Journal of Computational and Applied Mathematics 291 (2016) 468–477

Contents lists available at ScienceDirect

Journal of Computational and Applied Mathematics

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

An optimization algorithm for solving the rich vehicle routing problem based on Variable Neighborhood Search and Tabu Search metaheuristics

Juan Antonio Sicilia [a,*], Carlos Quemada [b], Beatriz Royo [c], David Escuín [d]

[a] Escuela de Ingeniería, Universidad Internacional de La Rioja, 26002 Logroño, Spain
[b] Virginia Polytechnic Institute and State University in Blacksurg, Virginia, USA
[c] Department of Mechanical Engineering, University of Zaragoza, 50018 Zaragoza, Spain
[d] Instituto Tecnológico de Aragón, María Luna 1, 50018 Zaragoza, Spain

ARTICLE INFO

Article history:
Received 13 October 2014
Received in revised form 9 March 2015

Keywords:
Rich vehicle routing problem
Optimization algorithm
Metaheuristic methods
Load balance

ABSTRACT

This paper presents a novel optimization algorithm that consists of metaheuristic processes to solve the problem of the capillary distribution of goods in major urban areas taking into consideration the features encountered in real life: time windows, capacity constraints, compatibility between orders and vehicles, maximum number of orders per vehicle, orders that depend on the pickup and delivery and not returning to the depot. With the intention of reducing the wide variety of constraints and complexities, known as the Rich Vehicle Routing Problem, this algorithm proposes feasible alternatives in order to achieve the main objective of this research work: the reduction of costs by minimizing distances and reducing the number of vehicles used as long as the service quality to customers is optimum and a load balance among vehicles is maintained.

1. Introduction

A vast number of problems from Applied Science including engineering can be brought by means of solving a nonlinear equation using mathematical modeling [1–3]. One of that problems, in concrete the capillary transport of goods problem, is studied in this paper.

The logistics of the capillary transport of goods has an essential urban dimension. On account of this, distribution requires efficient systems and the process between warehouses and customers must be efficient and clean. Therefore, it is necessary to optimize urban logistics efficiently and improve the connections between urban and interurban freight transport in order to ensure efficient distribution [4].

In the European Union, over 60% of the population lives in urban areas, generating just under 85% of the EU's Gross Domestic Product (GDP) [5]. In addition to this, pickup and delivery actions in urban areas represent about 40% of the total cost of transport activities carried out at home. These expenses are further increased by the reduction of stocks and size of goods and by the increase in the number of requests.

* Corresponding author.
E-mail addresses: juanantonio.sicilia@unir.net (J.A. Sicilia), cquemada@vt.edu (C. Quemada), broyoa@unizar.es (B. Royo), descuin@itainnova.es (D. Escuín).

http://dx.doi.org/10.1016/j.cam.2015.03.050
0377-0427/

Due to this, there is great potential for freight transport in these areas. Therefore, it is necessary to find logistics solutions for urban freight distribution that are consistent with the restrictions imposed by the law in order to protect the interests of the public.

This paper presents an optimization algorithm that solves a Rich Vehicle Routing Problem (RVRP) and arises from a research project carried out for an important Spanish distribution company. The main goal of this project is to manage its resources in urban areas by reducing costs caused by inefficiency and ineffectiveness as much as possible. Therefore, this research work consists in reducing the constraints and complexities currently encountered in the urban distribution of goods by using the Variable Neighborhood Descent (VND), the General Variable Neighborhood Search (GVNS) and Tabu Search (TS) metaheuristic methods.

Most problems in industry, particularly in city logistics, are multi-objective in nature. This makes it difficult to apply classical routing models to real-life problems because these models are developed with the single objective of minimizing the cost of the solution [6]. However, in real life there may be different requirements related to a single tour such as balancing workloads, time, distance, cost, etc. That need to be taken into consideration simply by adding new constraints.

This paper is organized as follows. In Section 2, the literature review is presented. Subsequently, Section 3 presents a formal mathematical definition of the RVRP. Section 4 proposes an optimization algorithm to solve this problem using metaheuristic methods. Section 5 shows the computational calculation results of this algorithm and these results are discussed in Section 6. Finally, conclusions are set out in Section 7.

2. Literature review

Over the last years, several variants of multiconstrained Vehicle Routing Problems have been studied, forming a class of problems known as Rich Vehicle Routing Problems. A comprehensive and relevant taxonomy for the RVRP literature and an attempt to provide a definition of RVRPs can be found in [7]. Several applications of such problems are close to real world as the work shown by [8] to deal with animal welfare and global constraints to handle production and inventory. Other authors have proposed to refer RVRPs as Multi-Attribute Vehicle Routing Problems (MAVRP). The work presented by [9] considers a multi-attribute vehicle routing problem derived from a real-life milk collection system. This problem is characterized by the presence of a heterogeneous fleet of vehicles, multiple depots, and several resource constraints. [10] claims that the attributes of vehicle routing problems are additional characteristics or constraints that aim to better take into account the specifications of real applications. It then takes a closer look at the concepts of 64 remarkable meta-heuristics, selected objectively for their outstanding performance on 15 classic MAVRP with different attributes. This cross-analysis leads to the identification of winning strategies in designing effective heuristics for MAVRP. This is an important step in the development of general and efficient solution methods for dealing with the large range of vehicle routing variants.

The problem RVRP considered in this paper is based on the optimization of the freight distribution in large urban areas taking into consideration the real characteristics presented in companies and trades. Given a fleet of vehicles and a set of customers dispersed over a geographic area, the system must be able to attain a feasible solution that leads to a decrease of the total cost of the problem. The purpose is to reach a solution with the minimum number of vehicles and minimizing the total distance traveled. The model of the problem depends on the following requirements:

- CVRP (Capacitated Vehicle Routing Problem): Vehicles have a maximum limit of capacity and are homogeneous [11].
- VRPTW (Vehicle Routing Problem with Time Windows): Each customer must be serviced in a set time interval [12].
- SDVRP (Site-Dependent Vehicle Routing Problem): Certain orders can only be transported by specific vehicles. Therefore, the fleet must be heterogeneous [13].
- VRPPD (Vehicle Routing Problem with Pickups and Deliveries): Customers may receive and send goods [14].
- VRPB (Vehicle Routing Problem with Backhauls): The goods that leave the depot must be delivered to customers and the goods that are picked up from customers must be transported to the depot [15].
- OVRP (Open Vehicle Routing Problem): Vehicles are not required to return to the depot after visiting the last customer and the route may finish near to the drivers home [16].
- Load balance among routes: It is important to balance the workload among vehicles since the competitiveness of a transport company depends not only on minimizing costs and distances to obtain higher profit margins but also on its ability to treat employees fairly [17].

3. Mathematical formulation

Prior to describing the mathematical formulation, it is important to define what an order is in the context of this paper. An order is a request made by a customer for the transport of goods. There are three different kinds of orders: one-pickup orders, one-delivery orders or pickup–delivery orders at dependent nodes. These nodes have to be passed through in a specific and proper sequence by the same vehicle with the time window imposed by the customer. Each vehicle has a maximum of a day to complete the service.

Since a customer might request more than one order, each customer can be visited more than once by different vehicles. In addition to this, there are dependent orders where vehicles have to pick up goods at a specific node and deliver them to another node without the need to return to the warehouse.