Linear Formulation of the driver-scheduling problem under the European driving rules regulation

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Introduction

Several legal driver's rules exist in the European Union, each one establish a general framework with the objective to improve the road safety and to define work conditions of drivers. These rules should ensure a fair competition between road transport operators in Europe. The Regulation rules (EC) 561/2006 [1] makes the transport companies legally responsible if schedules do not let time for drivers for compulsory break and rest periods. This set of rules imposes restrictions on the daily driving time, daily working time, as well as the scheduling of several types of breaks along the shift and the week. As a result, the set of feasible solutions of the *Vehicle Routing Problem* will strongly decrease. Xu et al. [2] considering the US hours of service regulation, make the conjecture that the timing and break scheduling problem in a fixed route is a NP-hard problem. Additionally, no polynomial-time algorithm is known for route evaluations subject to the European Union regulations [3].

Few researches have proposed linear formulations on this problem with different settings [4][5] which make comparisons difficult to perform. Our first contribution is a new MILP formulation of the driver scheduling problem which extends Goel et a 2012 contribution. Secondly, we propose a new set of instances with detailed description of optimal solutions available at https://perso.isima.fr/~igpenaar/Roadef_2021/

Mixed Integer Linear Problem formulation

A MILP formulation is proposed to schedule driver's shifts under the European Union regulations. To evaluate a sequence σ of customers that starts and ends at the depot, and that is fully defined by the following information at each customer i: the arrival time (A_i), the starting time of the service (St_i), the finishing time (Ft_i), the departure time (D_i), the break before the service (Bf_i) and the break after the service (Ba_i). The MILP investigates the possibility to schedule breaks only at customer location. A route S is composed of both transport operations from one customer i to the next one j of duration $T_{i,j}$ and customer operation (often called service) of duration p_i.

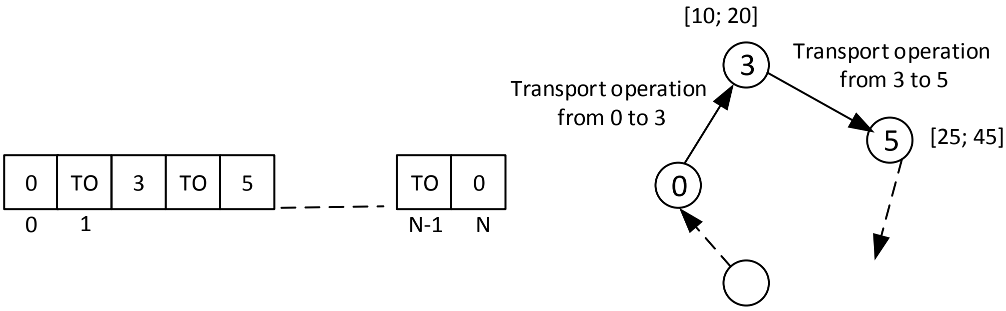

Figure 1. A route S

By consequence, the evaluation of S consists in computing the starting time St_u of each operation (u refers to either one customer operation for odd position or transport operation), and to define the break schedule at the end of one operation (either transport operation or customer operation). Each operation S_u has a given time window $[e_{S_u}, l_{S_u}]$ if S_u is a customer operation, and a processing time p_u set to p_{S_u} for a customer operation and set to $T_{S_{u-1},T_{S_{u+1}}}$ for a transport. Figure 1 gives an example of a route S starting at the depot node 0 ($S_0 = 0$) : S_1 is the transport operation from customer $S_0 = 0$ to customer $S_2 = 3$ and the second customer operation in the sequence is the customer 5 at position 5 in S. The total number of activities N is equal to the number of customers including starting and final depots plus the transport operations. Breaks are scheduled after the operation completion only. The objective function is either the makespan $z = min[St_N - St_1]$ or the completion time $z = min[St_N]$ minimization.

The model we propose has $5N^2 + 2bN + 8N$ constraints and $N[2 + b]$ binaries variables, where b is the types of breaks. We generated a benchmark of 29 instances from $N = 8$ to $N = 32$ activities. The computational time varies from 32.5 milliseconds for one of the smallest instances up to 1.79 seconds for one of the largest ones.

Conclusion

This work presents a new linear formulation for the driver-scheduling problem including some European driving rules not previously considered on earlier linear models. Results show that the average computational time to solve instances up to 32 activities using GUROBI is about 668.9 ms. The model also could be used to develop tailored exact or heuristic algorithms to solve in a more efficient way the problem.

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