Innovative Applications of O.R.

Effective location models for sorting recyclables in public management

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A B S T R A C T

The recycling of urban solid wastes is a critical point for the "closing supply chains" of many products, mainly when their value cannot be completely recovered after use. In addition to environmental aspects, the process of recycling involves technical, economic, social and political challenges for public management. For most of the urban solid waste, the management of the end-of-life depends on selective collection to start the recycling process. For this reason, an efficient selective collection has become a mainstream tool in the Brazilian National Solid Waste Policy. In this paper, we study effective models that might support the location planning of sorting centers in a medium-sized Brazilian city that has been discussing waste management policies over the past few years. The main goal of this work is to provide an optimal location planning design for recycling urban solid wastes that fall within the financial budget agreed between the municipal government and the National Bank for Economic and Social Development. Moreover, facility planning involves deciding on the best sites for locating sorting centers along the four-year period as well as finding ways to meet the demand for collecting recyclable materials, given that economic factors, consumer behavior and environmental awareness are inherently uncertain future outcomes. To deal with these issues, we propose a deterministic version of the classical capacity facility location problem, and both a two-stage recourse formulation and risk-averse models to reduce the variability of the second-stage costs. Numerical results suggest that it is possible to improve the current selective collection, as well as hedge against data uncertainty by using stochastic and risk-averse optimization models.

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1. Introduction

According to IPEA (IPEA, 2012), Brazil can obtain approximately R$ 8 billion per year through the recovery of recyclable materials. In 2011, 177 t of urban solid waste were generated daily, of which 31.9% were recyclable materials (ABRELPE, 2012). Although recycling in Brazil has experienced a rapid increase in the last decade, there are still some barriers that account for the low recycling rate when compared to other countries. Among the factors that contribute to this are the high cost of the selective collection and the scarcity of adequate rating systems related to the storage and the processing of waste at the sorting centers (Simonetto & Borenstein, 2006). Because selective collection involves the reverse logistics of many types of products, it is necessary to clearly define the roles that the society, companies and the government play to achieve a successful selective collection. In order to bring materials such as plastic, metal and glass back to the industry, a significant commitment between the society, the government and companies is

required. Despite the increase in environmental awareness, it is essential to define legislative, economic and social incentives to support recycling, as the recovery of used materials and products may not be economically attractive (Cruz-Rivera & Ertel, 2009). In turn, the government is responsible for establishing both economic incentives and environmental legislative regulations for companies and citizens. Many economic incentives are based on reducing the consumption of raw materials and reducing costs for waste treatment. These issues are important for Green Supply Chain Management (GSCM) practices in public management.

Since October 2010, The National Solid Waste Policy (PNRS, in the Portuguese abbreviation) regulates recycling activities in the country, and establishes rules for cooperation among the federal, the state and the municipal governments. Although the PNRS is a federal law (Law no. 12.305/10), all states and municipalities can determine regional rules regarding their own residues. Since different regions might face the same challenges, regional cooperation is stimulated so that good practices and solutions can be shared. The PNRS clearly states that the management of solid urban waste is the responsibility of the municipal government, and conditions the transferring of federal funds to the municipalities which are in compliance with the recycling goals. This policy is also crucial to achieve proper urban waste management, as it extends the

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responsibility of the product's life cycle and their sustainable reuse in the same cycle or in others. In compliance with the PNRS initiatives, more and more companies have designed eco-friendly products and packages. However, there is no guarantee that recyclable materials will be effectively recycled due to market limitations. As a result, most of these residues are simply disposed of in landfills. The PNRS also attributes the responsibility for the end-of-life of products such as tires and batteries to producers, but the management of the end-of-life of most urban solid wastes depend on their selective collection so the recycling process can start. In this context, an efficient selective collection has become a mainstream tool of the National Solid Waste Policy.

Despite the fact that waste collection in Brazil is undertaken by statutory authorities, the PNRS increases the social role of recycling operations by encouraging cooperative-based initiatives. In turn, these organizations encourage social inclusion and income generation for marginalized members of society, since working in the cooperatives provides better financial benefits and resocialization through intense participation in the cooperative decisions, education, training and information. For these reasons, many enterprises have been supporting selective collection programs by cooperatives, by recognizing not only their social impact, but also the environmental and economic importance of recovering recyclable materials.

One of the major challenges in the recycling process is the coordination of the different members in the green supply chain: consumers, producers, and suppliers. Fig. 1 presents the relationship between the main stakeholders involved in the supply chain of recyclable materials. These actors are not all necessarily in the same supply chain, as consumer goods are composed of different materials (plastic, metal, glass, paper/cardboard). Consequently, the GSCM practices adopted are not homogeneous along the chain. An example of non-homogeneous practices along the GSCM is the lack of reverse plans by many of the companies that develop products and packaging and do not worry about retrieving their value after use, or whether there are recycling companies capable of

dealing with post-consumption waste. Hence, one of the great challenges faced by public management lies in managing the collection of recyclable materials from the population (consumers), supporting the sorting activities (sorting centers), and regulating the procurement of recyclable materials by recycling companies in the presence of various groups with possible divergent interests.

The collection of recyclable materials in urban settings also poses inherent challenges, such as the vast collection area, the low density of the transported material, and the high transportation costs. The manner in which the products are transported, the number of facilities and their locations have a great impact on global transportation efficiency, as pointed out by Dekker, Bloemhof, and Mallidis (2012). Also, since a large number of journeys is necessary to generate a large enough amount of materials for recycling, decisions concerning the number and/or location of the facilities are crucial for the economic viability of the selective collection.

In this paper, we address the problem of location planning for sorting centers in the city of Sorocaba (23°30′7″S, 47°27′28″W, Sao Paulo State, Brazil; see Fig. 2 for an overview of the region), whose population is approximately 580 thousand inhabitants. The location of sorting centers is the corner-stone of the reverse logistics in Sorocaba, since the selective collection and all the reverse supply chain operations are primarily dependent on it. Since 2006, the municipal government has been working with cooperatives in order to recover the value of recyclable waste in an effort to minimize landfill consumption. Also in 2006, public authorities and civil society entities agreed to develop a selective collection program where the cooperatives would perform the recycling activities jointly with the support of the municipal government. To encourage the creation and maintenance of cooperatives in Sorocaba, the municipal government and some private companies have been providing trucks, shed rental, equipments (baler, conveyor, forklift, scale, etc.), informative leaflets to raise awareness about this issue, as well as training and education to the members of the cooperatives (Simões, Ferraz, Mancini, Bonilla, & Bizzo, 2011).
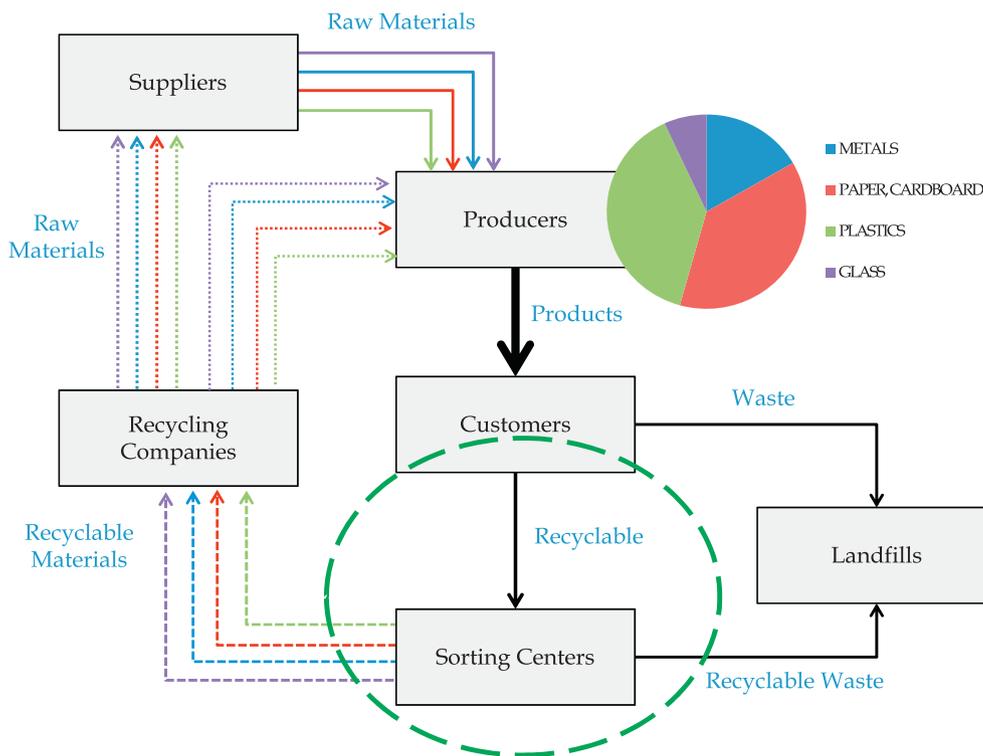

Fig. 1. Framework for recyclable materials from urban waste.