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Computers & Operations Research 33 (2006) 3624–3642
computers & operations research
www.elsevier.com/locate/cor

Waste collection vehicle routing problem with time windows

Byung-In Kim[a,*], Seongbae Kim[b], Surya Sahoo[b]

[a] *Department of Industrial and Management Engineering, POSTECH, Pohang, Kyungbuk, 790-784, Korea*
[b] *Institute of Information Technology, Inc., 2204 Timberloch Place Suite 225, The Woodlands, TX 77380, USA*

Available online 21 November 2005

Abstract

In this paper, we address a real life waste collection vehicle routing problem with time windows (VRPTW) with consideration of multiple disposal trips and drivers' lunch breaks. Solomon's well-known insertion algorithm is extended for the problem. While minimizing the number of vehicles and total traveling time is the major objective of vehicle routing problems in the literature, here we also consider the route compactness and workload balancing of a solution since they are very important aspects in practical applications. In order to improve the route compactness and workload balancing, a capacitated clustering-based waste collection VRPTW algorithm is developed. The proposed algorithms have been successfully implemented and deployed for the real life waste collection problems at Waste Management, Inc. A set of waste collection VRPTW benchmark problems is also presented in this paper.

Waste collection problems are frequently considered as arc routing problems without time windows. However, that point of view can be applied only to residential waste collection problems. In the waste collection industry, there are three major areas: commercial waste collection, residential waste collection and roll-on-roll-off. In this paper, we mainly focus on the commercial waste collection problem. The problem can be characterized as a variant of VRPTW since commercial waste collection stops may have time windows. The major variation from a standard VRPTW is due to disposal operations and driver's lunch break. When a vehicle is full, it needs to go to one of the disposal facilities (landfill or transfer station). Each vehicle can, and typically does, make multiple disposal trips per day. The purpose of this paper is to introduce the waste collection VRPTW, benchmark problem sets, and a solution approach for the problem. The proposed algorithms have been successfully implemented and deployed for the real life waste collection problems of Waste Management, the leading provider of comprehensive waste management services in North America with nearly 26,000 collection and transfer vehicles.

Keywords: Waste collection; Vehicle routing problems with time windows; Capacitated clustering

* Corresponding author. Tel.: +82 54 279 2371; fax: +82 54 279 2870.
E-mail address: bkim@postech.ac.kr (B.-I. Kim).

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doi:10.1016/j.cor.2005.02.045

1. Introduction

We have developed and implemented various vehicle routing algorithms for Waste Management, Inc. (WM), the leading provider of comprehensive waste management services in North America with nearly 26,000 collection and transfer vehicles (see [1]). In this paper, we present the algorithms for waste collection vehicle routing problem with time windows (VRPTW) with consideration of multiple dump site locations and drivers' lunch breaks.

The waste collection business is divided into three major areas: commercial, residential and roll-on-roll-off (see [2]). Each area includes municipal solid waste and recycling material, and each is very different from the others. The commercial waste collection involves servicing customers such as strip malls, restaurants and small office buildings. Each commercial route of WM may service 60–400 customers, with two or three disposal trips to dump sites each day. Depending upon the customer base, the same driver may visit the same customer multiple times in one week. The weekly service schedule is fairly static, as most customers do not change the frequency of service often. The commercial customers may have time windows.

The residential waste collection generally involves servicing private homes. The number of homes a residential route may service varies widely from 150 to 1300 homes every day. The frequency of service per week will vary based on the climate, geography, competition and price of service. In the northern states, it is common to service a residential home once per week. Conversely, in the southern states, it is more typical to service a residential home two times per week. Once the weekly frequency is determined for a set of routes, the schedule repeats itself every week. The service activities for Monday will repeat every non-holiday Monday.

The roll-on-roll-off collection introduces a different routing problem. The differentiator between roll-on-roll-off and commercial is the size of the container. A typical commercial container is eight loose yards, while a roll-on-roll-off container may range from 20 to 40 loose yards and only one container may be serviced at a time. Note that 1 cubic yard is $0.765\,m^3$. While hauling these large containers, it is common for each container to be disposed of and returned to the original customer's location. To complicate the problem, many different approaches are used to make this operation more efficient. One example of servicing the customer would be to first deliver an additional empty container at the customer location, pick up the full container, travel to a disposal facility and then dispose of the contents. At this point, the vehicle may service another customer with the same size container. The difficulty arises when a driver is scheduled to perform different types of services throughout the day to customers with different container sizes and different service requirements. Driver-experience level, vehicle types, container types, material types and security clearance are all contributing factors when creating industrial routes.

In this paper, we mainly focus on the daily commercial waste collection problem. The problem can be characterized as a variation of vehicle routing problems with time windows and intermediate facilities (VRPTW–IF). The weekly service schedule is assumed predetermined. The algorithm for the weekly service schedule will be published in other literature in the near future.

It is hard to find research work that considers multiple disposal trips and drivers' lunch break in the VRPTW literature. In most of the literature, each vehicle is assumed to depart from the depot, serve (pick-up or delivery) only one route consisting of multiple stops, and return to the depot as shown in Fig. 1. Considering disposal trips is not a simple matter. One may attempt to solve the problem by generating initial route without considering disposal trips and then inserting disposal trips to the route. However, that method does not work because the route feasibility is not guaranteed in the disposal trip