Eco-efficiency as an auxiliary measure for the definition of interregional public consortia responsible for the collection of recyclable domestic waste

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ABSTRACT

This article presents as its main contribution a set of procedures for the definition of interregional public consortia responsible for the implementation and operation of door-to-door selective collection, which is a new approach to this definition. This procedure is structured in ten steps which are necessary for the generation of options of partitioning in a study region in a number (k) of groups, considering that groups with two or more subregions represent consortia, and the analysis of these options by means of financial and environmental performance measures. The referred procedure has been applied here to a case concerning a region in the State of Rio de Janeiro, Brazil. Through the study of this case, it is concluded that the most adequate option is $k = 2$ groups. In this option, there is the formation of a public consortium comprising five study subregions and one of the subregions must not enter the consortium (this subregion is responsible for the generation of 73% of recyclable waste produced in the study area). The application of this procedure provides assistance in decision-making on the part of the analyst who needs to implement door-to-door selective collection, as an action for the improvement of solid waste management in a group of studied subregions.

1. Introduction

With the growth in rates of waste generation worldwide, it is necessary to implement, improve and increase recycling practices (Suttibak and Nitivattananon, 2008). In general, recyclable domestic waste is collected by means of a selective collection system. The most common system is door-to-door selective collection, in which vehicles collect recyclable waste which has been sorted and stored in each residence. This system is carried out by solid waste management which is usually the responsibility of local governments, especially in developing countries (Damghani et al., 2008).

It is estimated that the cost of door-to-door selective collection is higher than that of undifferentiated collection (CEMPRE, 2012), in which unsorted solid waste is transported to final disposal locations. Based on this premise, great difficulty is verified in implementing door-to-door selective collection in subregions with low financial potential and in lightly populated subregions in which it is not viable to mobilize resources for the collection of a small quantity of generated recyclable waste. A possible solution to this problem would be the joint implementation of door-to-door selective collection through the formation of public consortia.

In this context, this work aims to identify components of public consortia, oriented to sharing resources and collection costs, by means of a ten step procedure.

The proposed procedure uses the *k*-means clustering algorithm for the partitioning of a study region in a number (k) of groups of subregions – it must be pointed out that consortia are groups with two or more subregions. The procedure also uses an eco-efficiency measure as a measure of environmental performance. This measure and a financial performance measure originate a single performance measure defined for each partitioning option in a number (k) of subregion groups. Thus, the partitioning option with the best performance is verified and then the public consortia are formed.

The procedure was applied to subregions of the mountainous region of the state of Rio de Janeiro (Brazil). Although the procedure is focused on helping decision making in the formation of consortia by the government, the role of the informal sector needs to be defined. In this study, we consider the organization of waste pickers

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in cooperatives that act in waste sorting centers created by the public consortia defined through the proposed procedure.

As for the results achieved after the application of the procedure, it can be seen how important environmental influence is in making decisions about how many and which public consortia should be formed for the joint implementation of door-to-door selective collection. Therefore, it is important to highlight the relevance of this approach, mainly in developing countries, where (Chattopadhyay et al., 2009; Ciccozzi et al., 2003) note that little attention is given to clean production, eco-efficiency and solid waste management – all dealt with in this article.

2. Solid waste management and eco-efficiency

With the appearing and growing of great urban agglomerations, the disposal of generated solid waste has become a problem all over the world (Vehlow et al., 2007). In order to solve this problem, the implementation of a management process has become necessary to promote adequate disposal of this solid waste.

Considering the above, solid waste management is here defined as a broad program of prevention, waste storage, collection and transport, resource recovery, recycling, composting and incineration, other physical and biological treatments and disposal of waste, coexisting in an integrated manner (EEA, 2010; EPA, 2002).

One of the actions related to solid waste management is the implementation of door-to-door selective collection. This action contributes to avoid the consequences of lack of solid waste management, such as soil and groundwater contamination, proliferation of plagues, bad odor and dissemination of diseases (Alam et al., 2008; EEA, 2010).

This collection practice contributes to the improvement of solid waste management and, at the same time, generates environmental impacts. Thus, it is interesting to consider eco-efficiency measures to assist in the implementation of this practice, mainly because there is great opportunity for reduction of environmental impacts related to the transport sector (Tsoulfas and Pappis, 2006).

These eco-efficiency measures take into consideration the environmental impacts that can be measured through indicators (Kharel and Charmondusit, 2008). Some of these indicators are common in application that involve the transport sector or supply chains. According to the works of (Michelsen et al., 2006), (Kuo and Chen, 2009), (Leal and D'Agosto, 2011), (Leal et al., 2012) and (Blengini et al., 2012), these environmental indicators may be energy consumption, carbon dioxide (CO_2) emissions and local atmospheric pollutant emissions, such as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC) and particulate matter (PM).

Consequently, these indicators and the eco-efficiency measures can be applied in the context of decisions about the formation of public consortia oriented to jointly spending resources for the implementation of door-to-door selective collection. According to (IBAM, 2007), the public consortium is a means of association and coordination among government entities for the joint or coordinated management of public services.

The formation of these consortia based on the concept of eco-efficiency may be stated in solid waste management policies, as mentioned in the National Solid Waste Policy (Política Nacional de Resíduos Sólidos – PNRS) established in Brazil in 2010 (Brazil, 2010). Polaz and Teixeira (2008) highlight the importance of the creation of such public policies oriented to the implementation of solid waste management.

Finally, it is important to highlight that the implementation of door-to-door selective collection together with the concept of eco-efficiency must respect local peculiarities. Wilson et al. (2001) and Papachristou et al. (2009) point out that these peculiarities must be considered in the process of elaboration and operationalization of solid waste management plans and (Mickwitz et al., 2006) highlight the importance of considering these peculiarities for the definition of indicators of eco-efficiency measures.

3. Procedure for the definition of interregional public consortia

Fig. 1 presents the procedure for the definition of interregional public consortia, composed of ten steps of which the first seven are responsible for the generation of partitioning options to be assessed during the last three steps. This assessment takes into consideration a Financial Performance Measure (FPM) and an Environmental Performance Measure (EPM) which are aggregated by means of the calculation of the weighted average, so as to obtain one single performance measure for each partitioning option. The weighted measure of these options is calculated with different weights attributed to the EPM, which shows an eco-efficiency measure. Thus, for each weight attributed to this measure, the analyst shall be able to verify the option with the highest performance. While defining this partitioning option, the groups and consequently the consortia – which are groups with two or more subregions – are verified.

3.1. Step 1

The first step aims to define the study region. The proposed procedure may be applied to any study region. This application will be even more relevant when the subregions that form the study region do not present financial potential to individually implement door-to-door selective collection and/or when the generation of recyclable domestic waste is low, mainly in lightly populated subregions – with less than 30 thousand inhabitants (IBAM, 2001), to the point of making it not viable to mobilize resources for door-to-door selective collection.

3.2. Step 2

The second step involves the identification of the subregions Sbi that form the study region. This definition is necessary, since the aim is to propose public consortia formed by these defined subregions. It is possible to identify these subregions by political division, administrative division or the subregions may be defined arbitrarily. The political division may be determined at different levels, such as municipalities, counties, districts and neighborhoods. It is up to the analyst to identify the subregions Sbi and define at which level they are to be treated. For this definition, one should consider the availability of data which may not exist or may not be accessible.

3.3. Step 3

The third step for the determination of public consortia is the definition and the choice of generation zones (j) of the subregions (i) Zij and the definition of their quantities of generated recyclable waste Gij. These zones are subdivisions of the defined subregions Sbi. It is worth mentioning that these subdivisions may be defined based on political division, administrative division or they may be arbitrary. For the definition of these subdivisions, one should consider the availability of data, mainly concerning composition and volume of generated solid waste. After this definition, it is important to highlight that the analyst may choose not to consider all the generation zones in the study, since it may be that the goal is to begin collection in part of these zones so that, later, the service can be expanded.