-Lizarazo [a], Jairo R. Montoya-Torres [a,b,*], Edgar Gutiérrez-Franco [a]

[a] Universidad de La Sabana, Km 7 Autopista Norte de Bogotá, D.C., Chia, Cundinamarca, Colombia
[b] Leeds University Business School, University of Leeds, Woodhouse Lane, LS2 9JT Leeds, UK

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ABSTRACT

As today's consumers are more and more concerned with the environmental impacts of products and services they buy, enterprises have been more and more concerned with "green operations". One of the key aspects of green logistics management is reverse logistics. This paper shows how the potential of managing reverse logistics flows can be implemented in the agro-industrial sector. As an example, the palm oil supply chain is considered. This study is carried out under the focus of the "closed-loop supply chain (CLSC) framework" in which forward and backward product flows are considered simultaneously. A mathematical model is proposed in order to represent the dynamic interaction between flows. The objective function considers energy, cost and economic profits. Different implementation scenarios of recovery processes are proposed and interactions between direct and reverse flows in the chain are evaluated. Results are analyzed using proper statistical tools, showing that the simultaneous analysis of direct and reverse flows positively impact the net economic profits in this complex supply chain of the agro-industrial sector.

1. Introduction

Most of the research on Supply Chain Management (SCM) has traditionally been focused on the analysis of forward flows, from suppliers to end customers, allowing the transformation of raw materials into final products [1,2]. The reverse flows (i.e., material movement from end customers to suppliers) have traditionally received much less attention [3–5]. However, with consumer behavior changing as they have started to assess the environmental impacts of the products and services they buy, enterprises have been more and more concerned with "green operations". As defined by Sbihi and Eglese [6], green logistics is concerned with producing and distributing goods in a sustainable way, taking into account both environmental and social factors, in addition to traditional economic performance measures. Thus the objectives are not only concerned with the economic impact of logistics policies on the organization carrying them out, but also with the wider effects on society, such as the effects of pollution on the environment [7]. green logistics activities include measuring the environmental impact of different distribution strategies, reducing the energy usage in logistics activities, reducing waste and managing its treatment. In recent years there has been increasing concern about the environmental effects on the planet of human activity and current logistic practices may not be sustainable in the long term.

Srivastava [8] proposed a framework to classify the different dimensions of green logistics/supply chain management (see Fig. 1), while Sasikumar and Kannan [9] present a taxonomy of research issues in reverse logistics. One of the key aspects of

* Corresponding author at: Universidad de La Sabana, Km 7 Autopista Norte de Bogotá, D.C., Chia, Cundinamarca, Colombia. Tel.: +57 3007711356.
E-mail address: jairo.montoya@unisabana.edu.co (J.R. Montoya-Torres).

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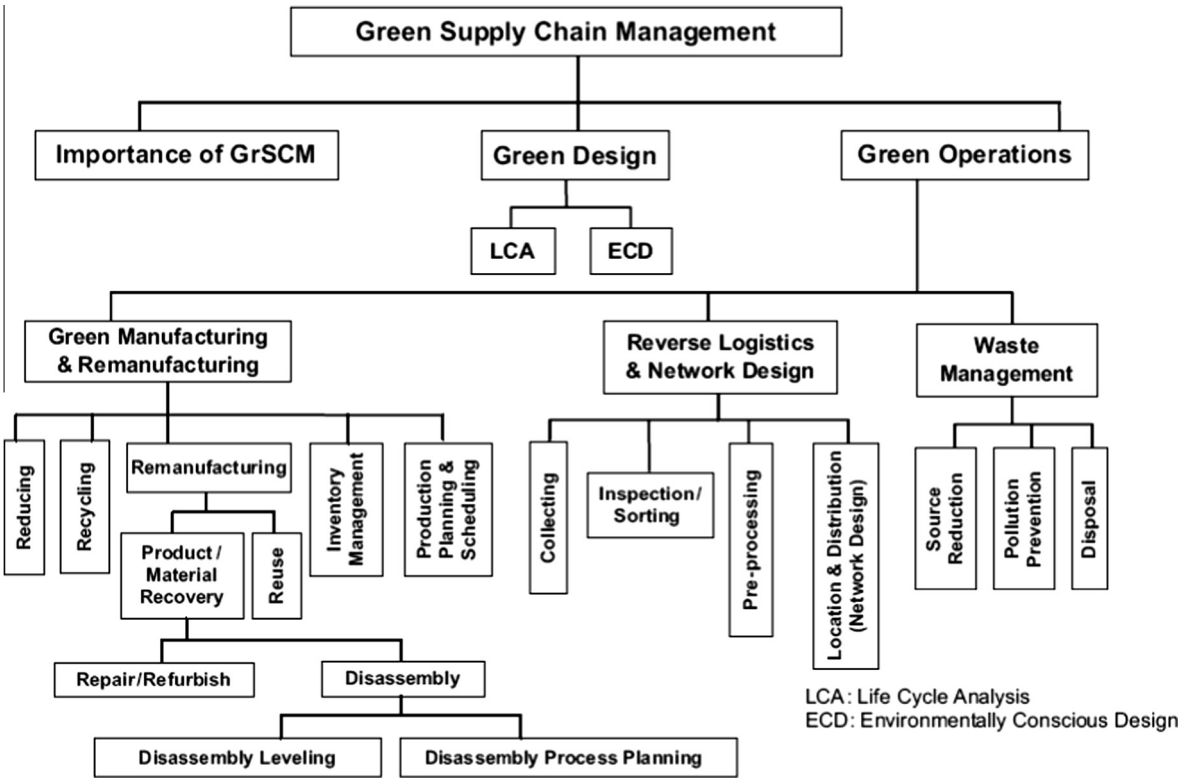

Fig. 1. Reverse logistics within the characterization of green logistics processes, according to [8].

green logistics management is reverse logistics (Halabi et al. [7]). In the literature, several definitions of Reverse Logistics have been proposed (e.g. [10–12]. According to the European Working Group on Reverse Logistics (REVLOG), reverse logistics is "the process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal" [13]. That is, the practice of Reverse Logistics enables the recovery of goods at the end of their lifetime in a way that is efficient and is also utilized to recover goods that are no longer useful for the consumer. This creates a backward flow of materials from any link of the supply chain, with the aim of recovering or re-integrating goods to the (forward) supply chain. Otherwise, they are disposed in such a way that the company can benefit financially, environmentally, and can generate added value [14,7]. In such a context, it is nowadays believed that RL as a field is "unique enough to undergo specialized research" [15].

It is to notice also that, in today's marketplace, effective RL management should be used as a competitive advantage, a positive profit center, and a tool to cut costs and to improve customer satisfaction [16,13,17,2,18]. In addition, a major issue in the reverse distribution is integration of forward and reverse supply chain. Returns information captured should be integrated with forward supply chain information to achieve optimum planning and reduction of costs. The whole support chain can then be designed in such a way that it can service both the forward and reverse logistics processes efficiently [19]. This is in line with the concept of a closed-loop supply chain design. Many authors have addressed the issues on closed loop supply chain for different case studies (see Section 2). However, the main feature of this paper is that the concept of closed-loop supply chain has not up to date incorporated in agroindustrial supply chains, to the best of our knowledge. We hence aim to study the impact of simultaneously considering forward (direct) and backward (reverse) product flows in a supply chain of the agro-industrial sector, taking as case study the palm oil supply chain. In order to present a formal framework for modeling such a complex supply chain, a mathematical model is proposed. This model is finally analyzed and experiments on the robustness of the closed loop configuration are carried out.

The reminder of this paper is organized as follows. Section 2 presents an overview of scientific literature on optimization methods applied to reverse logistics. Section 3 is devoted to present the supply chain under study (i.e., the production and distribution of palm oil). Section 4 presents in detail the proposed mathematical model, while Section 5 is devoted to the analysis of computational results. The paper ends in Section 6 by presenting some concluding remarks.

2. Overview of related literature

As stated previously, there exist in the scientific literature various definitions of reverse logistics: see for instances the surveys of Fleischmann et al. [10], Dowlatshahi [11] and Srivastava [8], among others. The European Working Group on