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A case study of packaging waste collection systems in Portugal – Part I: Performance and operation analysis

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ABSTRACT

The need to increase packaging recycling rates has led to the study and analysis of recycling schemes from various perspectives, including technical, economic, social, and environmental. This paper is part one of a three-part study devoted to comparing two recyclable packaging waste collection systems operating in western Portugal: a mixed collection system, where curbside and drop-off collections are operated simultaneously (but where the curbside system was introduced after the drop-off system), and an exclusive drop-off system. This part of the study focuses on analyzing the operation and performance of the two waste collection systems.

The mixed collection system is shown to yield higher material separation rates, higher recycling rates, and lower contamination rates compared with the exclusive drop-off system, a result of the curbside component in the former system. However, the operational efficiency of the curbside collection in the mixed system is lower than the drop-off collection in the mixed system and the exclusive drop-off system, mainly because of inefficiency of collection. A key recommendation is to ensure that the systems should be optimized in an attempt to improve performance. Optimization should be applied not only to logistical aspects but also to citizens' participation, which could be improved by conducting curbside collection awareness campaigns in the neighborhoods that have a mixed system.

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1. Introduction

Waste collection is one of the most visible activities in a waste management system and one that the public perceive highly. Although the goal of waste collection is to keep a city clean, the activity needs to deal with budgetary challenges, logistical constraints, public acceptance, and the reduction of environmental and health impacts, as well as be capable of reaching collection and recycling targets set by legislation (Rogge and De Jaeger, 2013; Usón et al., 2013; Williams and Cole, 2013).

The way in which waste collection is conducted varies between developing and developed countries. In some developing countries, waste is collected by manual labor and is deposited in bins and then transported by vehicle for disposal (Amponsah and Salhi, 2004), with informal waste recycling being prevalent (Wilson et al., 2006). In the latter case, and especially in European countries, waste collection systems involve high degrees of material separation into categories such as glass, paper, metals, plastics, and organic (kitchen and garden) waste (Jank et al., 2015). Such systems ensure that appropriate qualities of materials are recovered and recycled. Waste collection systems applied in these countries can be curbside collection, where recyclables are placed by citizens on the curbside near their houses for collection by a truck on an appointed day, or by drop-off (or "bring") collection, where recyclables are taken by citizens to drop-off points at various localities in their neighborhood and then picked up by truck at an identified frequency. Both the curbside and drop-off systems are characterized by a diversity of implementation technologies and by different collection frequencies and logistics needed to support them. The way in which each country or region operates its waste collection depends on socio-economic conditions, available infrastructure, and service provision (Timlett and Williams, 2011). The specificities of these characteristics according to location means that copying successful collection systems from one country or region to another does not necessarily ensure the same success, and adaptation is needed to suit local conditions in terms of both technical design and social factors (Martin et al., 2006; Mattsson et al., 2003; Timlett and Williams, 2011). More case studies of waste collection systems are needed to generate a greater

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knowledge base of such systems and to understand how they should be adapted in order to be successfully implemented.

Source-separated waste collection systems for extracting recyclables from urban waste have been analyzed according to their performance in terms of costs (Rogge and De Jaeger, 2013; Teerioja et al., 2012), environmental impacts (Maimoun et al., 2013; Powell, 1996; Teixeira et al., 2014; Yildiz-Geyhan et al., 2016), recycling/collection rates (Wilson and Williams, 2007), and public participation and behavior (Bolaane, 2006; Martin et al., 2006; Shaw et al., 2006; Oskamp et al., 1996; Wang et al., 1997). Focusing on performance and operations, Huang et al. (2011) developed key performance indicators to assess the efficiency of municipal solid waste collection. Gallardo et al. (2010) compared four selected collection systems operating in cities of over 50,000 inhabitants using efficiency indicators to provide information on material quality and quantity. García-Sánchez (2008) analyzed 113 municipalities with populations exceeding 50,000 inhabitants, with the intention of identifying the factors influencing the efficiency of waste collection and street-cleaning services. Gaiola (2002) have analyzed the quantity of source separated waste in several waste management systems in Portugal. Rodrigues et al. (2016a) have analyzed 22 waste collection systems for source separated packaging waste using 12 technical/operational indicators. Teixeira et al. (2014) and Ferreira et al. (2016) have applied performance indicators on their assessment of a case study in Portugal. Woodard et al. (2006) calculated citizen participation rates for curbside schemes in England and showed that the rates were higher for schemes that collected more types of material. The diversity of performance perspectives (technical and social) and of indicators used to assess waste collection performance reflects the difficulty of collecting and analyzing information, as well as the goal of the performance assessment, which is most often for planning and management decision making.

In Portugal, the drop-off collection is the most widespread source-separation system for collecting packaging waste, which consists of paper/cardboard (packaging and non-packaging), lightweight packaging (including all plastic, metal, and composite materials, such as liquid packaging cartons or LPCs), and glass. Although drop-off collection systems have been used for more than 15 years in Portugal, their success in collecting recyclables has been moderate. In 2012, the recycling rate for packaging waste was 44%, much lower than the 2020 target of 70% set by the Strategic Plan for Urban Waste ("PERSU 2020" in Portuguese) (MAOTE, 2014), meaning that a marked increase in the rate of the collection of recyclables is needed. If such an increase is to be achieved, then comparisons of different recycling schemes are needed to discover which recycling schemes are more successful and why they are more successful.

The purpose of our three-part study is to compare a mixed (curbside plus drop-off) collection system with an exclusive drop-off collection system in two municipalities in Portugal, by measuring a range of waste collection system indicators. This paper, which constitutes part one of the three-part study, examines the operations and performance of the waste collection systems. Part two covers the environmental and economic aspects of the study (Pires et al., 2016), and part three covers the social aspects (Martinho et al., submitted manuscript).

2. Materials and method

2.1. The studied waste collection systems

In Portugal, the management of urban waste is the responsibility of municipalities if daily waste production is less than 1100 L per producer (MAOT, 2011). Packaging waste is generally collected by municipalities, with economies of scale in managing and treating urban waste being achieved by several municipalities joining together and using private contractors to fulfill their urban waste responsibilities. In this study, a private company manages the urban waste generated in several municipalities in western Portugal. The mixed collection system examined in the study is used in two neighborhoods located near the landfill, namely, A and B, and the drop-off system examined is used in the neighborhood of C (Table 1).

Part of the reason for studying these particular waste collection systems is the interest of the private company in comparing different collection systems in neighborhoods of similar socio-economic characteristics and housing, with the selected neighborhoods being composed mostly of single-family homes. Also, the curbside collection in the mixed system neighborhoods was initiated in different years (2001 in A and 2008 in B), and for that reason, the study also compares performance indicators for A and B, neither of which has been exposed to citizen recycling awareness campaigns since the initiation of the curbside collections. The number of drop-off points for the mixed and exclusive drop-off collection systems is similar, namely, 1 drop-off point per 125–250 households (1 drop-off point per 350–650 inhabitants). Normally, the presence of both curbside and drop-off collection systems (i.e., a mixed system) would be characterized by a lower number of drop-off points; for example, the occurrence of drop-off points in Sweden varies from 1 per 400 households to 1 per 2,000–2500 households (Dahlén et al., 2007). In the present study area, the purpose of retaining the drop-off system when implementing a curbside system in a neighborhood was to keep both systems working at the same time, ensuring that there is always a place/way for citizens to dispose of their recyclables. Another reason to study the neighborhoods of A and B was to discover any evidence for the informal management of waste, that is, the delivery of packaging waste to unofficial waste operators. The neighborhoods of A and B are located in different municipalities, with different cultural backgrounds. M1 municipality (in which A and C neighborhoods are located) has a glass industry as one of its main activities. For that reason, managers at private company believe that the amount of glass collected is lower because it is diverted to this industry informally.

Collection in the mixed system neighborhoods is characterized by curbside and drop-off collection components. Lightweight packaging (termed the "yellow stream") and paper/cardboard packaging/non-packaging (termed the "blue stream") are collected by curbside, with free 50-L bags offered by the private company. The drop-off system collects the same waste streams, but also includes glass packaging (termed the "green stream"). According to the classification of waste collection systems developed by Rodrigues et al. (2016b), curbside collection can be classified by container component, vehicle component, and collection system. Concerning the container component, curbside collection is characterized by surface emplacement of bags, is mobile without wheels, without compaction, and without a vehicle-coupling system between the bag and the collection vehicle. Concerning the vehicle component, the body is open, with a single compartment, without body mechanization, without lifting mechanization, and without a specific loading location. Given these features, the collection system is considered to be manual. The collection in the neighborhoods of A and B is made by a crew of two workers and takes around three hours. The collection frequency is once a week for both the yellow stream and the blue stream.

Besides the curbside collection, there are also drop-off containers to collect packaging waste: one container for each packaging waste stream (yellow, blue, and green). Based on the taxonomy of Rodrigues et al. (2016b), the containers are placed at the surface, immobile, without compaction, and with vehicle coupling by double-ring crane. The vehicle has a closed body, a single compartment, with intermittent compaction, with a crane double hook lift-

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