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Considering departure time window on generic integrated vehicle routing and driver scheduling problems

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1 Introduction and motivations

Integrated Vehicle Routing and Driver Scheduling Problems (IVRDSPs) involve the simultaneous planning of vehicle routes and driver schedules to perform a given set of tasks where each task has a predefined timing and is associated with departure and arrival locations. Unlike classical routing problems, IVRDSPs relax the assumption that each vehicle is associated with a single driver throughout its entire route. The flexibility of the utilization of transportation resources is considered. For instance, a single vehicle can be operated by multiple drivers over time, and drivers may change vehicles or even travel as passengers as needed. Moreover, IVRDSPs have been studied in various transportation applications, such as the airline industry [2], railway [3], trucks, buses [1]. Although these transportation applications have different characteristics, they share several main similarities.

In a previous work, we proposed a generic model for the IVRDSP capable of covering different transportation applications. Then, we developed a two-phase solution method, using a column generation approach for solving the driver scheduling subproblem. Building on this foundation, we now explore treating departure times of tasks as decision variables rather than fixed inputs. We relax the predefined departure time into a given time window, which specifies the earliest and latest allowable departure times for each task. The interest is to check if by modifying a little bit the departure time we manage to have better planning with fewer drivers or vehicles or to decrease variable cost related to waiting times for vehicles and drivers. Indeed, flexible departure times enable to optimize scheduling by reducing idle time for drivers and vehicles caused by unnecessary waiting between tasks. Moreover, flexible departure times provide more potential successive connections between transportation tasks compared to a fixed timetable. These new connection options can lead to new planning solutions that potentially require fewer vehicles and drivers.

2 Problem definition

Three main entities are considered : vehicles, drivers, and tasks. A task is defined by its origin and destination locations, a specified number of vehicles, its duration, and a given departure time window. Usually, a single vehicle is required to perform a task, but in some application, e.g. railway, it is possible to combine two vehicles (trains) to perform a trip with many passengers. At the beginning of the planning horizon, drivers and vehicles start from any depot. Given a fleet of vehicles, a set of drivers, and a set of tasks, the IVRDSP with a departure time window aims to determine the departure time of each task while simultaneously providing a sequence of tasks for each vehicle and driver. Each sequence must consist of feasible connections, meaning that two tasks T_A and T_B could be performed consecutively. Specifically, a feasible connection

from T_A to T_B exists 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 the departure time of T_B and the arrival time of T_A is named the connection time. The solution of IVRDSP with a departure time window must ensure that all tasks are completed by the required number of vehicles and at least one driver, and each task is started within the given time window. Each driver has to end at the same depot he started from. During the planning horizon, a driver may change vehicles, traveling as a passenger. When the connection time between two consecutive tasks is too short, drivers have to stay in the same vehicle. In addition, drivers must respect the regulations regarding limited driving hours and working time. It is not required that a vehicle ends at its starting depot, but at the end of the planning horizon, each depot has to contain as many vehicles as at the beginning of the horizon.

The objective is to minimize the total cost, which consists of two main components : (i) fixed cost, including vehicle utilization costs and drivers' salaries, and (ii) variable cost, which include costs associated with the waiting time for vehicles and drivers, as well as penalties incurred when drivers change vehicles or change working statuses (e.g., from driving to passenger and vice versa). It is important to note that in practice the unit fixed costs are significantly higher than the unit variable costs.

3 Validation of the interest of departure time windows

We extend a compact mixed-integer programming (MIP) formulation for the IVRDSP to consider the departure time windows. This leads to a more complicated model with several linking constraints of type “big-M”. We also propose a fast and simple two-step heuristic : first, all departure times are set to the middle of the time windows, and a MIP solver is called to provide a feasible solution for the IVRDSP ; second the structure of the solution is fixed and an LP model permit to optimize the departure times of the tasks. We generated a set of instances with relevant characteristics, ensuring the existence of a feasible solution. For small-size instances (up to 45 tasks), the MIP is solved within a 10-minute time limit. Results show that enlarging the time windows can reduce fixed costs by providing solutions few drivers and/or vehicles. For cases where the fixed costs remain unchanged, enlarging the time windows helps to decrease variable costs. The reduction is of course due for some part to the fact that with larger time windows the planning can be shrink, but also, solving the the integrated model permit to provide new solutions in term of planning for the drivers and vehicles.

4 Conclusion and perspectives

The model in our work covers scenarios involving tasks with departure time windows, drivers changing vehicles, drivers acting as passengers, and two vehicles combined performing certain tasks over the planning horizon. The problem is challenging to solve for large-size instances, due to vehicle-driver interactions and “big-M” constraints introduced by time windows. Therefore, our main perspective is to build a more sophisticated heuristic solving method.

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