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Multi-depot vehicle routing problem with time windows considering delivery and installation vehicles

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ABSTRACT

We extend the multi-depot vehicle routing problem with time windows (MDVRPTW), a practical and challenging problem in logistics and supply chain management, to a study of service vehicles used for delivery and installation of electronics. This study shows that MDVRPTW results can be used to minimize fixed costs of the depots and the delivery and installation vehicles as well as expenses related to travel distances and labor. Along with a mixed integer programming model, we develop a heuristic and a genetic algorithm to identify a near-optimal solution. Computational results demonstrate that the proposed algorithms can efficiently be used to solve relatively large problems.

1. Introduction

The multi-depot vehicle routing problem with time windows (MDVRPTW) is used to determine the optimal set of fleet routes for satisfying the delivery demands of a customer set under time window constraints in several depots at different locations. It is considered a practical problem in the fields of transportation, distribution, and logistics. We consider the MDVRPTW under heterogeneous service vehicles and an additional service level constraint. In the MDVRPTW applied to delivery and installation vehicles, one vehicle is assumed to be dedicated solely to the delivery of products, while another is dedicated to transporting people and equipment needed for professional installation of the products. Each customer is associated with a specific delivery demand and choice of installation options. In this case, some customers require only delivery while others also need installation services. Generally, customers want their product installed as soon as possible after they receive the delivery. In addition to time window requirements of the basic VRP, another time constraint is imposed such that the installation service is provided within a certain time interval after product delivery. The delivery and/or the installation service can be outsourced to achieve service specialization in some industries. In such a case, to achieve the synchronization of the delivery and installation vehicle for each customer, different types of service vehicles and several scattered depots should be considered simultaneously. The coordination of delivery and installation is the main focus of this paper. Firms simultaneously attempt to meet customer demand and try to secure minimum transportation and labor costs. The problem arises in various supply chain management systems, including those associated with the electronics industry.

In the literature, several variants of the VRP exist. The multi-depot vehicle routing problem (MDVRP) is the problem of allocating customers to several depots, so that the optimal set of routes is determined simultaneously to serve the delivery demands of customers within scattered depots. The MDVRP was recently studied by Cordeau and Maischberger [1],

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Escobar et al. [2], Shimizu and Sakaguchi [3], Subramanian et al. [4], and Vidal et al. [5]. Many heuristic methods have been developed in the context of the MDVRP, including the local search method (Subramanian et al. [4]), the tabu search algorithm (Cordeau and Maischberger [1]; Escobar et al. [2]), the genetic algorithm (Vidal et al. [5]), and the hierarchical hybrid meta-heuristic (Shimizu and Sakaguchi [3]).

The location routing problem (LRP) is a generalized problem of the MDVRP because it includes decisions of the number of depots and their locations. It calls for the determination of opening and operation of depots based on routes of vehicles. For a most recent survey on the LRP, the reader is referred to Drexl and Schneider [6], Drexl and Schneider [7], and Prodhon and Prins [8]. Recently, many heuristic methods have also been developed in the context of the LRP, including the local search method (Contardo et al. [9]; Hemmelmayr et al. [10]), the Lagrangian relaxation-based search method (Özyurt and Aksen [11]), the tabu search algorithm (Escobar et al. [12]; Escobar et al. [13]), the particle swarm algorithm (Liu and Kachitvichyanukul [14]), and the ant colony algorithm (Ting and Chen [15]). Sariçiçek and Akkuş [16] recently considered models in which the locations of the hubs were decided prior to the routing of unmanned aerial vehicles which were used for monitoring border security. Mousavi et al. [17] formulated the location routing problem under uncertainty as two mixed-integer linear programming problems and solved them via fuzzy possibilistic-stochastic programming. The MDVRPTW is not a special case of the LRP because heterogeneous service vehicles are considered under time windows and additional service level constraints are imposed.

Among problems involving several variations of vehicles, the VRP as applied to a heterogeneous fleet has been studied extensively (Golden et al. [18]; Liu [19]; Naji-Azimi and Salari [20]; Salhi et al. [21]). One related variant of the heterogeneous fleet problem is the fleet size and mix vehicle routing problem (FSMVRP), which simultaneously considers vehicles with different fixed costs within a fleet. In the FSMVRP, the number of available vehicles for each type is not given or limited. This variant was first studied by Golden et al. [18], and later by Liu [19]. Recently, the FSMVRP with backhauls was proposed by Salhi et al. [21]. In the VRPB, delivery and pickup service for customers can be considered simultaneously. A combined problem with the FSMVRP and VRPB is considered representative of a realistic routing and logistics distribution problem (Salhi et al. [21]). Recently, research on the VRP has also focused on more realistic situations such as overtime and capacity overloads. Moon et al. [22] presented a mixed integer programming model and a genetic algorithm for the VRPTWOV that included driver overtime and vehicle outsourcing. Lee and Kim [23] proposed a distributed dispatching method for large-scale pickup and delivery systems. Kim and Lee [24] developed an ant colony algorithm for a delivery schedule and proposed an expert system based on the developed algorithm to improve service quality for customers.

Interest in the VRP stems from its practical importance as well as considerable difficulty in finding optimal solutions for it. The VRP is regarded as one of the most challenging integer programming problems. Lenstra and Rinnooy Kan [28] showed that the VRP is NP-hard. The MDVRPTW is NP-hard in the strong sense, because it generalizes the VRP as further complexity is added through time windows and multiple depots. Due to the NP-hard nature of the problem, many good heuristic approaches have been developed for it. Here, we propose a heuristic method and a genetic algorithm for the MDVRPTW under installation vehicles and dual time constraints for customers. The concept of the service level for installation vehicles was first presented by Sun [25], who set it as the duration between delivery and installation services and also determined the delivery and installation vehicle routes and schedules for a fixed depot. Sun [25] synchronized the delivery and installation vehicles by using an endosymbiotic evolutionary algorithm based on a stochastic search mechanism. More recently, a vehicle scheduling problem for simultaneous delivery and installation was studied by Sim et al. [27] and Kim et al. [26]. Sim et al. [27] developed an ant colony algorithm for creating a vehicle schedule for simultaneous delivery and installation. The developed algorithm was applied to and tested in the context of a logistics company. Kim et al. [26] developed a genetic algorithm for creating a vehicle schedule.

The differences among the vehicle routing studies that include a service level and an investigation described in this paper are summarized in Table 1. We minimize transportation distances and labor time while satisfying dual time constraints of

Table 1
Characteristics of literature review.

Authors	This paper	Sun [25] and Kim et al. [26]	Sim et al. [27]
Number of depots	Multi-depot	Single-depot	Single-depot
Delivery time windows	Time windows	None	Time windows
Installation time constraint	Service level constraint	Service level constraint	Synchronization constraint
Total cost (Objective function)	Depot cost, Vehicle cost, Transportation cost, Labor cost	Transportation cost	Vehicle cost, Transportation cost
Decision	Number of depots, Number of vehicles, Routing	Routing	Number of vehicles, Routing
Methodology	MILP, Genetic algorithm	MINP[a], Endosymbiotic evolutionary algorithm, Genetic algorithm	MILP, Ant colony algorithm

[a] MINP(Mixed integer nonlinear programming).