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Annotated Bibliography in Vehicle Routing

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Abstract

One of the most significant problems of supply chain management is the distribution of products between locations, most known as the Vehicle Routing Problem (VRP). The vehicle routing problem is one of the most challenging problems in the field of combinatorial optimization. Dantzig and Ramser first introduced the VRP in 1959. They proposed the first mathematical programming formulation. In 1964 Clarke and Wright proposed an effective greedy heuristic that improved Dantzig and Ramser approach. Since then, hundreds of models and algorithms were proposed for the optimal and approximate solution of the different versions of the VRP. In this paper, we present an annotated bibliography of the vehicle routing problem and its variant.

Keywords: Vehicle routing problem, annotated bibliography, survey.

1. Introduction

The Vehicle Routing Problem (VRP) was first introduced by [Dantzig and Ramser (1959)]. The first book devoted to the Vehicle Routing Problem was published in 1971 by [Eilon et al. (1971)]. Since then, a number of books dealing with Vehicle Routing Problem have been published [Crainic and Laporte (1998)], [Golden and Assad (1988)], [Toth and Vigo (2002b)].

Vehicle Routing Problem and its variant have very important applications in the area of distribution management. As a consequence they have become some of the most studied problems in the combinatorial optimization and a large number of papers dealing with the numerous procedures have been proposed to solve them. Survey papers can be found in [Assad (1988)], [Bodin and Golden (1981)], [Bodin et al. (1983)], [Christofides et al. (1979)], [Christofides (1985)], [Cordeau et al. (2002)], [Cordeau et al. (2005)], [Desrochers et al. (1990)], [Fisher (1995)], [Laporte (1992)], [Laporte et al. (2000)], [Lenstra and Rinnoy Kan (1981)], [Marinakis and Migdalas (2002)], [Magnanti (1981)], [Toth and Vigo (2002c)].

The success of vehicle routing must be attributed to the close interplay between theory and practice. A large scale in the success must be attributed to effective modelling and implementation. The key to the success has been to bring the power of algorithms and the capabilities of the computer to bear on the routing problem at hand.

The distribution of goods concerns the service in a given time period of a set of customers by a set of vehicles, which are located in one or more depots and perform their movements by using an appropriate road network. In particular, the solution of a VRP calls for the determination of a set of routes, each performed by a single vehicle that starts and ends at its own depot, such that all requirements of the customers are fulfilled, all the operational constraints are satisfied, and the global transportation cost is minimized.

In this paper, the most important papers published in the field of the vehicle routing problem and of its variants are presented. We will focus in papers published in the last fifteen years and in some classic papers of the previous years. The reason that we will focus in these papers is that in 1995 a complete Annotated Bibliography of the Vehicle Routing Problem was published by [Laporte and Osman (1995)] and in 1997 a second Annotated Bibliography was published by [Laporte et al. (1997)] that focuses in papers published from 1985 - 1996. In section 2, the most important papers in Capacitated Vehicle Routing Problem are presented, while in section 3, the most important papers for the Vehicle Routing Problem with Time Windows are presented. Finally, the last section includes a number of papers of other variants of the Vehicle Routing Problem.

2. Capacitated Vehicle Routing Problem

The **vehicle routing problem (VRP)** or the **capacitated vehicle routing problem (CVRP)** is often described as the problem in which vehicles based on a central depot are required to visit geographically dispersed customers in order to fulfill known customer demands. The problem is to construct a low cost, feasible set of routes - one for each vehicle. A route is a sequence of locations that a vehicle must visit along with the indication of the service it provides. The vehicle must start and finish its tour at the depot.

Exact methods obtain the optimal solution by implicit enumeration of all solution alternatives. Thus, as VRP is an NP-hard problem, it is not expected (and is in general believed impossible) to develop exact solution methods that can solve a VRP instance in reasonable amount of running time. Some of the exact methods for the solution of VRP are presented in the following [Brammel and Simchi-Levi (2002)], [Christofides et al. (1981)], [Cullen et al. (1981)], [Fisher (1994)], [Laporte et al. (1985)], [Laporte and Nobert (1987)], [Lysgaard et al. (2004)], [Naddef and Rinaldi (2002)], [Toth and Vigo (1998)], [Toth and Vigo (2001)], [Toth and Vigo (2002a)].

Due to the general inefficiency of the exact methods and their inability to solve large scale VRP instances, a large number of approximation techniques have proposed. These techniques are classified into two main categories, the classical heuristics that were developed mostly between 1960 and 1990 and the metaheuristics that were developed in the last fifteen years.

In the 1960s and 1970s the first attempts to solve the vehicle routing problem focused on route building, route improvement and two-phase heuristics. In the 1980s a number of mathematical programming procedures are proposed for the solution of the problem. The most important of them can be found in [Altinkemer and Gavish (1991)], [Beasley (1983)], [Clarke and Wright (1964)], [Desrochers and Verhoog (1989)] [Fisher and Jaikumar (1981)], [Foster and Ryan (1976)], [Gaskell (1967)], [Gillet and Miller (1974)], [Haimovich et al. (1988)], [Laporte and Semet (2002)], [Mole and Jameson (1976)], [Stewart and Golden ()], [Wark and Halt (1994)]

The last fifteen years an incremental amount of metaheuristic algorithms have been proposed. Simulated annealing, genetic algorithms, neural networks, tabu search, ant algorithms, together with a number of hybrid techniques are the main categories of the metaheuristic procedures. These algorithms have the ability to find their way out of local optima. Surveys in metaheuristic algorithms have been published by [Gendreau et al. (1997)], [Gendreau et al. (2002)], [Golden et al. (1998)].

A number of metaheuristic algorithms have been proposed for the solution of the Capacitated Vehicle Routing Problem. The most important papers published for each metaheuristic algorithm are given in the following:

- **Simulated and Deterministic Annealing:** [Breedam (2001)], [Dueck and Scheurer (1990)], [Dueck (1993)], [Osman (1993)], [Tarantilis et al. (2002a)], [Tarantilis et al. (2002b)].
- **Tabu Search:** [Barbarosoglu and Ozgur (1999)] [Gendreau et al. (1994)], [Osman (1993)], [Rego and Roucairol (1996)], [Rego (1998)], [Rego (2001)], [Taillard (1993)], [Xu and Kelly (1996)], [Toth and Vigo (2003)], [Willard (1989)].
- **GRASP:** [Hjorring (1995)], [Marinakis et al. (2006b)].
- **Adaptive Memory:** [Rochat and Taillard (1995)], [Taillard et al. (2001)], [Tarantilis (2005)], [Tarantilis and Kiranoudis (2002)].
- **Genetic Algorithms:** [Alba and Dorronsoro (2004)], [Alba et al. (2005)], [Alba and Dorronsoro (2006)] [Baker and Ayechew (2003)], [Berger and Mohamed (2003)], [Jaszkiewicz and Kominek (2003)], [Marinakis et al. (2006a)], [Marinakis et al. (2006c)], [Mester et al. (2007)], [Prins (2004)].
- **Ant Colony Optimization:** [Bullnheimer et al. (1997)], [Bullnheimer et al. (1999)], [Doerner et al. (2002)], [Mazzeo and Loiseau (2004)], [Reimann et al. (2002)], [Reimann et al. (2003)], [Reimann et al. (2004)].
- **Neural Networks:** [Modares et al. (1999)].

- **Other:** [Coy et al. (2001)], [Irnich et al. (2006)], [Kytöjoki et al. (2005)], [Li et al. (2005)], [Marinakis and Marinaki (2006)], [Mester and Braysy (2005)].

3. Vehicle Routing Problems with Time Windows

The Vehicle Routing Problem with Time Windows (VRPTW) specifies that customers must be serviced within some time window (i.e. each customer must be visited within a specific time interval, known as time window). Vehicles may also be associated with time windows within which they are allowed to operate [Cordeau et al. (2002)], [Desrochers et al. (1988)], [Desrosiers et al (1995)], [Golden, B. L., and Assad, A. A. (1986)].

Although it is very difficult to solve the VRPTW with exact algorithms a number of exact algorithms have been proposed [Desrochers et al. (1992)], [Desrosiers et al (1986)]. Heuristics for the VRPTW have been proposed by [Baker and Schaffer (1986)], [Brammel et al. (1993)], [Potvin and Rousseau (1993)], [Rousseau et al. (2004)], [Russel (1995)], [Solomon (1987)], [Solomon et al. (1988)].

A number of metaheuristic algorithms have been proposed for the solution of the Vehicle Routing Problem with Time Windows. The most important papers published for each metaheuristic algorithm are given in the following:

- **Simulated Annealing:** [Arbelaitz et al. (2001)], [Chiang and Russell (1996)], [Czech and Czarnas (2002)], [Li and Lim (2003)].
- **Tabu Search:** [Badeau et al. (1997)], [Brandao (1998)], [Bräysy and Gendreau (2001)], [Cordeau et al. (2001)], [Homberger and Gehring (1999)], [Li et al. (2004)], [Lim and Wang (2004)], [Potvin et al. (1996)], [Taillard et al. (1997)].
- **GRASP:** [Chaovalitwongse et al. (2003)], [Kontoravdis and Bard (1995)], [Li et al. (2004)], [Lim and Wang (2004)].
- **Genetic Algorithms:** [Alvarenga et al. (2007)], [Hwang (2002)], [Potvin and Bengoi (1996)], [Tan et al. (2001)], [Thangiah et al. (1991)], [Thangiah (1993)].
- **Ant Colony Optimization:** [Gambardella et al. (1999)].
- **Neural Networks:** [Potvin and Robillard (1995)].
- **Other:** [Cordone and Calvo (2001)], [Kilby et al. (1999)], [Liu and Shen (1999)], [Mester and Braysy (2004)], [Russell and Chiang (2006)].

4. Other Variants of Vehicle Routing

The problem may involve both deliveries to and collections from customers. In addition, it may be possible to mix deliveries and collections on a single route, or alternatively, it may be required from a vehicle to first perform all the deliveries in the route before performing the collections. Many applications involve pick-up and

delivery serves between the depot and peripheral locations (warehouses, stores, stations). 'Delivery' refers to transportation of goods from the depot to customers, and 'pick-up' means shipment in the opposite direction (to the depot). In the literature, this problem is known as **pick-up and delivery problem (PDP)** or vehicle routing problem with backhauls (VRPB) and the objective is to find a set of vehicles routes that serve the delivery and backhaul customers so that vehicle capacities are not violated and the total distance traveled is minimized. The difference between the **VRP with Pick-up and Deliveries** and the **VRP with Backhaul and Linehaul** customers is that in the second it may be required from a vehicle to first perform all the deliveries in the route before performing the collections [Bianchessi and Righini (2007)], [Brandao (2006)], [Caretto and Baker (2002)], [Casco et al. (1988)], [Deif and Bodin (1984)], [Desaulniers et al. (2002)], [Goetschalckx and Jacobs – Blecha (1989)], [Gribkovskaia et al. (2006)], [Katoh and Yano (2006)], [Mosheiov (1998)], [Nanry and Barnes (2000)], [Ropke and Pisinger (2006)], [Ruland and Rodin (1997)], [Swihart and Papastavrou (1999)], [Tavakkoli-Moghaddam et al. (2006)], [Thangiah et al. (1996)], [Toth and Vigo (1997)], [Toth and Vigo (1999)], [Toth and Vigo (2002d)], [Tzoreff et al. (2002)], [Wade and Salhi (2003)].

In companies with more than one depot, it is often the case that each depot is autonomous, with its own fleet of vehicles and its own geographical customer area to serve. In such cases, the company would simply face a number of similar single - depot vehicle routing problems. In other cases, depot operations are interdependent and vehicles leaving one depot may, after delivering to customers, end up at another depot. These problems are called **multiple depot vehicle routing problems** [Breedam (2002)], [Chao et al. (1993)], [Cordeau et al. (1997)], [Crevier et al. (2007)] [Gillet and Johnson (1976)], [Renaud et al. (1996)], [Salhi and Sari (1997)], [Wren and Holiday (1972)].

The problem of managing routing and dispatch operations under conditions of random demand fluctuations is often referred to as the **stochastic or dynamic routing problem** [Chitty and Hernandez (2004)], [Gendreau et al. (1996)], [Haugland et al. (2006)], [Haughton and Stenger (1997)], [Jaillet and Odoni (1988)], [Laporte and Louveaux (1998)], [Powell (1988)], [Powell et al. (1995)], [Psaraftis (1988)], [Secomandy (2000)] , [Tan et al. (2007)], [Tian et al. (2003)].

Other variants of the Vehicle Routing Problem are the **Multi-Period Vehicle Routing Problem** [Beltrami and Bodin (1974)], [Christofides and Beasley (1984)], [Drummond et al. (2001)], [Francis and Smilowitz (2006)], [Mourgaya and Vanderbeck (2006)], the **Heterogeneous Fleet Vehicle Routing Problem** (HVRP) [Choi and Tcha (2007)], [Dondo and Cerdá (2007)], [Gendreau et al. (1999)], [Li et al. (2006b)], [Nag et al. (1988)], [Ochi et al. (1998)], [Prins (2002)], [Renaud and Boctor (2002)], the **Open Vehicle Routing Problem** [Brandao (2004)], [Li et al. (2006a)].

Real World Applications of the Vehicle Routing Problem can be found in [Baptista et al. (2002)], [Braca et al. (1994)], [Chao (2002)], [Chiang and Russell (2004)], [Hirota et al (2002)], [Hsu et al. (2007)], [Matsatsinis (2004)], [Ozdamar et al. (2004)], [Ruiz et al. (2004)], [Sambracos et al. (2004)], [Semet and Taillard (1993)], [Tarantilis et al. (2004)], [Tarantilis and Kiranoudis (2005)], [Tung and Pinnoi (2000)], [Zografos and Androutsopoulos (2004)].

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