A generic model for integrated vehicle routing and driver scheduling problem

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1 Introduction and motivations

Integrated vehicle Routing and crew Scheduling Problems (RSPs) consist in simultaneously planning routes for vehicles and scheduling for drivers. Usually, classical routing problems assume that each vehicle is associated with a single driver throughout its entire route. However, when planning over a large horizon, vehicles can be used over the whole horizon, while drivers have to rest. Hence, in order to better use the vehicles, in this work, we consider that each of them can be driven by different drivers during the planning horizon. Moreover, the consideration of both drivers and vehicles makes the vehicle route planning and driver scheduling highly interdependent.

RSPs have been investigated in different transportation applications, including airline industry [2], railway [3], trucks [6], buses [1]. Although these transportation applications have different characteristics, they all share several main similarities. Given a set of tasks where each task has a predefined timing and is associated with departure and arrival locations, the aim is to plan the sequence of tasks to be performed by each vehicle and each driver such that each task is performed by a single vehicle and at least one driver. During its planning, a driver can change vehicle, and a vehicle can have several drivers. In addition, a driver can be passenger in a task performed by another driver, which allows to change his location. Each driver has a maximum driving duration and a maximum total working duration (including the time when he is not driving). Our objective is to propose a generic model for these different applications and model the main features specific to some of the applications. For example, in railway and truck applications, some tasks are associated with a large demand and thus have to be performed by more than one vehicle, but the vehicles have to be combined together to perform the task at the same time.

Similar works on RSPs not dedicated to a specific application have been proposed by [4] and [5]. They consider tasks not as time-stamp type. However, the problem is restricted to two depots, does not consider the possibility of combining vehicles, and does not consider a timing aspect. Hence, drivers can have very long working times.

2 Problem definition and a generic model

Three main entities are considered in our work : vehicles, drivers, and tasks. Vehicles and drivers initially stay at predefined locations at the beginning of the planning horizon. These locations are called depots. A task is usually defined by four attributes : origin location, destination location, departure time, and arrival time. Two tasks T_A and T_B can be performed consecutively by a driver or a vehicle, i.e. there is a possible connection from T_A to T_B only if : (i) the destination of T_A is the origin of T_B, and (ii) the departure time of T_B is after the arrival time of T_A. The difference between departure of T_B and arrival of T_A is named the connection time. Note that because of the timing aspect, it is not possible to have a cycle of possible connections.

Specifically, given a fleet of vehicles, a set of drivers with their departure depots, and a set of tasks, the aim of the RSP is to provide a sequence of tasks for each vehicle and each driver such that each sequence is composed of possible connections, and all tasks are performed by a single vehicle and by at least one driver. If several drivers are performing a task, one has to be driving while the others are considered as passengers. Each driver has to end at the same depot he started, i.e. drivers must have a closed route. During the planning horizon, a driver may change vehicle or have rest at certain locations or be passenger in some tasks. When the connection time between two consecutive tasks is too short, drivers have to stay in the same vehicle and keep the same working status. In addition, he must respect the regulations of limited driving hours and total working time. We assume that in each depot, the number of vehicles at the end of the planing horizon is predefined. A vehicle can end at a different depot than the one it started from, i.e. a vehicle can have an open route. It can be used without interruption throughout the planning horizon. The objective is to minimize the total cost that consists of three parts : (i) the cost of vehicles, (ii) the drivers' salary, and (iii) the penalty when drivers change vehicle or working status (from driving to passenger and reciprocally).

In addition, we emphasize the combination of vehicles in the model. Tasks with a large demand are predefined. For such tasks the number of coupled vehicles should be equal to the required quantity. There is one leading vehicle in these tasks. When the connection time for vehicles is too short, combined vehicles are not allowed to change configuration, i.e. the leading vehicle has to be the same.

We propose a compact mixed-integer programming formulation for the RSP. To validate the model, we first solved small-size instances with Cplex. We will evaluate the model on larger random instances.

3 Conclusion and perspectives

A general model for the RSP has been proposed, which covers the case of drivers sharing vehicles and changing their working status, as well as combined vehicles during the planning horizon. We will develop a solving method to efficiently solve large size instances for different transportation applications.

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