Integrated vehicle and crew scheduling in practice

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Introduction

Public transit providers are facing continuous pressure to improve service quality and reduce operating costs. Flexible and powerful optimization algorithms have thus been developed and used for many years to help them with this challenge. Vehicle and crew scheduling are among the most studied problems in this area. These problems can be solved independently (in a sequential manner) or simultaneously (integrated vehicle and crew scheduling). In the latter case, models become more complex and grow in size, but may lead to significant savings if they can be tackled efficiently. Among the research groups that have recently contributed to this topic, we note GERAD [2], ECOPT [3], and ZIB [1]. The aim of this paper is to report on applications of integrated vehicle and crew scheduling with several transit companies worldwide, and discuss our experiences and some of the practical issues we have encountered.

Solution methods

The software company GIRO Inc. offers an extended suite of optimization algorithms for different phases of the planning process. The *CrewOpt* module is based on column generation techniques and can be used to simultaneously generate duties and vehicles so that global costs are minimized. Its basic model is similar to the one reported in [2] in which only duty variables are present. Additional constraints are added to ensure the existence of a compatible vehicle schedule and to count the resulting vehicles so they can be considered in the objective function. This formulation guarantees that a global optimum of the integrated problem can be found once a compatible vehicle schedule is identified, which can easily be done in polynomial time. The model used by *CrewOpt* can also handle complex vehicle constraints that are often found in practice, such as capacities for multiple garages and vehicle types.

Alternative integrated optimization methods can also be used, and may include advanced features that handle vehicle and crew constraints, as well as modifications to the initial timetable (trip shifting). For instance, GIRO's *Minbus* algorithm, which combines network flow models and adapted heuristic procedures, can form the basis of an integrated timetabling-vehicle-crew scheduling optimization approach.

Problem contexts

Integrated vehicle and crew scheduling can be helpful in various contexts. For regional operators covering large geographic areas, relief opportunities are often scarce and sequential approaches may not lead to efficient solutions. Furthermore, regional problems frequently include other complicating factors such as multiple garages (e.g. ten or more), some of which may have very limited capacity (10 buses or less). Trips are also typically long (more than an hour), and may be restricted to specific garages and vehicle types. In urban problems, service is usually concentrated in a smaller area and relief opportunities are more numerous. Significant gains can nevertheless be achieved when organizations are ready to integrate the vehicle and crew scheduling optimization processes.

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Operating practices can also have an impact both on the results obtained and the selection of solution approaches. For example, some organizations require that drivers work on the same vehicle for their entire duty. In some instances, there is a direct equivalence between vehicles and duties, which can lead to selecting *Minbus* as the most efficient algorithm. When drivers can be relieved in the middle of trips, thereby dividing the workload of some vehicles, column generation techniques are appropriate. Integration of vehicle scheduling involves adding a very large number of additional constraints to the linear master problem in order to count the number of vehicles assigned to each garage and vehicle group and to ensure the solution will lead to compatible duties and vehicles. These large scale problems create a great challenge, and careful implementation is essential so that good solutions can be obtained in a reasonable time. Among the important features that we found to be most effective, we mention the initial relaxation of some constraints which are later dynamically generated as violations are detected, and decomposition strategies that can permit parallel implementations of the algorithm.

Specific examples

More than 250 transit companies use the *HASTUS* software, and many of these use an integrated optimization approach. In North America, Europe and Australia, many regional and urban transit companies use *CrewOpt* and *Minbus* with specific options that allow simultaneous optimization of vehicle and crew schedules. Examples of cities and operators that benefit from these approaches are Minneapolis, Albany, Kansas City, Boston, San Diego, Los Angeles, Sydney, Brisbane, Montpellier, Valenciennes, Hamburg, Köln, Rotterdam, Arriva, Connexxion, Nettbus and many others.

To give an idea of gains that can be obtained using an integrated approach, we mention a few specific cases. Minneapolis (USA) recently moved to *CrewOpt* and an integrated solution approach which led to significant productivity gains that were reported in a conference [4]. The city of Montpellier (France) recently upgraded to a newer *CrewOpt* version and achieved cost savings of more than 1.7% over schedules that were previously operated. Execution times were also very acceptable (about four hours on a 3GHz Pentium 4 processor with 1 GB RAM). Very good results were also observed in Hamburg and Köln (Germany), where *CrewOpt* and *Minbus* were respectively used to integrate the scheduling optimization process.

Conclusion

Integrated vehicle and crew scheduling offers significant optimization opportunities for transit companies that want to reduce vehicle and manpower costs without sacrificing service quality. While the associated mathematical models give rise to much larger problems to solve, careful implementation can still lead to tangible savings.

References

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