

The Probabilistic Profitable Tour Problem

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ABSTRACT

A new routing problem is introduced and named as the probabilistic profitable tour problem in this paper. The problem is defined on a complete graph where profits are associated with the vertices and travel costs are associated with the edges. Each vertex (customer) has a probability of requiring a visit on a given day. The tour starts and ends at a fixed vertex, and each vertex can never be visited more than one time. Once a vertex is visited, an associated profit is collected and the corresponding travel cost occurs. The objective is to find a subset of vertices and an a priori tour through those vertices that maximizes the difference between the expected profits and the expected travel costs. The problem is confronted by some big e-tailing companies who need to determine, among the set of all potential customers, the customers to be served by themselves and outsource the unselected customers. The problem under study is shown to be NP-hard in this paper. The authors provide a non-linear mathematical formulation for it. Consequently, a genetic algorithm is developed to solve this problem. The computational experiments carried out on small- and moderate-size instances show a good performance of the proposed algorithm.

KEYWORDS

Customer, Genetic Algorithm, Profitable Tour Problem, Stochastic Routing

1. INTRODUCTION

The probabilistic profitable tour problem (PPTP) is defined on a fully connected graph $G = (V, E)$, where V denotes the set of vertices with associated profits and E denotes the set of edges with associated travel costs. Each vertex has a probability of requiring a visit. The tour starts and ends at a fixed vertex, and each vertex can never be visited more than one time. Once a vertex is visited, an associated profit is collected and the corresponding travel cost occurs. The objective of this problem is to find a subset of vertices (customers) and an a priori tour through those vertices that maximizes the difference between the expected profits and the expected travel costs.

The study of this problem is motivated by the situation where a set of customers is given with a probability of requiring service every day and only a subset of them has to be selected and served. Nowadays customers are increasingly interested in purchasing products online instead of through traditional retail outlets, and each customer has a probability of purchasing products online every day. Once a carrier provides transportation service for a customer who shops online, he will receive a value of profit. At the meantime, he should pay for the corresponding travel cost. Some e-commerce platforms, such as JINGDONG in China, provide transportation services partially by themselves and outsource some of them. In this case, the e-commerce companies need to determine, among the set

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of potential customers, the customers to be served by themselves and the delivery routes, and then outsource the service of the rest customers to third party logistics companies.

Since each customer arises on a stochastic basis, it is desirable to design the tour through an *a priori* optimization (Bertsimas et al., 1990). In the *a priori* optimization, an ordering of all possible customers that a particular driver may need to visit is constructed first, once the information of customer presence is revealed, the driver then skips those customers on the tour who do not require a service. *A priori* tours can be easily implementable and are an alternative to the high cost of re-optimization. In addition, *a priori* tours offer both drivers and customers consistency and help to improve driver efficiency as the driver becomes familiar with the tour (Campbell and Thomas, 2008; Muscatello et al., 2016; Wang and Wu, 2014).

If there is only one vehicle involved, the problem can be viewed as an instance of the PPTP. To the best of our knowledge, the two most common features of numerous variants of TSP are that the presence of the customer is deterministic and that no profit is associated with each customer (Bellmore and Nemhauser, 1968; Gutin and Punnen, 2002). Previous studies have not addressed how to deal with stochastic customer presence under the environment in which an associated profit is obtained once a customer is visited. Thus, our research focuses on the probabilistic profitable tour problem in which the customer presence is stochastic. The PPTP can be considered an extension of the profitable tour problem (PTP) (Dell'Amico et al., 1995). In the PTP, it is assumed that each customer has a deterministic service request and the objective is to maximize the difference between the total profits and the total costs. In the PPTP, the PTP is extended to the case where each customer has a probability to request a delivery.

In this paper, we restrict our attention to the homogeneous PPTP, a problem where each vertex has the same visiting probability. We present an integer non-linear formulation for this problem and develop a genetic algorithm to solve it. Experiments were conducted on several sets of instances to assess the efficiency of the proposed approach in this paper. The computational results indicate that the proposed genetic algorithm is a promising tool to handle the PPTP.

The paper is structured as follows. In the following section, we provide an overview of the related literature. In section 3, the problem formulation is presented. Section 4 provides a genetic algorithm to solve the PPTP. Computational results are presented in section 5. The final section contains conclusions and directions for future research.

2. LITERATURE REVIEW

The PPTP has its roots in both the travelling salesman problems with profits (TSPs with profits) (Feillet et al., 2005) and stochastic routing problems literature. TSPs with profits seek for an elementary tour (i.e., a tour in which each vertex can never be visited more than once) that includes the depot, with a concern in both the profits and costs. In the TSPs with profits the customer presence is deterministic whereas in the PPTP, the customer presence is stochastic. Since the PPTP has some features of the stochastic routing problems, it is much harder than the TSPs with profits.

According to the way the two objectives (profits and costs) are addressed, the TSPs with profits could be categorized into three types of problems: the orienteering problem (Golden et al., 1987), the prize-collecting travelling salesman problem (Balas, 1989) and the profitable tour problem (Dell'Amico et al., 1995). Among these problems, only the profitable tour problem considers both the profits and the travel costs in the objective function. Literature is rare in the optimization of a combination of both profits and costs in the objective function. Archetti et al. (2009) introduce the capacitated profitable tour problem and propose exact and heuristic procedures to solve it. Chow and Liu (2012) explore the profitable tour problem in generalized cases by extending single nodes to clusters and present heuristics to solve it.

In contrast with these deterministic problems, some researchers studied stochastic variants of the TSPs with profits. Tang and Miller-Hooks (2005) propose the selective travelling salesperson problem

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