

Integrated Vehicle and Crew Scheduling for Extra-Urban Transport

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1 Introduction

Crews and vehicles are the main resources to provide services in transport systems. The way these resources are employed directly impacts the quality of service and the operational costs, which explains the importance gained by transportation scheduling systems.

The conventional crew and vehicle scheduling process is the *sequential* approach which determines first the vehicles schedule and then the crews schedule. This dichotomy is mainly due to the complexity of each sub-problem. Indeed, the Multi Depot Vehicle Scheduling Problem (MDVSP) is known to be NP-hard ([2]) and the Bus Driver Scheduling Problem (BDSP) also constitutes a difficult problem.

In the early 1980s, Ball et al. criticized this sequential approach [1], but the first real *integrated* solutions, in which vehicles and crews are simultaneously scheduled, were only developed in 1995 ([3]). This integrated treatment of both resources demonstrated its efficiency in [4] where relief locations, i.e. places where a driver can be relieved by a colleague, are spatially distant. Integration is also profitable when a driver is not allowed to change from one vehicle to another.

In this study, we propose a new heuristic approach based on a constraint satisfaction optimization problem for the simultaneous vehicle and crew scheduling problem. We implemented a Greedy Randomized Adaptive Search Procedure (GRASP) which constitutes, to our knowledge, the first application of metaheuristics to this problem. In our situation, all vehicles are parked within the same depot. However, the problem is more general than the usual single depot case which imposes a homogenous fleet of vehicles. Here, they may belong to different categories. Treating an extra-urban situation, we adopt the same assumption as in [4], namely that changeovers only take place at the depot.

2 Vehicle and Crew Scheduling: Problem Presentation

Informally, given a set of trips within a one-day planning horizon, a set of drivers, a fleet of vehicles parked at a given depot, a set of workday types, the Vehicle and Crew Scheduling Problem (VCSP) consists in determining a minimum cost schedule for crews and vehicles, such that generated duties are feasible and mutually compatible.

The trips are characterized by starting and ending locations with corresponding times. Travel times between all pairs of locations are also known. The other inputs concern the vehicles availability per category. Similar bounds exist for the crews.

The whole schedule has to comply with a set of imperative constraints. Crews and vehicles assigned to successive trips must have enough time between these trips to move from one to the other. Category requirements must be satisfied as well. Eventually, crew members are subjected to labor rules (maximum length, maximum working time, etc.).

The cost structure of the problem is composed of fixed and operational costs. For evident economic reasons, the main objective is to reduce the number of working drivers and used vehicles. In order to further reduce costs, it is also useful to minimize idle time and deadheads.

3 Problem Formulation and Solution Approach

Our problem is modeled as a constraint satisfaction optimization problem inspired from [6]. We aim to simultaneously assign a couple (driver and vehicle) to each trip. Therefore, we will define the set of decision variables as the set of trips \mathcal{T} . Naturally, the associated value domain \mathcal{I}_k for each such variable corresponds to driver-vehicle pairs.

To tackle this problem, we implemented a Greedy Randomized Adaptive Search Procedure. GRASP is a multi-start metaheuristic for combinatorial problems, in which each iteration consists basically of two phases: construction and local search. Constraint programming techniques are used to build initial solutions. Improvements of these solutions are achieved with a local search algorithm which embeds a powerful "ejection chain" neighborhood exploration mechanism.

4 Comparison Between Sequential and Integrated Scheduling

In our computational experiments, we compared the sequential and the integrated approach on 7 real-world instances representing different workloads. For each approach, we report in Table 1 the number of required drivers and vehicles, the total duration of deadheads (dh) and idle periods (idle). For the sequential approach, we developed a Branch & Bound algorithm on a multi-commodity flow model for the vehicle part and on a set covering model for the crew part (see [5]). Concerning the tuning of GRASP, after some preliminary experimentations, we obtained the best results with the following set of parameters:

- 10 iterations,
- a size of 5 for the restricted candidate list,
- each local search procedure stops after $100 \times |\mathcal{T}|$ iterations without improvement.

With these settings, the computational effort does not exceed 10 minutes on the largest instances. Figures for the simultaneous approach correspond to the best solution obtained over 20 runs.

Table 1: Comparison between sequential and integrated scheduling

	Seq				Int. GRASP			
	drivers	vehicles	dh	idle	drivers	vehicles	dh	idle
bea_59	18	16	23:17	3:54	16 (16.0, 0.0)	16 (16.0, 0.0)	24:24	4:14
cor_67	20	15	19:28	1:55	15 (15.8, 0.4)	15 (15.0, 0.0)	22:12	0:28
cha_105	22	22	39:38	9:36	22 (22.0, 0.0)	22 (22.0, 0.0)	40:53	9:44
sem_151	27	27	57:05	15:45	27 (27.0, 0.0)	27 (27.0, 0.0)	58:20	15:07
dij_159	34	29	51:56	16:02	29 (29.0, 0.0)	29 (29.0, 0.0)	61:10	14:29
otp_215	-	48	-	-	49 (49.0, 0.0)	49 (49.0, 0.0)	145:17	21:13
aux_249	48	44	115:35	22:59	46 (46.8, 0.4)	44 (44.0, 0.0)	123:35	21:21

From this Table, we observe that the integrated approach clearly outperforms the sequential one. In particular, the savings in terms of number of drivers are significant. The sequential approach

provides a lower bound in the number of vehicles that is always reached in the integrated solutions. The only loss concerns the dh-tasks: the schedules are sub-optimal regarding this criterion to allow drivers reliefs.

The integrated approach is more powerful than the sequential one. The latter sometimes fails to solve instances - it occurs with "opt_215" - while solutions are possible when crews and vehicles are considered simultaneously. In the sequential methodology, the vehicle phase might result in a schedule with no relief opportunity along some bus duty and consequently leads to an unresolvable problem for the driver scheduling part.

5 Conclusion

We proposed a new heuristic on a simultaneous drivers and vehicles scheduling problem in an extra-urban area. The assumptions retained are suitable to tackle practical problems in this context. The ability of managing a heterogeneous fleet for a given depot is thus especially relevant.

The formulation as a constraint satisfaction optimization problem and the application of meta-heuristics on such a problem constitute to our knowledge the first attempts in the targeted field.

The computational study carried out on a set of real-world instances clearly shows the dominance of the integrated approach over the conventional sequential approach.

References

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