A Decision Support System for Sustainable Waste Collection

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ABSTRACT

This paper presents a decision support system (DSS) for making the waste collection process more sustainable. Currently, waste collection schedules and routes are created manually in most waste management organizations. This is both very time consuming and likely to result in poor solutions, as the task is extremely difficult due to the large number of bins combined with the many parameters to be considered simultaneously. With a sophisticated DSS, it becomes possible to address the complexities of optimal waste collection and improve sustainability—not least from the environmental perspective. The DSS proposed here is designed to be used on the operational level in the waste management organization and supports daily operations and activities. System evaluation indicates that it can reduce truck operating time by approximately 25%, corresponding to a saving of approximately 21,300 kg of carbon dioxide and 187 kg of nitrogen oxides per year and truck.

KEYWORDS

Decision Support System, Simulation-Based Optimization, Sustainability, Waste Collection

INTRODUCTION

An important part of our welfare concerns ensuring properly functioning and environmentally sound waste management in both cities and rural areas. This is becoming increasingly important with the use of new raw materials and steady yearly increases in the total amount of waste. Over the past decade, the amount of household waste in Sweden has increased by 15 percent and in 2015 more than 4.3 million tonnes of household waste were generated – approximately 460 kilograms per person (Swedish Waste Management Association, 2016). One consequence of the increasing amount of waste is an increased number of waste collection trucks, which release greenhouse gas (GHG) emissions that contribute to climate change and cause health problems for people in urban areas. From the environmental and health perspectives, there is a strong need to optimize the procedures of planning and executing waste collection routes. From the societal and civic perspectives, there are also reasons to consider the economic aspects of household waste collection, as it is financed by taxes and/or fees.

This paper presents a decision support system (DSS) for improving the waste collection process and optimizing it from a sustainability perspective. The main focus is on the environmental aspect, as waste collection is associated with large GHG emissions from garbage trucks, each of which consumes

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an average of approximately 30,000 liters of diesel per year. We propose a DSS that helps the waste management organization optimize its truck operations and increase their efficiency, making them more environmentally sustainable. The DSS is designed to be used on the operational level in the waste management organization and supports the daily operations and activities. Note that, although various waste collection systems have been proposed in the literature (see, e.g., Giribone et al., 2002; Abeliotis et al., 2009; Caballini et al., 2010; Revetria et al., 2011; Chang and Lin, 2013), as far as the authors are aware, none of these focuses on a complete DSS for operational use with an explicit focus on optimization from a sustainability perspective.

Waste collection schedules and routes are currently created manually in most waste management organizations. Manually planning truck operations is very difficult due to the large number of bins combined with the many parameters to be considered simultaneously. Parameters include driver working hours and breaks, truck capacity (in terms of both weight and volume), and time windows at offload facilities. Even greater difficulties are created by the temporal constraints that must be considered, meaning that some bins preferably should, or should not, be emptied at certain times (e.g., bins at daycare centers should be avoided when children are outside playing). Furthermore, the problem of route optimization is a highly complex mathematical problem: finding the shortest route between a number of points (in this case represented by bins) is classified as an “NP-hard” problem in its simplest form. This means that the time it takes to solve the problem grows exponentially with the problem size, i.e., number of nodes. Finding the optimal route is possible, but might take a very long time because all possible routes must be evaluated to find the best one. Even for small-sized problems of this sort, a huge number of possible routes must be considered; for example, in a problem with only 15 nodes to visit, there are 6,227,020,800 possible routes.

The high complexity of efficiently optimizing the waste collection process, in combination with the obvious need to reduce emissions from garbage trucks, has motivated this study and the development of a DSS for sustainable waste collection. The next section describes the research method used in the study. In Section 3, the conceptual modeling of the waste collection problem used as a basis of the DSS is presented. Sections 4 and 5, respectively, present the optimization algorithms and simulation used in obtaining sustainable solutions. The DSS is presented in Section 6, followed by an evaluation of the system in Section 7. Finally, conclusions from the study are presented in Section 8.

**RESEARCH METHOD**

The research method chosen for this work may be characterized as an action case method (Vidgen & Braa, 1997). The action case study can be described as a hybrid between interpretative case studies and interventional action research (Vidgen & Braa, 1997). The action case method aims to balance the potential contradiction for the researcher in being both the observer of a particular case and simultaneously interfering with the process by contributing knowledge and ideas as part of bringing the process forward. This balance can also affect the generality of the results. The action case method has been criticized (Baskerville & Wood-Harper, 1996), and to alleviate some of these criticisms, an iterative approach has been applied. The iterative approach is inspired by Susman’s (1983) generic model, which comprises the following five cyclic activities guiding the process: diagnosing, action planning, action taking, evaluation, and specifying learning. Here, it is also worth mentioning that although the activities are sequentially connected, some parallelism normally occurs, especially in relation to the specifying learning activity.

The action case study, which started in 2010 and is still ongoing, has been conducted at a waste management company. The company is responsible for collecting household waste in nine municipalities in western Sweden from a total of approximately 134,000 bins. Each bin is emptied once or several times during a 14-day period according to a predefined schedule. The company has 50 employees and an annual turnover of EUR 8.5 million. Currently, 25 trucks are needed to collect the waste and most of them are fueled with diesel. During the study, and following Creswell’s (2009)
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