Transportation Research Part E 96 (2016) 135–157

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

The multi-period service territory design problem – An introduction, a model and a heuristic approach

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A R T I C L E I N F O

Article history:
Received 22 April 2016
Received in revised form 16 September 2016
Accepted 18 September 2016
Available online 11 November 2016

Keywords:
Territory design
Multi-period planning horizon
Mixed integer linear programming
Location-allocation heuristic

MSC:
90B06
90B80
90C59

A B S T R A C T

In service territory design applications, a field service workforce is responsible for providing recurring services at their customers' sites. We introduce the associated planning problem, which consists of two subproblems: In the partitioning subproblem, customers must be grouped into service territories. In the scheduling subproblem, customer visits must be scheduled throughout the multi-period planning horizon. The emphasis of this paper is put on the scheduling subproblem. We propose a mixed integer programming model for this subproblem and present a location-allocation heuristic. The results of extensive experiments on real-world instances show that the proposed heuristic produces high-quality solutions.

1. Introduction

Many companies employ a field service workforce for providing recurring services at their customers' sites. For example, manufacturers and wholesalers of consumer goods typically operate a sales force that regularly visits their customers to promote sales or to supply product range information (see, e.g., Fleischmann and Paraschis, 1988; Polacek et al., 2007). Also, some engineering companies employ field service technicians to carry out regular technical maintenance at their customers' sites (see, e.g., Blakeley et al., 2003). The frequency and duration of the visits depend on customer-specific factors, e.g., the customer's sales volume or the tasks to be performed at the customer. To increase customer satisfaction, two aspects of service consistency play an important role in these applications: personal and temporal consistency. The former means that always the same field worker is responsible for a particular customer, which is desirable as it helps establish and foster long-term personal relationships with customers (see, e.g., Kalcsics et al., 2005; López-Pérez and Ríos-Mercado, 2013; Zoltners and Sinha, 2005). The latter expresses the expectation of customers to be visited on a regular basis (see, e.g., Groër et al. (2009) for a similar consistency requirement arising in the small package shipping industry). Regularity means, on the one hand, that the visits should be equally distributed over the weeks of the planning horizon according to

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http://dx.doi.org/10.1016/j.tre.2016.09.007
1366-5545/

customer-specific visiting rhythms. On the other hand, regularity refers to the weekdays on which visits take place as customers might prefer to be served always on the same weekdays.

Typically, the following three planning tasks arise in these applications. (1) The customer base must be partitioned into service territories with one field worker being responsible for each territory. This partition is usually maintained over a long period of time to promote the development of personal relationships between field workers and customers. (2) On a tactical level, the visit schedules have to be created, which means that the visiting days for each customer must be determined. The planning horizon for this task is typically between 3 and 12 months. (3) On an operational level, the detailed planning must be performed, which includes the planning of the daily routes and, when necessary, the rescheduling of visits. It is important to note that short-term customer requests and unexpected events must be taken into account in this step. According to estimates of our project partner, about 20% of the customer visits need to be rescheduled to another day in the short term. Therefore, both the route planning and the rescheduling are done by the field worker in the daily business. Ideally, planning tasks (1)–(3) would be tackled by a single, integrated approach, but the size of realistic problem instances (sometimes with ten thousand or more customers) prohibits an integrated approach. Moreover, integrating the calculation of the daily routes and the visit schedules is only of little use due to the potential necessity to reschedule customer visits in the daily business.

The above problem was brought to our attention by our project partner PTV Group, a commercial provider of districting and clustering software headquartered in Karlsruhe, Germany. In our joint project, we tackled the partitioning task (1) and the scheduling task (2); we omitted the routing and rescheduling task (3) as this task can only be solved reasonably in the short term when all operational details are known.

One of PTV's products is the xCluster Server (PTV, 2014), which solves the optimization problem resulting from the scheduling task (2). When the planning algorithm for the xCluster Server was initially designed several years ago, the technological possibilities were limited, in particular with regard to the availability of high-performance mixed integer programming (MIP) solvers and computational power in general, which lead PTV to develop a simple local search procedure. The goal of the cooperation with PTV is the development of a new solution approach that takes advantage of recently available technologies. Since PTV has many different customers, it is important that the new solution approach covers a wide range of real-world requirements. Additionally, it must be easily adaptable to further planning requirements. The new approach is intended to replace the existing planning algorithm in the xCluster Server.

The main contributions of this paper are the following:

- We introduce a new problem, which we call the Multi-Period Service Territory Design Problem (MPSTDP). Despite its high practical relevance, it has not been studied in the literature before. This is, to the best of our knowledge, the first paper to elaborate the problem from a scientific point of view.
- We formally define the scheduling subproblem, i.e., the subproblem corresponding to planning task (2), as a mixed integer linear programming model.
- We propose a heuristic solution approach for the scheduling subproblem. The approach is capable of considering the relevant planning requirements of PTV's customers. It involves the repeated solution of an integer programming model, which can easily be extended by additional planning requirements.
- We perform extensive computational experiments on real-world instances and on instances that were derived from real-world data by varying the values of some parameters. The results show that the new approach produces high-quality solutions and outperforms the existing solution method of PTV.

The remainder of this paper is organized as follows. In Section 2 we give a detailed description of the problem under study. In Section 3 we review related problems and point out the differences to our problem. In the subsequent section, we introduce a mathematical model for the subproblem that corresponds to the scheduling task (2). In Section 5 we propose a heuristic approach based on a location-allocation scheme. To evaluate our approach, we introduce appropriate evaluation measures in Section 6. In Section 7 we report the results of extensive computational experiments on real-world data and benchmark our approach against PTV's xCluster Server (PTV, 2014). Finally, we provide some concluding remarks in Section 8.

2. Problem description

In this section, we describe the MPSTDP and introduce the notation for the scheduling subproblem, which is the major focus of this paper.

There is a given set of *customers* (e.g., supermarkets), represented by index set $B = \{1, \ldots, |B|\}$, which demand recurring on-site services. The services must be carried out by a given set of field workers, which we call *service providers*. Corresponding to planning tasks (1) and (2), the MPSTDP consists of the following two subproblems.

Partitioning subproblem (MPSTDP-P): This subproblem corresponds to the well-known territory design or districting problem (see Kalcsics (2015) for an overview of typical planning criteria). The set of customers must be partitioned into service territories with exactly one service provider being responsible for each service territory. As the service providers have to travel within their territories, geographically compact and connected territories are desired because they lead to short travel