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Reverse logistics network for municipal solid waste management: The inclusion of waste pickers as a Brazilian legal requirement

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ABSTRACT

This study proposes a reverse logistics network involved in the management of municipal solid waste (MSW) to solve the challenge of economically managing these wastes considering the recent legal requirements of the Brazilian Waste Management Policy. The feasibility of the allocation of MSW material recovery facilities (MRF) as intermediate points between the generators of these wastes and the options for reuse and disposal was evaluated, as well as the participation of associations and cooperatives of waste pickers. This network was mathematically modelled and validated through a scenario analysis of the municipality of São Mateus, which makes the location model more complete and applicable in practice. The mathematical model allows the determination of the number of facilities required for the reverse logistics network, their location, capacities, and product flows between these facilities. The fixed costs of installation and operation of the proposed MRF were balanced with the reduction of transport costs, allowing the inclusion of waste pickers to the reverse logistics network. The main contribution of this study lies in the proposition of a reverse logistics network for MSW simultaneously involving legal, environmental, economic and social criteria, which is a very complex goal. This study can guide practices in other countries that have realities similar to those in Brazil of accelerated urbanisation without adequate planning for solid waste management, added to the strong presence of waste pickers that, through the characteristic of social vulnerability, must be included in the system. In addition to the theoretical contribution to the reverse logistics network problem, this study aids in decision-making for public managers who have limited technical and administrative capacities for the management of solid wastes.

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1. Introduction

Regarding Municipal Solid Waste – MSW, Agenda 21 proposes the reduction of waste generation and an efficient reuse of generated waste (UN, 1993). Therefore, various regulations and guidelines were prepared to enable the implementation of adequate MSW Management (MSWM) and to establish responsibilities affecting all stages from the exploration of raw materials to the disposal of the MSW (Campos, 2014; Chen et al., 2010; Machado, 2012).

Amongst the regulations created for the appropriate management of the MSW in Brazil, Law No. 12.305/2010 is important (Brazil, 2010), as it instituted the Brazilian Solid Waste Policy

(BSWP), which regulates the solid waste management as an expansion of some objectives of Agenda 21 on a national level (Chaves et al., 2014). The primary objectives established by this law are to put an end to dumps by the end of 2014 and to implement selective collection, reverse logistics (RL) and the composting of organic materials (Brazil, 2010; Guarnieri et al., 2014).

The BSWP also defines basic guidelines with regard to the economic and environmental sustainability of the MSWM system, addressing various minimum targets to be achieved, including reduction, reuse and recycling, as well as the transfer of refuse to environmentally appropriate forms of final disposal (Jabbour et al., 2014; IPEA, 2012b). Other targets considered by the BSWP are the social inclusion and economic emancipation of collectors of reusable and recyclable materials (waste pickers) (Xavier et al., 2014), in addition to the use of measures to incentivise and enable regionalised MSWM (Scheinberg, 2012; Wilson et al., 2012; Guarnieri and Cerqueira Streit, in press). The formalisation of the inclusion of the waste pickers occur through selective collection, whose gradual implementation is regulated and will allow the

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MSWM to be economically self-sustaining (Brazil, 2010). However, Campos (2014) indicates that a challenge to put into practice the BSWP is the planning, design, implementation and operation of selective collection and of the necessary MRFs.

This article proposes a reverse logistics network involving MSWM to solve the challenge of managing these wastes in an economic way considering the new legal requirements and the inclusion of waste pickers. The study aimed to examine the allocation of material recovery facilities (MRF) as intermediate points between the generators of these wastes and the places for reuse and disposal, as well as the participation of associations and cooperatives of waste pickers. These MRFs are not transshipment points, but points of sorting and cargo consolidation on a small scale that reduce the cost of transport and enable the collection door-to-door by waste pickers. The main contribution of this network is the reduction, in the long term, of solid waste transport cost from households to the MRFs with consequent reduction in greenhouse gases emissions and also, including informal sector as an important stakeholder of the MSW, as required in BSWP. Thus, this model seeks to fill the literature gap including other aspects as political, regulations and social facets related to SWM that should be taken into account along with the minimising costs objective (Ghiani et al., 2014). Ghiani et al. (2014) affirm that a new challenge in operational research is represented by studying and modelling a unified framework in which decisions related to the collection sites, transfer stations, processing facilities and landfills location are combined with decisions on shipping multi-commodity waste flows on the basis of how profitable it is to convert fractions of the waste into recycling materials.

The design of reverse logistics networks address the number of collection, recovery and disposal centres needed; their locations and capacities; and the product flows amongst these facilities (Ferri et al., in press; Chaves et al., 2014; Ramezani et al., 2013; Pishvaei et al., 2010). A network was modelled mathematically and validated through the analysis of scenarios in the municipality of São Mateus in the state of Espírito Santo (Brazil), which was chosen for the case study because it is a medium-sized city and is representative of a large portion of Brazilian municipalities.

The centralisation of materials and the consequent increasing of the volume of waste tends to facilitate commercial negotiations for the purchase and sale of recyclable materials because it is possible to structure and formalise buying and selling processes on a large scale (Damásio, 2014). With this opportunity, the associations increase the variety of wastes with commercial potential for recycling, their inclusion in the markets and, therefore, their income (Guarnieri and Cerqueira Streit, in press; IPEA, 2013; AMUNES, 2014b; Paul et al., 2012; Chen et al., 2010). This is important in developing countries such as Brazil, where approximately 23% of families are in a situation of vulnerability (characterised by social vulnerability, which identifies the capacity of family members – including both supporting and vulnerable members – to display resilience to adverse situations, such as barriers in access to knowledge, access to work, resource availability, infant/child development and living conditions) (IPEA, 2012a; Furtado, 2012; Auler et al., 2014).

Considering the environmental, legal, social and technical aspects, the reverse logistics network aimed at managing MSW proposed facilitates some objectives of Agenda 21 at a local level (Chaves et al., 2014; Llamas-Sanchez et al., 2013), assisting the municipalities in handling the challenges of a multi-dimensional issue (Guerrero et al., 2013; Othman et al., 2013; Sujauddin et al., 2008). Wilson et al. (2012) and Marshall and Farahbakhsh (2013) emphasise that a holistic view integrating the interconnectedness of socio-cultural, environmental, economic and technical spheres is particularly necessary in developing countries, where the complexities of MSW systems are often greater.

Despite the appropriated formulation phase, the BSWP implementation phase has faced many obstacles, mainly at the local level, due to the low administrative capacity to address such a complex legal instrument (Jabbour et al., 2014; Chaves et al., 2014; Godoy, 2013; Gomes, 2012; Jacobi and Besen, 2011; Lisboa et al., 2013). This difficulty also occurs in other developing countries, as shown by Barton et al. (2008), Chen et al. (2010), Couth and Trois (2010), Paul et al. (2012), Troschinetz and Mihelcic (2009) and Wilson et al. (2009).

Although the Brazilian reality is examined, this model can be an example to integrate the informal sector and to minimise costs for the MSWM in other developing countries that face the same challenges. A reverse logistics network could provide a useful tool to help municipalities in their decision-making process related to the adequacy of SWM to address national policies requirements. The state of SWM varies widely amongst nations, regions, cities, communities, households, and even individuals. It is for this reason that systems approaches, which are founded upon specific or locally appropriate methodologies, are so crucial to the future of SWM practices (Chang et al., 2011; Marshall and Farahbakhsh, 2013).

The remainder of this paper is organised as follows. Section 2 presents a brief literature review about SWM and a panorama of the MSWM in Brazil which allows a support for understanding the aspects considered in the proposed reverse logistics network. In Section 3 we describe the mathematical model for this generic reverse logistics network for MSW. In order to validate the model, we show the parameters for the São Mateus case in Section 4. Section 5 presents the practical application of the mathematical model through scenarios. For this, first we expose the considered scenarios and then we analyse and discuss the results. Finally, conclusions are presented in Section 6.

2. Materials and methods

2.1. Municipal solid waste management: brief literature review

In developing countries, the recent urbanisation increased concentration of people which implies an accumulation of waste that needs to be properly managed and disposed. With limited resources, only basic technologies for treatment and disposal, and deficient enforcement of relevant regulations, serious problems remain for the MSWM in developing countries (Chen et al., 2010; Couth and Trois, 2010).

One of these challenges also involves understanding that the MSW has two streams: the formal and the informal sectors. The informal sector is an important stakeholder group in MSW mainly in developing countries; however, until recently they were not recognised as a legitimate (Campos, 2014) and, consequently, not considered in the MSWM. As waste management is an important social, economic and environmental requirement, public–private partnership schemes to MSW should incorporate the informal sector (Couth and Trois, 2010).

Wilson et al. (2009) present successful examples of SWM systems developed including the informal sector. Cooperation between the informal and the formal sector can be part of the solution in SWM, but it requires support to the informal sector (Sembiring and Nitivattananon, 2010; Wilson et al., 2009). They are considered as the most directly vulnerable group in municipal SWM (Paul et al., 2012).

Chen et al. (2010) proposed a framework for integrated waste management that must consider factors that affect MSWM in developing countries as legal regulations/policy and the inclusion of waste pickers in the collection, transportation, storage and treatment/disposal phases. Nevertheless, some factors influence

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