

A hybrid simulated annealing for capacitated vehicle routing problems with the independent route length

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Abstract

This paper presents a linear integer model of capacitated vehicle routing problems (VRP) with the independent route length to minimize the heterogeneous fleet cost and maximize the capacity utilization. In the proposed model, the fleet cost is independent on the route length and there is a hard time window over depot. In some real-world situations, the cost of routes is independent on their length, but it is dependent to type and capacity of vehicles allocated to routes where the fleet is mainly heterogeneous. In this case, the route length or travel time is expressed as restriction, that is implicated a hard time window in depot. The proposed model is solved by a hybrid simulated annealing (SA) based on the nearest neighborhood. It is shown that the proposed model enables to establish routes to serve all given customers by the minimum number of vehicles and the maximum capacity used. Also, the proposed heuristic can find good solutions in reasonable time. A number of small and large-scale problems in little and large scale are solved and the associated results are reported.

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1. Introduction

A classical vehicle routing problem (VRP) consists of finding the least routes for a set of homogeneous vehicles located at a depot to geographically scattered customers. The service may be involved delivery of goods, pick-up and delivery of students or pick-up of the packages for express mail delivery, just to name a few of the possible applications.

In this paper, we present an extended type of the capacitated vehicle routing problem (CVRP) in which unlike the classical type [1], we assume that the service is pick-up of the customers in which the cost of the routes is independent of their lengths, but it is only dependent on the type and capacity of available vehicles. As a result, the VRP can be divided into two main categories: the VRP with the independent route

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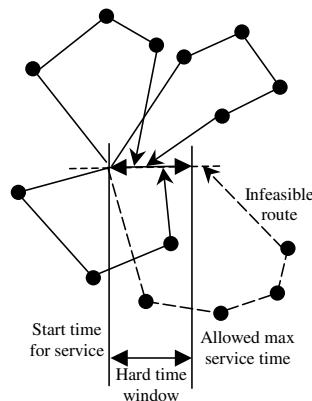


Fig. 1. Example solution-VRPIRL schema.

length (VRPIRL) and the VRP with the dependent route length (VRPDRL). In previous researches, the VRPDRL has been only considered. The VRPIRL often occurs when the fleet is rental and the route length is not important, instead, the travel time is limited. Thus, the objective is to minimize the fleet cost and maximize the fleet capacity utilization. Also we assume that the service time for fleet is limited and fleet is heterogeneous (HVRP). Actually, the limitation of service time is implicated a hard time window in depot. The hard time window forces the fleet to be into depot in specific time. A typical VRPIRL is shown in Fig. 1. The route marking by dash is infeasible, because its service time is violated the allowed bound.

The CVRP and HVRP have been the subject of many researches. VRP belongs to the category of NP-hard problems [2], thus it is faced with the use of heuristic algorithms such as backtracking adaptive threshold accepting (BATA) meta-heuristic methods [3–5], Minimum K-trees [6], Local search algorithms [7], adaptive memory (AM) heuristic [8], column generation methods [9], constraint programming [10] and location based heuristics [11]. Also meta-heuristic algorithms such as simulated annealing (SA) [12–14], genetic algorithms (GAs) [15,16], tabu search (TS) [17–19] and ant system [20,21] are widely used for solving the VRP. To date the best approaches for the VRPDRL are based on TS. This paper shows that a hybrid simulated annealing based on the nearest neighborhood algorithm is very efficient for the VRPIRL.

This paper is organized as follows. The problem formulation is described in Section 2. The proposed heuristic algorithm for solving the developed model is presented in Section 3. The instruction of simulated annealing algorithm for improving the initial solutions from the proposed heuristic algorithm is described in Section 4 followed by computational results in Section 5 and by the conclusion in Section 6.

2. Problem formulation

The proposed model is a three-index vehicle flow formulation using $O(VN^2 + V^2)$ binary variables where N is equal to the number of nodes and V is equal to the number of available vehicles. The problem is defined as follows: Let $G(D, A)$ be a complete graph, where $D = \{1, 2, \dots, i, \dots, N\}$ is the node set and $A = \{(i, j) : i, j \in D, i \neq j\}$ is the arc set. Node $i = 1$ represents a depot while the remaining nodes correspond to the demand points. The problem is solved under the following constraints:

1. Each node is visited only once by a single vehicle.
2. Each vehicle must start and end its route at the depot.
3. Total demand serviced by each vehicle can not exceed its capacity.
4. The travel time for each vehicle cannot exceed an allowable value.
5. The mean velocity of travel for all vehicles is constant.
6. The fleet is heterogeneous and there are three types of capacity as follows: small, medium, and large for vehicles. Also, the cost of each type of vehicle is fixed.

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