Multi-period waste collection with preferred pickup days

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Abstract. This paper studies the multi-period vehicle routing problem with preferred pickup days in waste collection scenarios. The planning horizon includes a number of consecutive periods, with customers having preferred pickup days in each period. Deviation from these days is allowed, but comes at a penalty representing customer dissatisfaction. Additionally, a maximum duration between consecutive visits is imposed to manage waste accumulation.

We propose an adaptive large neighborhood search heuristic to solve this problem. The method assigns service days to customers and optimizes vehicle routes for each day of the planning horizon. The heuristic is validated on a real-world dataset, and different penalty scenarios are compared for the deviations from preferred days.

Keywords: Multi-period vehicle routing, Waste collection, Preferred days, Large neighborhood search .

1 Introduction

Regular periodical visits to customers are important in the case of many problems arising in real life, and waste collection is no exception. Accumulated waste has to be collected from customers and transported to drop-off points in given periods, preferably on days when it is the most suitable for the customers. However, deviating from these preferences can come with cost benefits in exchange for customer dissatisfaction. While constructing optimal routes for vehicles servicing customers belongs to the class of vehicle routing problems (VRP), the introduction of periodic decisions leads to a more general version of this problem.

Periodic variations of the VRP exist in the literature, most of which fall into the periodic vehicle routing (PVRP) problem class. PVRP is the generalization of the classical VRP, where routes are constructed over a time horizon T, and customers have a service frequency, pre-defining their possible visit patterns over the days of this period [3]. The goal of the PVRP is to assign customers to a visit pattern and prepare optimal vehicle routes for the days of the period based on these patterns. The PVRP with service choice [7] introduces extra complexity to this decision by making determination of the visit frequency part of the optimization as well. Multi-periodicity in vehicle routing is introduced usually combined with inventory routing decisions, where customers have to be visited in multiple periods (which are the individual days) [2,8]. Dynamic variations of the PVRP also exist, focusing on due dates of the deliveries and introducing penalties for lateness or cancelled visits [1,10].

This paper deals with the problem of multi-period vehicle routing with preferred pickup days that can arise in various real-world waste collection scenarios. The planning horizon of the problem contains P consecutive periods, each period consisting of D days. For every customer, a period pickup frequency is given to denote the periods in which they have to be visited, as well as a preferred day on which they are expecting the visit in a period. Visits to a customer are also allowed outside of their preferred days, however, these come with a penalty of deviating from the original schedule. Moreover, as the customers are accumulating waste over time, a maximum duration between two consecutive visits to the same customer also has to be introduced. The optimization questions in this case are twofold: first, a decision has to be made on choosing the visit days for each customer, then optimal vehicle routes have to be constructed for each day of the planning horizon. While the concept of preferred visiting days have been examined in the past [6], the deciding on the visiting days of each customer in each period over a longer time horizon with limits between two visits has not been studied to our knowledge. This paper will present our progress in an adaptive large neighborhood heuristic for the solution of the above problem. This method will consider both assigning the days of visit for customers in each period, as well as optimizing vehicle routes on each day based on the customers to be visited. The heuristic will be validated on inputs based on both real-world data and adapted benchmark datasets from the literature, and compared to the scenarios where no deviation is allowed from the preferred days of customers.

2 Problem definition

The problem introduced in Section 1 can be formalized as follows. Let us consider a planning horizon T, with length (in days) $|T|$, and period P with length $|P|$. T can be divided into $|T|/|P|$ periods. A specific i-th period of T is denoted by P_i, with starting day $1 + (i-1)|P|$ and ending day $i|P|$. The customers of the problem are given by set C. Each customer has to be serviced exactly once in each period. Every customer $c_i \in C$ has a preferred collection day p_i, where $1 \leq p_i \leq |P|$. Servicing a customer is allowed outside of their preferred day: the maximum allowed deviation (in days) is defined by Δ. Moreover, two consecutive visits to the same customer have to happen in at most M days. While the set of visit patterns could be defined for each customers over the entire planning horizon with the help of δ and M, this would yield a large amount of possibilities even for horizons with 3 or 4 periods.

If the service days are known for the customers, the route planning for each day can be defined as a capacitated vehicle routing problem with deliveries (to waste disposal sites) and route length constraints.

3 Solution method

An adaptive large neighborhood search algorithm (ALNS) was developed for the solution of the above problem. This algorithm closely follows the outline given by Ropke and Pisinger in [9].

In order to create an initial solution, we considered every customer to be serviced on their preferred day in each period. We solved the arising daily vehicle routing problems with two different methods.

The MILP model of Buhrkal et al. [4] was modified to accommodate all constraints of our problem. While this provides optimal vehicle routes with regards to the preferred days of the customers, the occasionally long running times for larger days made it an inefficient method to use in the ALNS. However, the results provided by this model were utilized for the evaluation of the heuristic.

A greedy heuristic was also developed for quick initial solution construction. The heuristic utilizes a 'best-fit' approach. Customers are ordered in ascending distance form the depot, and the current customer is scheduled to the vehicle with the least cost. Vehicle capacities and route lengths are managed by sending the vehicles to a disposal site if they reach a certain threshold of capacity/route length.

This initial solution was modified in each iteration using randomly selected destroy and repair methods.

The objective of the algorithm is to minimize the combined travel duration of vehicles and the deviation penalty from the preferred days. Each day of deviation by a customer service from its preferred day uniformly contributes a δ penalty to the costs.

4 Results

Input instances were generated based on real-world data from a waste collection company. Several instance sets of varying sizes were generated based on this data by randomly selecting a given number of customers. Each input instance considered a 28-day planning horizon, with four 7-day periods in the horizon. Datasets with 50, 100, and 150 customers per period have been created, resulting in 200, 400, and 600 customer visits over the horizon respectively. Ten different inputs were created in each instance set,

The original preferred days were used for each customer, and M (the maximum number of days between two consecutive visits) was set to 8. No parameter tuning has been performed yet on the ALNS: the original parameters from [9] have been used instead. The number of iterations was set to 25 000, which was the only terminating condition for the algorithm. Three scenarios were considered for the δ penalties for deviation: 0%, 5%, 10% or 15% of the average daily costs given by the optimal solution of the MILP model when servicing every customer on their preferred days.

A summary on our preliminary results can be seen in Table 1.

The three rows of the table give the average results of the 10 inputs for each instance set. The columns show the scenarios with different values of deviation penalty. The results in the table give the ratio of the ALNS solution costs compared to the optimal solution with preferred days. The expectation for the algorithm would be that if it can't find a better solution then the preferred day one, then it should find the optimum with

Table 1: Aggregated test results for all instance sets.

Instance set	δ =0%	δ =5%	δ =10%	δ =15%
200 visits	0.72	0.86	0.97	1.03
400 visits	0.76	1.03	1.12	1.09
600 visits	0.74	1.13	1.23	1.14

preferred days (which would provide the 1.0 ratio). The starting costs of the greedy initial solution were more than double that of the preferred day optimum.

It can be seen from the results that without any additional penalty for deviation, the solutions found by the ALNS were about 75% of the costs of the preferred day optimum for every instance set. The 200 visit instances also met the original expectation of finding a solution close to the 1.0 ratio if the penalties turn out to be too high. However, with an increase in the number of visits, this ratio became harder to reach for the ALNS. Our preliminary tests showed that the number of iterations is too low for these instances sizes, as the algorithm still found better results if left running. Moreover, we have not experimented with setting the parameters of the ALNS, which might also improve the quality of the results.

5 Conclusions and future work

This paper presented our preliminary results for solving a multi-period vehicle routing with preferred days for waste collection. An ALNS algorithm was developed for the problem, and initial test results were shown on real-world data. While the results are promising, there is still room for improvement. The ALNS itself can be improved both by finding the appropriate parameters for this problem class, and also by implementing additional destroy and repair algorithms. The scope of testing will also be increased by using benchmark datasets from the literature [5], but a method should be developed for transforming the visit patterns of these input to preferred days.

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