Waste Management 59 (2017) 3–13

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Assessment strategies for municipal selective waste collection schemes

Fátima Ferreira [a], Catarina Avelino [a], Isabel Bentes [b], Cristina Matos [b], Carlos Afonso Teixeira [c,*]

[a] CMAT-UTAD, CEMAT-IST-UL, Universidade de Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal
[b] C-MADE UBI/UTAD, Universidade de Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal
[c] CITAB/UTAD, Universidade de Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal

ARTICLE INFO

Article history:
Received 28 June 2016
Revised 6 October 2016
Accepted 27 October 2016
Available online 12 November 2016

Keywords:
Selective collection
Waste management
Solid waste collection
Collection schemes
Performance indicators
Performance índex

ABSTRACT

An important strategy to promote a strong sustainable growth relies on an efficient municipal waste management, and phasing out waste landfilling through waste prevention and recycling emerges as a major target. For this purpose, effective collection schemes are required, in particular those regarding selective waste collection, pursuing a more efficient and high quality recycling of reusable materials.

This paper addresses the assessment and benchmarking of selective collection schemes, relevant to guide future operational improvements. In particular, the assessment is based on the monitoring and statistical analysis of a core-set of performance indicators that highlights collection trends, complemented with a performance index that gathers a weighted linear combination of these indicators. This combined analysis underlines a potential tool to support decision makers involved in the process of selecting the collection scheme with best overall performance. The presented approach was applied to a case study conducted in Oporto Municipality, with data gathered from two distinct selective collection schemes.

1. Introduction

A linear economy is being progressively replaced by a circular economy that ideally seeks for a zero waste framework (Loughlin and Barlaz, 2006; Jenkins et al., 2009; Sidique et al., 2010; Cruz et al., 2012; Park and Chertow, 2014; Ghisellini et al., 2016). The linear economy is a basic structured model that relies on the extraction of raw materials and their processing into products, which, after used, are treated as waste and mainly disposed into landfills. During the last decades, this model has been considered as a successful model, driving to a lot of products at very low prices, boosting the economies of developed industrialized countries, and encouraging consumption. However, such "take-make-dispose" approach resulted in a massive increase of waste produced, in the extensive use of non-renewable raw materials and in the emergence of inherent environmental problems, quickly pointing to circular economy practices, where all the materials should be reused yielding new products through reuse, recovery and recycling, for an infinite number of cycles (Zhijun and Nailing, 2007; EMF, 2012). In this context, waste recycling must achieve higher targets in the near future.

Currently, Directive 2008/98/EC establishes, as a goal for 2020, that waste reuse and recycling reach 50% of the total waste produced. In Portugal, the Strategic Plan for Municipal Solid Waste (PERSU 2020, 2014) provides the same target, highlighting that the reference value in 2012 was 25%. European Commission goes even further, proposing as a target level to be attained on 2030 that at least 70% of the municipal waste is reused or recycled (EC, 2014).

Despite the huge benefits of recycling, the costs associated with recycled waste management are significantly high (Naustdalslid, 2014), where the waste collection, transfer and transport comprise the major part of the total cost, reaching 70% of the overall management expenses (Tavares et al., 2009).

Many of waste management systems are not financially sustainable, particularly due to the high collection costs (Ferreira et al., 2014). In order to reduce these costs, that will increase with the intensification of recyclable waste production and with the number of materials to separate, the management of selective waste collection systems must engage a cautious analysis of designs and equipment to reach efficient and effective systems.

This problem is a challenge and an incentive to innovation, technological progress and research to support the design of new equipment and materials, new technologies and new management models (Rada et al., 2013; Ranieri et al., 2014), but also in the systems performance improvement that, among others, comprises the selective collection costs reduction.

* Corresponding author at: Centro de Investigação de Tecnologias Agro-Ambientais e Biológicas (CITAB), Escola de Ciências da Vida e Ambiente (ECVA), Universidade de Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Apartado 1013, 5001-801 Vila Real, Portugal.

E-mail addresses: mmferrei@utad.pt (F. Ferreira), cavelino@utad.pt (C. Avelino), ibentes@utad.pt (I. Bentes), crismato@utad.pt (C. Matos), cafonso@utad.pt (C.A. Teixeira).

http://dx.doi.org/10.1016/j.wasman.2016.10.044
0956-053X/

In most part of the European countries the waste separation model is not mandatory nor unique (Ragazzi and Rada, 2008; Alvarez et al., 2009; Passarini et al., 2011), and Portugal is not an exception. Nevertheless, the traditional process relies on source separation that reveals the largest achievements in collection rates and ensures the quality of the recyclable material (EC, 2015). The recycling model is basically organized in ecopoints, which have three different colors of containers according to the type of material to be collected, namely paper/cardboard, light packaging and glass. These containers are emptied according to a frequency stipulated by the management entity, and the waste is transported to sorting units.

There is a wide range of containers that differ regarding their shape, capacity and emptying process. The emptying process – hereinafter designated by collection scheme – requires that the collection vehicle owns a special configuration able to maneuver the containers. The types of collection schemes most used in Portugal are: (i) the Street-Side collection – that load the container through the rear of the vehicle, with hydraulic lifting, usually with a three workers team; (ii) the Drop-off collection – that lift the container through a crane to the top of the vehicle, with a team of two or three workers.

The efficiency and inherent cost of the collection service heavily rely on several factors, including the selected collection scheme, with implications on the expended time to maneuver the vehicle and empty the container, on the distance travelled in each circuit and on the fuel consumption, among others. Easier containers maneuver, with better coordination between the container and the collection vehicle, result in smaller discharge times, increasing labor efficiency. Fuel consumption significantly depends on the collection time and distance, but it is also an intrinsic characteristic of each collection vehicle, according to the power required to perform the containers emptying operation. These factors are decisive in the efficiency and costs of the systems. Thus, performance evaluation of collection schemes should be a factor to be taken into account in the selection of equipment (containers/vehicles), which is traditionally based on its acquisition cost and its suitability for the territory (Bing et al., 2014). The performance evaluation of collection schemes may also encourage the equipment manufacturers to improve their products.

A current practice on performance evaluation of waste collection systems is based on the use of performance indicators (Sanjeevi and Shahabudeen, 2015; Woon and Lo, 2016; Halkos and Papageorgiou, 2016; Rigamonti et al., 2016;). However, the application of indicators has some limitations, mainly related with the number of indicators used. While a single indicator only allows a partial and restrictive analysis of the problem, a large number of indicators lead to a complex and ineffective analysis. There are additional difficulties related to data availability for the indicators calculation and also persists a lack of a systematic and standardized culture to perform a gathering of proper data and its subsequent processing (Gamberini et al., 2013).

Teixeira et al. (2014) have developed and implemented a performance assessment methodology for mixed waste collection based on a statistical analysis of a core-set of three performance relevant indicators, namely the effective collection distance, the effective collection time and the fuel consumption. As the selective waste collection is a multi-material collection, in order to optimize equipment resources, the same collection scheme must be used for the different materials collected. In such case, the overall performance evaluation involving more than one indicator could reveal a difficult inconclusive task if the indicators for different materials indicate better performance for a specific material and worse to another.

The aim of this study is to contribute to the development of performance evaluation methodologies to be applied in the selective collection schemes. As the selective collection focuses on multiple recyclable materials, the methodology developed in Teixeira et al. (2014), for the undifferentiated collection performance assessment, has been adapted to analyze the efficiency of selective waste collection along a performance comparison at operational level of the described collection schemes. The analysis has been performed through several performance indicators, evaluated for each type of recyclable materials. As the performance indicators do not show the same trend for the different materials, the analysis was further complemented with the proposal of a performance index to enable an integrated analysis of the results obtained by the indicators. Such performance index consists in a proper weighted linear combination, reflecting the relative importance of each indicator in the analysis of the different collection schemes.

The presented framework was tested through a case study conducted in Oporto Municipality, Portugal, that uses two distinct schemes in the waste selective collection. Nevertheless, this methodology is sufficiently general and flexible to be easily applied or adapted to other selective collection schemes and municipalities.

2. Methodology

The main goal of this study consists in a reliable decision-making of a best collection strategy taking into account the analysis of different selective collection schemes. In a first stage data is collected, treated and statistically analyzed, based on selected variables and performance indicators. This phase can provide conclusive information if selective waste collection behaviors and trends follow in the same direction for all type of selective waste collected in each collection scheme. Otherwise, it is necessary a second stage, where a global performance index is established, combining the performance indicators, properly weighted. This methodology provides a useful tool to support decisions concerning the selection of better collection schemes and is easily adapted to other different systems and locations.

The first stage of the methodology is similar to the one described in Teixeira et al. (2014), in particular the variables surveyed and the core-set indicators framework adopted. In the collection circuits, the vehicle drivers register information that is subsequently processed into the variables collection distance (De), collection time (Te), fuel consumption (Fc) and amount of selective waste collected (MSWc). A sampling method was chosen in order to minimize the interference in the normal operating service, nevertheless insuring a representative sample. At each collection circuit, these data measures begin with the stop to load at the first collection point and end with the final container emptying. The selected performance indicators are the Effective Collection Distance (IDe), Effective Collection Time (ITe) and Effective Fuel Consumption (IFe) (cf. Table 1). This indicators core-set arises from the normalization of the variables De, Te and Fc by the variable MSWc, allowing a more effective benchmarking.

Table 1
Core-set performance indicators IDe, ITe and IFe.

Performance indicator	Definition	Unit	Description
Effective collection distance	$\text{IDe} = \frac{\text{De}}{\text{MSWc}}$	km t^{-1}	Distance travelled by the collection vehicle per unit of selective waste collected
Effective collection time	$\text{ITe} = \frac{\text{Te}}{\text{MSWc}}$	h t^{-1}	Time spent per unit of selective waste collected
Effective fuel consumption	$\text{IFe} = \frac{\text{Fc}}{\text{MSWc}}$	l t^{-1}	Amount of fuel consumed by the collection vehicle per unit of selective waste collected