Router: A Fast and Flexible Local Search Algorithm for a Class of Rich Vehicle Routing Problems

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Abstract. We describe a flexible indirect search procedure which we have applied for solving a special pick-up and delivery vehicle routing problem with time windows. The heuristic is based on an encoding of a solution as a sequence/permutation of tasks, a cheapest insertion decoding procedure, and, a threshold-accepting like local search meta-heuristic.

1 Introduction

During the last years there has been extensive research on extensions of the classical Vehicle Routing Problem (VRP) with respect to additional constraints which occur in real-world applications. The family of those "new" and difficult VRP-variants is often referred to as *Rich Vehicle Routing Problems (RVRP)*. Algorithms have been developed which build upon construction and improvement principles which have been used for the classical VRP already. For a survey of different classes of rich vehicle routing problems as well as traditional heuristic approaches see Toth and Vigo [3]. Our research on RVRP has been motivated by a real-world routing and scheduling problem which had nearly all of the complexities which are discussed in the literature: multiple time-windows, pick-up and delivery, heterogeneous fleet, multiple use of vehicles and multiple objectives.

2 Problem Description

The application for which we have developed a Decision Support System (DSS) is the daily routing and scheduling problem for a removal firm which, using a small (sub-) fleet of dedicated vehicles, supplies services like packing cases etc. and which arranges the reservation of parking lots in a metropolitan area. Yet, in contrast to the benchmark situations studied in the literature not all of the constraints are valid for all tasks. For instance, there are only some tasks which have time-windows and these time windows are of different nature, i.e. they can be a fixed time interval or they may exclude certain time intervals. Also, we have some tasks which are deliveries from the depot,

some which collect goods and some which are pick-up and delivery tasks. Another significant difference from the standard models is that most of the services have to be scheduled on fixed days (in some cases within a specific time interval), but some specific services and service types could be scheduled flexibly several days ahead. Thus in the solution process we have to distinguish between optional and required tasks. Also, due to miscalculations on the demand and additional requirements, the plan has to be revised during the day, i.e. during operation.

Now a service plan consists of a number of routings which are associated to vehicles such that every task is contained in at most one route, every route is feasible with respect to capacity, time-window, coupling and precedence constraints. Also, every single route is feasible for the vehicle which it is assigned to and the set of routes assigned to a vehicle which represents the service plan for this vehicle and the associated crew are feasible in the sense that the vehicle is able to sequentially operate these routes with intermediate stops at the depot.

The quality of a service plan is evaluated by several criteria. Since the service is performed by a division which is a cost-center within the logistic firm these criteria are related to operational cost and service quality. Here we distinguish between so-called primary criteria and secondary criteria. Primary criteria are the distance and time for routing based on the geographic data, the waiting time at a customer, overtime cost, i.e. the cost if a vehicle/crew is operating more than its duty time, opportunity cost for not servicing a customer on the respective day and a fixed cost per tour which is assigned to a vehicle. Secondary criteria evaluate the "fairness" of a service plan and measure the difference between the longest and the shortest deployment time of the vehicles/crews and the difference between the largest and smallest service time of the vehicles/crews.

In our DSS-model these 8 criteria are aggregated into one objective function to measure the "cost" of a service plan. This objective function can be controlled by the user through appropriate parameterization over the DSS-dialog component, and the user can have the DSS construct alternative service plans under variations of the parameters. Thus we had to develop a rather flexible algorithmic approach as the core of a highly interactive DSS which is able to react on modifications with respect to incorporating constraints and objectives. In the following we shortly describe the solution approach for ROUTER, the solver component of the DSS.

3 The ROUTER-Heuristic

Respecting the complexity of the application and the necessity of the system to be able to generate alternate solutions in relatively short time it became obvious that the DSS had to be based on a heuristic which is outmost flexible with respect to possible combinations of criteria, i.e. configurations of the