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The Stochastic Capacitated Traveling Salesmen Location Problem: a computational comparison for a United States instance

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Abstract

We study a problem in which a facility has to be located in a given area to serve a given number of customers. The position of the customers is not known. The service to the customers is carried out by several traveling salesmen. Each of them has a capacity in terms of the maximum number of customers that can be served in any tour. The aim is to determine the *service zone* (in a shape of a circle) that minimizes the expected cost of the traveled routes. The center of the circle is the location of the facility. Once the position of the customers is revealed, the customers located outside the service zone are served with a recourse action at a greater unit cost. For this problem, we compare the performance of two different approaches. The first is a solution based on a heuristic proposed for a similar well known problem and the second is a solution based on a stochastic second–order cone model. An illustrative example on a United States instance with 13509 nodes shows the different solutions and expected costs obtained by the two approaches.

Keywords: Facility Location, Traveling Salesmen Location Problem, Stochastic Second–Order Cone, Computational Results.

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1. Introduction

One of the most important classes of problems in the strategic design of logistic networks is given by the *Facility location problems*. We refer to Klose and Drexl (2005), ReVelle and Eiselt (2005) and Melo et al (2009) for recent surveys on facility location problems and to Snyder (2006) and Nagy and Salhi (2007) for surveys on facility location problems under uncertainty.

Location-Routing Problems (LRP) is a relatively new class of problems, in which the classical facility location and the vehicle routing problems are integrated. We refer to Laporte (2009) for a recent survey on vehicle routing problems. Although it is well known that facility location and routing are often interrelated, LRP received little attention in the past. However, in the last years, several papers about deterministic location–routing problems have been published. Instead, a few papers have been devoted to location–routing problems with stochastic demand.

The *Traveling Salesman Location Problem* (TSLP) is the simplest location–routing problem with stochastic demand. A set of customers is served by a single facility. At each time, only a subset of customers has to be served. A TSP is built to serve this subset of customers. The aim is to determine where to locate the facility in order to minimize the expected cost of the TSP. This problem has several applications in many service systems, such as delivery services, customer pickup services, repair vehicles. It has been introduced by Burness and White (1976) and studied by Berman and Simchi-Levi (1986), Simchi-Levi and Berman (1987, 1988) and McDiarmid (1992). It has been extended to the case, referred to as the *Capacitated Traveling Salesmen Location Problem*, with several capacitated salesmen, by Simchi-Levi (1991). The main difficulty of these problems is that there exist $2^n - 1$ different subsets of n customers that can require to be served and therefore an exponential number of TSP has to be solved. A polynomial time heuristic algorithm, with known relative worst-case error, has been proposed in Simchi-Levi (1991). A different case is given by the *Probabilistic Traveling Salesman Location Problem* (PTSLP). In this case, first an a priori TSP visiting all customers is computed. Then, for each time, the TSP to serve the subset of customers that have to be visited is obtained by just skipping in the a priori tour the customers that have not to be served at that time. The aim is to simultaneously determine where to locate the facility and the a priori TSP that minimize the expected cost. This problem has been introduced by Berman and Simchi-Levi (1986) and has been studied by Bertsimas (1989). Recent papers are Klibi et al. (2010), Santoso et al (2005) (see also Beraldi & Bruni, 2009 for an emergency service vehicle location).

We study a problem in which a single facility (typically a service station) has to be located in a given area. This facility is used to serve a given number of customers. The position of the customers is not known. The service to the customers is carried out by several traveling salesmen. Each of them has a capacity in terms of the maximum number of customers that can be served in any tour. The aim is to determine the *service zone* (in a shape of a circle) that minimizes the expected cost of the traveled routes. The center of the circle is the location of the facility. Once the position of the customers is revealed, the customers located outside the service zone are served with a recourse action at a greater unit cost. This problem is referred to as the *Stochastic Capacitated Traveling Salesmen Location Problem with Recourse* (SCTSLP–R).

Our aim is to propose stochastic optimization models (see Birge & Louveaux, 1997; Kall & Wallace, 1994; Shapiro, 2008; Maggioni et al 2009; Maggioni et al. 2013 for two logistic applications) and solution methodologies to solve the SCTSLP–R. We first consider a solution of the problem based on the heuristic proposed by Simchi–Levi (1991) for the *Capacitated Traveling Salesmen Problem*. Bertazzi and Maggioni (2012) proved that in the worst–case, this algorithm can give a solution infinitely worse with respect to the optimal one. Then, the problem was first modeled as a two-stage stochastic semidefinite programming problem (see Ariyawansa & Zhu, 2006; Pataki, 2003; Vandenberghe & Boyd, 1996; Ko & Vaidya 2000) and then as a two-stage stochastic second-order cone programming problem (see Alizadeh & Goldfarb, 2003; Maggioni et al. 2009; Maggioni et al. 2010; Maggioni & Wallace 2012), in which the first stage decisions are the facility location and the radius of the service zone. Each scenario is represented by a set of ellipses. Each ellipse represents the area covered by a traveling salesman to supply its customers, randomly generated by uniform distribution inside