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Collection of recyclables from cubes – A case study

Morten Bie Bogh [a], Hardy Mikkelsen [b], Sanne Wøhlk [c,*,1]

[a] Aarhus University, Fuglesangs Allé 4, DK-8210 Aarhus V, Denmark
[b] Reno Djurs I/S, Nymandsvej 11, DK-8444 Balle, Denmark
[c] CORAL – Cluster for Operations Research and Logistics, Department of Economics and Business, Aarhus University, Fuglesangs Allé 4, DK-8210 Aarhus V, Denmark

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ABSTRACT

Collection of recyclable materials is a major part of reverse logistics and an important issue in sustainable logistics. In this paper we consider a case study where paper and glass are collected from recycling cubes and transported to a treatment facility and processed for reuse. We show how outsourcing the planning and transportation of this service may result in conflicts of interest and unsustainable solutions. Finally, we suggest an alternative payment structure which can lead to a common goal, overall financial sustainability, and an improved financial situation for both the public company and the logistics provider.

1. Introduction

In the modern world, the amount of waste increases rapidly. Households in Denmark alone annually generate more than 1.7 million tons of domestic waste and deliver 1.8 million tons of reusable materials for recycling. The recyclable materials are partitioned into more than 20 groups depending on type, and they do not include materials returned directly to the producer. The total amount of waste and reusable materials generated from businesses and industry exceeds 12 million tons annually (all values are 2009 level) [25].

The collection and handling of waste and reusable material are thus matters of large practical relevance. Waste management is often seen as an obligation, and models are often built to comply with the law. However, if done properly, the use of reverse logistics not only reduces waste and CO_2 emissions, but it also provides raw materials for new production processes.

Beullens et al. [10] gave an overview of transportation of waste and reusable material from an operations research point of view. They argue that research of reverse logistics systems is very inadequate and sparse compared to that of (normal) forward logistics, and that new research needs to be conducted with the goal of making reverse logistics systems efficient.

In Denmark, the collection and handling of waste and reusable materials is a public responsibility. Each county is responsible for the waste and reusable materials generated by its households and businesses. Often, a number of counties establish a joint non-profit public company for collection and handling. One such public company is Reno Djurs, which is the subject of our case study.

Comprehensive regulation has been implemented with regard to these services [13,24], but we will not describe the regulation in detail. Waste and reusable material generated by households in Denmark are collected in three ways: A) A few recycling depots are located in each county and the citizens bring their recyclable materials and sort them into containers according to 20–25 types: metal, electronics, building materials, garden waste, etc. B) Cubes for collection of paper and glass are scattered around the country, e.g. near supermarkets, sports and parking facilities. C) General waste is collected from each household via curbside collection on a weekly or bi-weekly basis. Most counties have a system with a single bin at each household, but some counties offer systems for partitioning the waste into organic household waste and non-biodegradable waste and some even collect paper, glass and batteries separately.

From the point of view of transportation planning, C) is often modeled as arc routing problems. See Refs. [14,32] for surveys. Note that issues such as regularity and geographical sectoring are only important in relation to type C). Transportation planning for types A) and B) is very different, but does, however, resemble inventory-routing problems [4,12]. A) can be classified as a few-to-few transportation system where large amounts are transported and the vehicle capacity is small, whereas B) can be classified as a many-to-one system in which the routing issue is important.

* Corresponding author. Tel.: +45 8716 4905.
E-mail address: sanw@asb.dk (S. Wøhlk).
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In this paper, we focus on transportation planning in relation to B); recycling cubes for paper and glass. In the case of Reno Djurs, transportation is handled by a logistics provider who has significant freedom in the planning of his work. We investigate the conflicts of interest that arise from this outsourcing and give suggestions on ways to solve these conflicts. We therefore study the system consisting of the logistics provider's activities related to emptying cubes and transporting the recyclables to their treatment facilities, the payment from Reno Djurs to the logistics provider related to this transportation, and the service experienced by the citizens. The system is financed by the citizens through a mandatory property-tax.

The aim of our analysis is to find a system structure that is more financially sustainable than the present structure. In this regard we define "financially sustainable" to mean a system with minimal overall cost that does not increase the financial burden of any of the parties in the system. Thus the structure of the new system must balance the profit of the logistics provider, the cost paid by Reno Djurs, and the service provided for the citizens. We conjecture that by changing the payment structure of the outsourcing, a financially more sustainable structure is obtained.

In Section 2, we study some related literature, and in Section 3, we describe the case problem in detail. In Section 4, we present our solution procedure, and we discuss our findings and propose a new payment structure in Section 5. Finally in Section 6, we bring our conclusions.

2. Literature

In this section, we take a closer look at the literature related to our problem. We first consider papers related to the three problems A), B), and C) as described above. We then review a number of descriptive as well as operations research based papers from the waste transportation literature.

Aringhieri et al. [7] describe a case study in Italy and investigate a transportation problem similar to A). The main difference between their problem and A) is that in Denmark, the vehicle carries two containers at a time (possibly with different origins and/or destinations), whereas the problem studied in Ref. [7] uses unit-capacity vehicles. Archetti and Speranza [6] study a similar problem with two groups of customers, where one group has higher priority than the other.

Collection of waste from a cube-like system as the one referred to as B) above has not been studied in the academic literature before. The problem shares many characteristics with several inventory-routing problems, for instance Archetti et al. [5], though no exact match to the problem could be identified. The problem can be seen as an inventory-routing problem with an order-up-to policy, stochastic demand, no inventory holding cost, multiple commodities (2), and quite a special definition of vehicle capacity. See Section 3 for details. We refer to [4,12] for recent surveys of the inventory-routing literature.

Several papers have studied curbside collection of waste, classified as C) above. The arc routing literature often refers to this as refuse collection [1–3,8,15,16,21]. Nuortio et al. [26] study the problem as a node routing variation and solve the problem for a waste collecting case of Finland.

A number of studies have been conducted in relation to waste transportation from an operations research angle but do not fall into the above groups. Here we mention a few. Kulcar [20] studies collection of waste in Brussels from a strategic perspective and evaluates several means of transport of the waste including rail, vehicles, and canals. Kim et al. [18] study the collection of commercial waste, which they model as a vehicle routing problem with time windows, multiple routes per day, lunch breaks, and multiple dump sites. They develop test instances for this problem based on real life data from North America. Tung and Pinnoi [31] study a case of collecting waste in Hanoi. They study a two layered system, where waste is collected by handcarts and transferred to a vehicle, which is routed between several collection points and finally emptied at a landfill. Teixeira et al. [30] study a problem of collecting three types of recyclable material. The collection of the three types is performed separately, but planned jointly as the algorithm, for each day of the planning period determines which type to collect.

In Ref. [23], McLeod et al. provide a comprehensive study of waste collection in the UK. In the UK, innumerable companies are involved in the highly privatized waste business and as a result, the waste market is very competitive and far less transparent than the Danish market with only a few companies operating in each area.

Several case studies deal with privatization of waste management in developing countries in particular. Two such studies [22,27] discuss the problems related to involvement of the private sector.

Massoud et al. [22] conclude that the quality of waste collection improved as a result of privatization, but the cost did not. They argue that more control is needed regarding the contracts of the public–private relationship.

Few papers consider planning problems in relation to paper recycling. Schweiger and Sahamie [29] study a facility location problem in relation to a paper recycling network. They solve the problem with Tabu Search and apply their algorithm to a real life case in Poland. The paper also presents a very nice classification of the existing literature. Pati et al. [28] also consider facility location in relation to paper recycling and study the impact of several objective functions. Kara and Onut [17] use stochastic programming to analyze a similar problem.

3. Case description

Reno Djurs covers an area with 211 locations with cubes for collection of paper and glass. These are shown in Fig. 1.

The majority of the locations hold at least one cube for each type of material but some locations only have cubes for one type. There are a total of 240 cubes for glass and 198 for paper. Each cube has a capacity of 1.65 m^3. An example of a glass cube can be seen in Fig. 2.

When a location has more than one cube of the same type, we consider the joined capacity of the location. This is due to the fact that citizens always place their material in a cube with vacant capacity if one is available. If all cubes are filled to their capacity limit,

Fig. 1. The 211 cube locations. The depot is indicated by a triangle.