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# Research challenges in municipal solid waste logistics management

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ABSTRACT

During the last two decades, EU legislation has put increasing pressure on member countries to achieve specified recycling targets for municipal household waste. These targets can be obtained in various ways choosing collection methods, separation methods, decentral or central logistic systems, etc. This paper compares municipal solid waste (MSW) management practices in various EU countries to identify the characteristics and key issues from a waste management and reverse logistics point of view. Further, we investigate literature on modelling municipal solid waste logistics in general. Comparing issues addressed in literature with the identified issues in practice result in a research agenda for modelling municipal solid waste logistics in Europe. We conclude that waste recycling is a multi-disciplinary problem that needs to be considered at different decision levels simultaneously. A holistic view and taking into account the characteristics of different waste types are necessary when modelling a reverse supply chain for MSW recycling.



## 1. Introduction

Municipal solid waste (MSW) logistics management is necessary to take care of the growing stream of waste and the need to reuse non-renewable resources. Despite of much legislation and public attention, in 2012 7% of waste in Europe was still landfilled (EUROSTAT, 2015). Recycling is among the most common waste treatment options that has the potential for further improvement in Europe. Increased recycling leads to lower environmental impact, lower consumption of energy sources and lower economic costs (Eriksson et al., 2005). There are large differences between countries in terms of their practice and performance in MSW recycling. The statistics from EUROSTAT (2015) show the highest rates for recycling in Germany (64%), Austria (58%), and Belgium (55%). Conversely, collection and recycling are still in their infancy in the new EU Member States with landfill rates ranging between 82% (Estonia) and 98% (Bulgaria). On EU average, still more than 40% of waste going into landfill indicates a potential and need to improve the recycling of MSW.

Municipal solid waste recycling is part of the field of reverse logistics; the logistics activities all the way from used products no longer required by the user to products again usable in a market (Fleischmann et al., 1997). It includes strategic and tactical decisions such as logistics network design and collection design. Dealing with all of these aspects is an increasingly complex task that can be supported by Operations Research techniques. Ghiani et al. (2014) give a survey on Operations Research models in strategic and tactical solid waste management. Strategic issues have been modelled using location models taking into account single or multiple periods, single or multiple objectives and uncertainty. Tactical issues have been modelled using flow allocation models, collection models and fleet composition models. However, it is unclear if the available models can cope with key issues in practice, such as the impact of taxations and different recycling targets. Therefore, the objective of this paper is to identify research opportunities for modelling MSW recycling in Europe with a focus on Operations Research models.

## 2. Research design

### 2.1. Research methodology

We conduct this research using a three-step approach. In the first step, using literature, we identify a general research framework comprising the drivers, the strategic and tactical/operational

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topics for analysing municipal waste management (Section 2.2). The second step is analysing and identifying issues in real life waste management in Europe that need to be addressed (Section 3). These issues have a major impact on the performance of the recycling system or show large differences in the practice of various countries. These findings are successively brought together in the research framework. The third step, using the framework, is to survey Operations Research literature on municipal waste management to analyse and evaluate issues that have been addressed and the modelling methods used to address them (Section 4). The research framework is used to categorise the literature review findings and identify major research opportunities for modelling MSW recycling.

### 2.2. Research framework

Decisions in MSW management can typically be classified into three levels: strategic, tactical and operational. The combined decisions at inter-related levels are often too complex to be solved at once. A common approach is to cut the total decision making problem into several sub-problems at each level, called decomposition. Ghiani et al. (2014) stated that for planning purpose, a waste management system can be decomposed into two major sub-systems: a regional waste management system, and a collection system. Rubio et al. (2008) suggest examining the design of the reverse logistics network, the analysis of transport routes and internal logistics. Reverse logistics network design belongs to the regional management system which is at the strategic level. Collection planning, transport routes and internal logistics related issues are part of the tactical and operational levels. Accordingly, we partition the decision making into two levels as presented in Fig. 1.

Externally, there are drivers and incentives that can influence decision making on the reverse logistics network and processes. Dekker et al. (2004) identified three main drivers that influence reverse logistics, which are economics, legislation and extended responsibility (public, social and economic). From macro-environmental angle, the well-known PESTEL analysis has also identified Political, Economic, Social, Technological, Ecological and Legal factors as key to guide strategic decision-making (Law, 2009). In Section 3 specific key external factors for municipal waste recycling will be identified.

Despite the obvious environmental gain from waste recycling, collection and transportation of recovered products have an environmental burden due to greenhouse gas emissions. Minimizing this burden is important in order to increase the total environmental gain from recovery (Tsoulfas and Pappis, 2006). The fast evolution of sustainable development changes the goals in almost every supply chain including reverse logistics for waste management. Sustainable development deals with balancing between ecological, economic and social impacts at the level of society in the long term (Seuring and Muller, 2008). This means that it stresses the importance of key issues closely related to human welfare and the natural environment. To meet the future demand of sustainable development, the output of the decision making on municipal solid waste management is a sustainable performance (see Fig. 1).

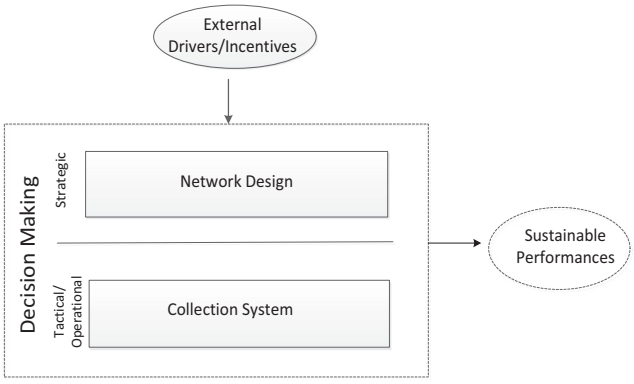


**Fig. 1.** Framework of reverse logistics for household waste recycling.

The complexity of waste recycling decisions is determined by external factors, such as EU regulation, rising oil prices, dynamic costs and varying interests of householders, collection companies and municipalities. In order to improve the sustainability of the complex recycling system of household waste, insights into the system is required. Ghiani et al. (2014) states a waste management system can be decomposed into two major sub-systems, (i) a regional waste management system dealing with strategic decisions in network design (e.g. investments for recovery facilities) and (ii) a municipal collection system dealing with tactical and operational decisions such as transport routes and waste flow allocation. Somplak et al. (2014) mention the impact of landfill and incineration tax on the waste flow in a MSW managing system. In the following section we expand the structure by adding the identified issues derived from the review of recycling practices in various countries. The explicit external factors, the issues to be addressed in the decision process at different levels, as well as the key sustainable performance indicators in the municipal solid waste recycling context will be analysed.

## 3. Waste recycling practices in Europe

Countries have been chosen based on a combination of two criteria: (i) they vary substantially in their recycling practices and (ii) they have recycling as a substantial waste handling strategy, apart from composting and landfilling. Information on recycling strategies, practices and their performances have been obtained using a triangulation of materials, i.e. (i) scientific and industrial publications related to waste collection in the countries of interest; Bing et al. (2014) for the Netherlands; Wong (2010) for the UK; Ramos and Oliveira (2011), Ramos et al. (2014a,b) and EIMPack (2011) for Portugal and Spain, (ii) industrial reports: INE (2010), SPV (2011), REA (2011) and APA (2011) for Portugal DEFRA (2012) for the UK and Nedvang (2012) for the Netherlands, and publications of EU and national organizations (EU, 2012; WRAP, 2012) and (iii) interviews with industry partners and field visits to the waste collection and processing facilities. From these sources the following countries appeared to be interesting according to criterium (i): the Netherlands, Germany, Sweden, UK, Spain and Portugal. Using Eurostat information (2015), these countries also fit criterion (ii): the Netherlands (50%), Germany (65%), Sweden (49%), UK (44%), Spain (30%) and Portugal (26%). Combining the variance in recycling percentages with the variance in recycling practices can explain the differences in waste management in EU countries.

Following the framework we compare the practices in various countries in three parts: (i) the external factors, (ii) strategic and (iii) tactical/operational decision levels. A discussion on what sustainable performance is all about is embedded in each part. For the external factors, an overview of EU regulations is presented, followed by a discussion of incentives as external drivers and actors strategy regarding environmental impact control. At the strategic decision level, the recycling procedures of various waste types and recycling network characteristics are reviewed. At the tactical/operational level an emphasis is given to collection planning. This section ends with a summary of identified issues from practice.

### 3.1. External factors

EU regulation on waste treatment is the main driver that puts increasing pressure on member countries to transfer landfilling into recycling and re-use. The European Union Landfill Directive

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