Reinventing Crew Scheduling at Netherlands Railways

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Sophisticated OR techniques were applied succssfully for scheduling the 6,500+ drivers and conductors of the Dutch railway operator NS Reizigers. The schedules were generated according to new rules aiming at increasing the punctuality and efficiency of the services, together with the satisfaction of the drivers and conductors. The produced plans trimmed personnel costs by about $7 million per year.

1. Introduction

Since a couple of years, there has been a separation in the Dutch railway system between the capacity management and maintenance of the railway infrastructure on one hand, and the exploitation of the railway infrastructure on the other. NS Reizigers is the main Dutch railway operator of passenger trains, employing 3,000+ drivers and 3,500+ conductors in 29 depots. Each workday, about 5000 timetabled trains are operated. For a railway operator, crew scheduling is a fundamental task. This paper describes how we were able to support the crew scheduling process within NS Reizigers with the planning support system TURNI, how this system also supported the definition of a new set of rules to be applied in the crew scheduling process, and how this system supported a reduction in the operational costs by about $7 million per year.

Within NS Reizigers, the main criteria in the scheduling process of drivers and conductors are *feasibility*, *efficiency* and *acceptability*. Feasibility means that it should be possible to carry out the schedules in practice, and that they are sufficiently robust for outside disruptions and for delays of trains. Key parameters here are the minimum connection time when changing from one train to another, and the maximum number of train changes per duty. Detailed knowledge of the rolling stock circulation is essential here. Efficiency means that the percentage of productive time in the duties is high. Non-productive time includes, besides the meal break and the required pre-time and post-time at the start and the end of a duty, also the gaps between the trips and the so-called P-trips (passenger trips or positioning trips). Acceptability is a qualitative aspect of a schedule, referring to the probability that the obtained schedule is accepted by the drivers and conductors. Within NS Reizigers, acceptability is related to the level of variation in the duties (the larger, the better). Also a fair division among the depots of the attractive work on Intercity trains and the less attractive work on trains with a lot of (anticipated) aggression is important.

2. The TURNI software

Until 2000, the crew scheduling process of NS Reizigers was carried out mainly manually, although several supporting information systems were used. However, these systems were not able to provide real active support in the crew scheduling process by automatically generating duties for drivers and conductors. The whole process relied heavily on the experience and the craftsmanship of the planners. Since 2000, NS Reizigers has been using the crew scheduling system TURNI that does provide active support in the crew scheduling process. TURNI was developed by *Double-Click sas* and customized several times in order to cope with the complex rules that are to be satisfied by the crew schedules of NS Reizigers. Furthermore, in the meantime an interface between TURNI and the usual information systems was developed, which allows to generate input for TURNI automatically, and to restore the resulting crew schedules in these usual information systems.

The TURNI solution mechanism consists of a duty generation module and a duty selection module, which are applied iteratively in order to find better and better solutions. After a set of feasible duties has been generated, the duty selection module aims at selecting a subset of feasible duties such that each of the trips is covered by at least one of the selected duties, that the relevant additional constraints are satisfied, and that the total involved costs are minimal. Both the duty generation and the duty selection are based on a set partitioning model with additional constraints, which is solved by Lagrangian relaxation, dynamic pricing, and powerful heuristics.

Set partitioning models for solving crew scheduling problems have been popular in the airline industry for many years. However, in the railway industry the sizes of the crew scheduling instances are, in general, a magnitude larger than in the airline industry. This prohibited the application of these models in the railway industry until recently. The main obstacle here was the complexity and very large sizes of the railway instances. Indeed, a typical instance of NS Reizigers related to the planning of a single duty type (driver or conductor) on a single workday involves about 14,000 time-tabled trips to be assigned to 1000+ duties in 29 depots. This produces set partitioning instances with several additional nasty depot constraints that are much larger than those addressed in the literature so far.

3. **Applications**

After its introduction within NS Reizigers, TURNI was used in several projects to study the effects of different sets of rules to be applied in the crew scheduling process. The system was also used in a bidding process, which finally resulted in the fact that NS Reizigers won a concession to operate trains in the neighborhood of Liverpool for many years. Furthermore, in 2001, the board of directors of NS Reizigers agreed with representatives of the drivers and conductors to set up a new set of such rules in which especially the variation in the duties as well as a fair division among the depots of the attractive (Intercities) and less attractive (aggression) work would get sufficient attention.

In the search for the new set of rules, which was carried out in the first part of 2002, hundreds of scenarios had to be analyzed, each one differing slightly from the others in several input parameter settings. Especially finding an acceptable balance between the above mentioned (conflicting) objectives lead to many scenarios to be evaluated. Furthermore, because of the time pressure during the project, the giant set partitioning instances modeling the various scenarios needed to be solved to near optimality on PCs within a number of hours of computing time. Altogether, several PCs were continuously running TURNI to evaluate the requested scenarios. As a result of the project, a new set of rules was obtained indeed. After a process of negotiation, all the involved parties (representatives of the drivers and conductors, unions, and board of directors) agreed on the new rules. This success received a lot of attention of the Dutch media, since the structure of the duties of the drivers and conductors has been a hot item in the Netherlands for several years. The new rules are highly complex: a large number of performance indicators, mainly concerning the division of the work among the 29 depots, have to satisfy certain pre-specified norms. Therefore, dealing with these rules without a sound Operations Research support would have been impossible: the success of the project relied heavily on the quality and the flexibility of TURNI.

The new rules indeed give a higher acceptability of the schedules together with a higher efficiency and robustness: since the introduction of the new schedules, the punctuality of the trains has grown steadily. Furthermore, the fairer division of the work among the depots is considered as a strong advantage over the previous schedules. Next, NS Reizigers was considered to operate its trains quite efficiently already. Nevertheless, it is estimated that the realized savings by the use of TURNI are at least 2% per year. For example, although the amount of work increased by about 3% (due to a higher number of trains for providing a better service to the passengers), the number of duties increased by only 1%. On a total number of 6500+ employees, this amounts to savings of about $7 million per year. Note that this figure is quite conservative, since, as was stated above already, the construction of the duties with the new rules would have been simply impossible without TURNI. The latter is also acknowledged by Tjeu Smeets, the manager of the Logistics Department of NS Reizigers.

4. **Conclusions**

To the best of our knowledge, this is the first time a large European railway company used Operations Research techniques successfully to actively support its crew scheduling process. Until recently, the sizes and complexities of the instances resulting from railway crew scheduling problems prohibited the successful application of such techniques. However, the application of TURNI supported NS Reizigers in generating a new set of rules to be applied in the crew scheduling process with a better balance between the relevant objectives. At the same time, the application of TURNI lead to operational savings of about $7 million per year. Over the next 5 years, it is estimated that the savings will be in excess of $30 million. Further recognized advantages of the use of a computerized crew scheduling system are the fact that the organization becomes less dependent on the experience and the craftsmanship of the planners, and the fact that it facilitates a reduction of the throughput time of the logistic planning process. The latter is important, since it implies an increased flexibility of the organization: a shorter throughput time of the planning process allows the organization to react faster to changes in the environment.

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Leo Kroon, Erwin Abbink,
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Reinventing Crew Scheduling at Netherlands Railways

This award recognizes outstanding work in the development and implementation of analysis methods and models to scheduling the 6,500+ drivers and conductors of the Dutch railway operator NS Reizigers. The authors used sophisticated Operations Research models and techniques. The schedules were generated according to new rules aiming at increasing the punctuality and efficiency of the services, together with the satisfaction of the drivers and conductors. The produced plans trimmed personnel costs by about $4.8 million per year. However, the application of the model showed that cost reductions of over $7 million per year are also conceivable.

The prize is in memory of the late Dr. Daniel H. Wagner. While President of his own practice-oriented consulting firm, Dr. Wagner brought many high-quality mathematicians into the operations research community, leading to significant applications for U.S. Navy, Coast Guard, and other organizations.

The prize is sponsored by CPMS, the Practice Section of INFORMS—the Institute for Operations Research and the Management Sciences. The cash award of $1,000.00 is made possible by generous endowments from Metron Inc., Daniel H. Wagner Associates, Inc., and Applied Mathematics, Inc.