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A survey on pickup and delivery problems

Part I: Transportation between customers and depot

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Abstract This paper is the first part of a comprehensive survey on pickup and delivery problems. Basically, two problem classes can be distinguished. The first class, discussed in this paper, deals with the transportation of goods from the depot to linehaul customers and from backhaul customers to the depot. This class is denoted as Vehicle Routing Problems with Backhauls (VRPB). Four subtypes can be considered, namely the Vehicle Routing Problem with Clustered Backhauls (VRPCB – all linehauls before backhauls), the Vehicle Routing Problem with Mixed linehauls and Backhauls (VRPMB – any sequence of linehauls and backhauls permitted), the Vehicle Routing Problem with Divisible Delivery and Pickup (VRPDDP – customers demanding delivery and pickup service can be visited twice), and the Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP – customers demanding both services have to be visited exactly once). The second class, dealt with in the second part of this survey, refers to all those problems where goods are transported between pickup and delivery locations. These are the Pickup and Delivery Vehicle Routing Problem (PDVRP – unpaired pickup and delivery points), the classical Pickup and Delivery Problem (PDP – paired pickup and delivery points), and the Dial-A-Ride Problem (DARP – passenger transportation between paired pickup and delivery points and user inconvenience taken into consideration). Single as well as multi vehicle versions of the mathematical problem formulations are given for all four VRPB types, the corresponding exact, heuristic, and metaheuristic solution methods are discussed.

Keywords Vehicle routing with backhauls · Pickup and delivery · Transportation · Survey

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Zusammenfassung Der vorliegende Artikel ist Teil I einer umfassenden Überblicksarbeit in zwei Teilen über *pickup and delivery* Probleme. Grundsätzlich können zwei Problemklassen unterschieden werden. Die erste Problemklasse, mit der sich dieser Artikel befasst, beinhaltet all jene Probleme, die Auslieferungen von einem Depot zu Auslieferungs-Kunden (*linehaul customers*) und Abholungen von Rückladungs-Kunden (*backhaul customers*) zu einem Depot behandeln. Diese Problemklasse wird im Folgenden als *Vehicle Routing Problems with Backhauls (VRPB)* bezeichnet. Vier verschiedene Problemtypen können weiters unterschieden werden: das *Vehicle Routing Problem with Clustered Backhauls (VRPCB)*, alle Auslieferungen müssen vor den Abholungen durchgeführt werden, das *Vehicle Routing Problem with Mixed linehauls and Backhauls (VRPMB)*, gemischte Ausliefer- und Abholsequenzen sind gestattet, das *Vehicle Routing Problem with Divisible Delivery and Pickup (VRPDDP)*, Kunden, die Ausliefer- und Abholservice verlangen, können zweimal besucht werden, und das *Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP)*, Kunden, die beide Services verlangen, können nur genau einmal angefahren werden. Die zweite *pickup and delivery* Problemklasse wird in Teil II dieser Arbeit behandelt. Sie beinhaltet all jene Problemtypen, die sich mit Transporten zwischen Abhol- und Auslieferungsorten befassen: das *Pickup and Delivery Vehicle Routing Problem (PDVRP)*, ungepaarte Abhol- und Auslieferungsorte, das klassische *Pickup and Delivery Problem (PDP)*, gepaarte Abhol- und Auslieferungsorte, und das *Dial-A-Ride Problem (DARP)*, Personentransport zwischen gepaarten Abhol- und Ablieferungsorten unter Berücksichtigung von serviceorientierten Kriterien. Die jeweiligen Problemtypen werden zuerst anhand von mathematischen Einfahrzeug- und Mehrfahrzeugproblemformulierungen definiert. Im Anschluss werden die in der Literatur beschriebenen Lösungsmethoden diskutiert.

Schlüsselwörter Tourenplanung · Vehicle Routing mit Rückladungen · Überblicksartikel

1 Motivation and basic definitions

Over the past decades extensive research has been dedicated to modeling aspects as well as optimization methods in the field of vehicle routing. Especially freight transportation involving both, pickups and deliveries, has received considerable attention. This is mainly due to the need for improved efficiency, as the traffic volume increases much faster than the street network grows (compare Eurostart, 2004, 2006, for data on the European situation). Thus, given the current efficiency, this may eventually lead to a breakdown of the system. However, with rapidly increasing computational power intelligent optimization methods can be developed and used to increase the efficiency in freight transportation and alleviate the above mentioned problem. Moreover, along with the increasing use of geographical information systems, companies seek to improve their transportation networks in order to tap the full potential of possible cost reduction. The rapidly growing body of research has led to a somewhat confusing terminology used to describe the various problem types arising in this context. Indeed,