Optimization of a routing problem for the collection of refillable glass bottles with integer linear programming

Isidoros Marampoutis[1,2], Marina Vinot[1], Lorraine Trilling[1]

[1] Univ Lyon, INSA Lyon, UCBL, Univ Lumière Lyon 2, DISP, EA4570, 69621 Villeurbanne, France
{marina.vinot,lorraine.trilling}@insa-lyon.fr

[2] University of Bath, Department of Mechanical Engineering, 12462 Bath, United Kingdom
i.maraboutis@gmail.com

Mots-clés : *Vehicle Routing Problem, Reverse Logistics, Reusable Glass Container, Waste Collection, Muli-objective Optimization, Integer Linear Programming*

1 Introduction

Deposit return systems have started to make their re-appearance as environmentally friendlier consumer practices are getting adopted. One such practice is the collection of refillable glass containers. The consumer purchases the product and is incentives to return the glass container which was used for its packaging. When returned, the container is sanitized and returned to the producer where the cycle can begin anew. This method greatly decreases the carbon footprint of the container. Such practices include the management of refillable glass bottles which require a well-organized collection network with inventory management.

The current research work considers the problem of effectively scheduling the collection/delivery of crates, full/empty of empty glass bottles, from stores with flexibility in the schedule. In these systems, the final customer brings the bottles back after use, and all crates are stored in a single depot. The problem can be formulated as a vehicle routing problem (VRP) [2] with time constraints searching to optimize multiple objectives, related to the total collection time, but also the satisfaction of the collection point that must not run out of space to store the crates. The mathematical model presented is solved using a ILP solver. It is based on a real-life application in the city of Lyon, and tested over a large panel of scenarios.

2 Problem Description

The network examined in this research work is focused on the flow between the stores (considered as clients) and the warehouse (named also depot) to ensure the competitiveness of the operation with respect to traditional bottle manufacturing operations.

Each customer has a maximum crate capacity. When a threshold of filling capacity is met, a pickup is requested and the location will be visited in the next time horizon. The filling capacity is assumed to be known upon pickup. However, it is not a typical Inventory Routing Problem (IRP) where the producer/collector decides when the pick-up will take place according to the level of inventory [3]. Several studies on VRP, with time constraints, seem to address similar problems, with flexible home delivery problem [4] or autonomous vehicle fleet sizing problems [1]. Nevertheless, in all these articles, the slots are defined by a start time and an end time or by a subset of time windows. The time constraint proposed in our model differs by allowing some flexibility, without restricting the collection time within a fixed time window. We define a number of time slots available over the time horizon and a duration for each time slot.

The constraints of the ILP model can be split into three categories. The first category deals with classical vehicle routing constraints (only one visit to each client, end and start at the depot,...). The second category deals with additional routing constraints taking into account the vehicle capacity and permitting to avoid partial routes. The third category of constraints models the time slots which are the novelty proposed. Time slots are defined with a maximum time limit and a number of routes. A time slot could be therefore defined as the summation of its routes.

The aim of this model is to minimize Z defined by four components : Z_1 the routing cost equal to the necessary time for the transportation and the collection of the crates, Z_2 the filling priority cost, Z_3 the requesting priority cost and Z_4 the total number of time slots used.

3 Methodology

The model is tested with case study data including 20 instances of crate collections for refillable glass bottles in the city of Lyon, France. These experiments consider several scenarios, using a single vehicle among three vehicle types (cargo-bicycle, car and van) and a network composed of 20 stores/clients to collect bottles from. Three scales of instances are studied, corresponding to the launch of the company, the current scale of the real-life problem and the future evolution of the organisation by incorporating more stores into the network. Each instance has a weekly planning horizon starting on Monday and finishing on Friday. Only part of the time slots will be selected and associated with one or several routes. It is then possible to schedule each time slot selected at anytime within the scheduling horizon, providing flexibility to the solution. Additional economical and environmental indicators are provided to measure the quality of the solutions : the cost linked to the vehicle used, the cost linked to the employee who drives and collect crates at each stop, the income linked to the number of bottles collected, the CO_2 emissions.

4 Conclusions and future work

We propose an integer linear program based on a multi-objective approach to solve the routing problem, including the service order of the store and the time slot assignment. Comprehensive scenarios with various numbers and positions of clients in the network, values of times slots parameters and vehicle types have been solved and the results analysed. Numerical experiments of the optimization model, with several weights associated to each components of the objective function, provide optimal solution for small and medium scale instances (corresponding to the current size of the problem currently encountered). It is now possible for the decision maker to generate the optimal routing for the collection over a time horizon. The analysis of performance indicators provided for these scenarios (transportation cost, environmental impact with CO_2 emission) also helps the decision maker to chose the best time organization and the most adapted vehicle.

Références

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