CREW ROSTERING FOR THE HIGH SPEED TRAIN

RAMON M. LENTINK, MICHIEL A. ODIJK & ERWIN VAN RIJN

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Email address corresponding author	rlentink@fbk.eur.nl
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BIBLIOGRAPHIC DATA AND CLASSIFICATIONS		
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Crew rostering for the High Speed Train

Ramon M. Lentink[1, 2], Michiel A. Odijk[1] & Erwin van Rijn[1]
[1] *ORTEC Consultants bv, the Netherlands*
[2] *Erasmus Center for Optimization in Public Transport (ECOPT), the Netherlands*

Abstract

At the time of writing we entered the final stage of implementing the crew rostering system Harmony CDR to facilitate the planning of catering crews on board of the Thalys, the High Speed Train connecting Paris, Cologne, Brussels, Amsterdam, and Geneva. Harmony CDR optimally supports the creation of crew rosters in two ways. Firstly, Harmony CDR contains a powerful algorithm to automatically generate a set of rosters, which is especially developed for this specific situation. As the user has some control over the objectives of the algorithm, several scenarios can be studied before a set of rosters is adopted. An important feature of the automatic roster generator is that it respects requirements, directives, and requests stemming from legal, union, and/or company regulations and/or from individual crew. Secondly, Harmony CDR provides user-interface data manipulation at various levels of detail. The user interface enables the planner to easily obtain many different views on the planning data and to manipulate the planning manually. So again, the planner gets optimal support from the system while he or she is still in control. Also, violating a requirement, directive, or request is detected and displayed, but can be accepted by the planner. In this paper we describe the crew rostering problem for the catering crews of the High Speed Train and the Harmony CDR solution in more detail.

Remembering Richard Freling, 1967 – 2002, a great colleague and a fine friend.

1. Introduction

ORTEC has been developing Decision Support Systems containing Operations Research components in various areas, such as railways, human resource management, aviation, production planning, vehicle routing and asset and liability management. One of such a system that ORTEC has been developing is Harmony CDR.

Part of the product line Harmony® CDR is an interactive crew planning system that combines the flexibility and creativity of planners with the computational power and effectiveness of a computer. It is able to automatically generate rosters for crew, while satisfying the needs of managers, planners, operational crew and unions. The planner remains responsible for generating rosters, in which he or she is supported by Harmony CDR.

With Harmony CDR the planner can analyze scenarios and use his or her creativity to develop an optimal solution. Because the system has been developed in close co-operation with end-users, it is implemented in the everyday practice of crew planning processes.

In this paper we will focus on the application of Harmony CDR for creating the rosters for the catering crew on board of the Thalys, the High Speed Train connecting Paris (and beyond), Cologne, Brussels, and Amsterdam. Furthermore, we give some insights in the modeling and Operations Research techniques that we use to mathematically represent and solve the crew rostering problem. Finally, we give some conclusions and directions for future research.

2. A more detailed introduction to Harmony CDR

Since 1995 the Harmony CDR system has been developed and applied to different situations in railway as well as aviation industry. More information on these situations can be found in [1], [2] and [3]. The following philosophy on the crew planning process is the basis for Harmony CDR system:

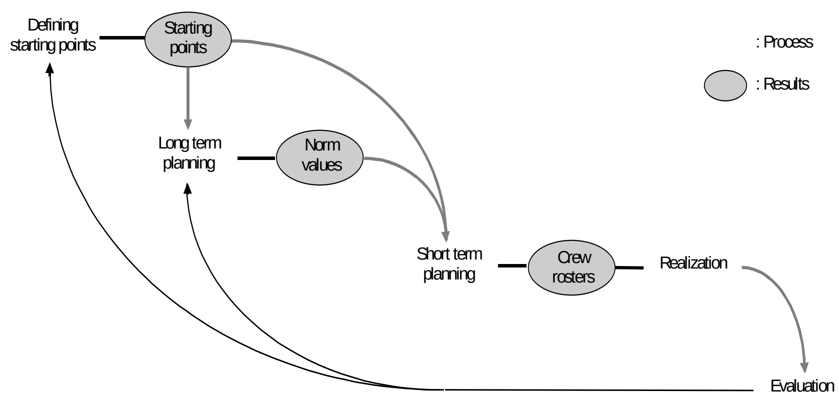

Figure 1: The planning process

Starting Points are determined by management and are influenced by aspects like the desired number of crew, the desired service levels and the desired robustness of a set of crew rosters (e.g. the influence of delays on the rosters). Harmony CDR assists management in determining the needed capacity for a set of tasks (and as a result the need for hiring extra, possible external, crew). These Starting Points results in norm values that can be used by the planners for the short term planning. These norm values restrict the freedom of the planner in creating the rosters and serve as guidelines. Additionally, between the publication of the rosters and the operations the planner must be able to handle mutations in the planning, e.g. caused by sickness or schedule changes. During realization the planner has to handle delays and other disruptions. After realization, the decision support system should generate several reports on different aspects of the planning to enable management and the planners to evaluate the results.

Harmony CDR is perfectly able to assist management and planners in this planning process. Determining the needed capacity for different scenarios can support management. These scenarios can differ for example in the number of tasks that have to be carried out, with their characteristics, and the relation between objectives of the management and the operational crew. An automatic roster generator supports the planners. Furthermore, the planner can manually assign work to crew. This enables him to plan e.g. days off, meetings and requests. The set of rosters is displayed on a sophisticated planboard. Here, different kinds of work are depicted in different colours and double clicking on such a portion of work displays a window with detailed information. In addition, the planner is able to swap, delete, move and enter portions of work. If this results in the violation of a rule or regulation, the planner is notified and can choose to either accept the violation and perform the change or undo the change. In addition, Harmony CDR has extensive report facilities on all kinds of aspects of the panning process, such as an overview of the hours worked by the crew, a delay overview, and information on the service level. In the following figure we give a screen shot of Harmony CDR in full action:

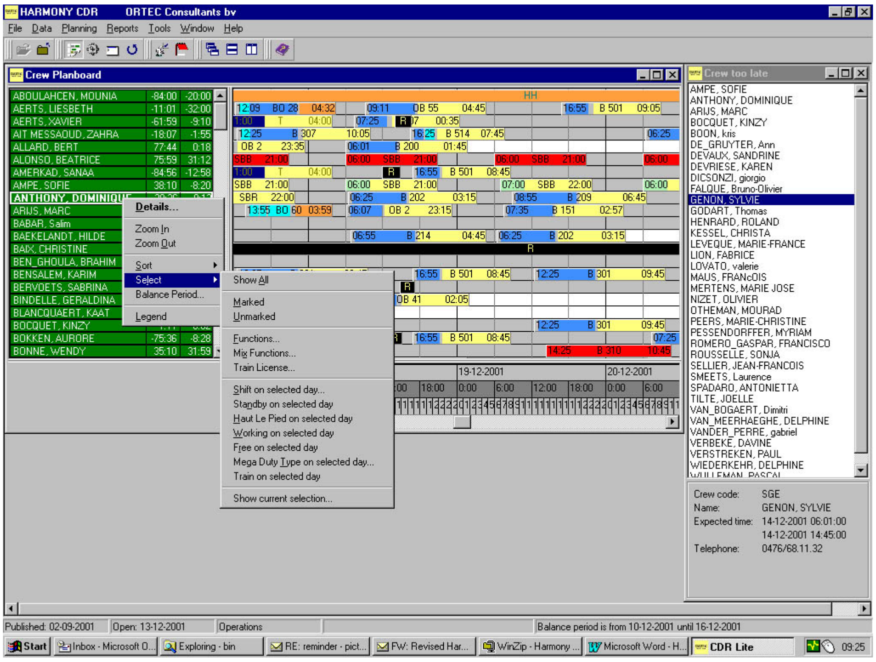

Figure 2: A screen shot of Harmony CDR

As mentioned before, Harmony CDR can be configured to handle peculiarities of different applications, while the look and feel of the system remains the same. Parts of this system have been used for a regional airlines' crew rostering, for railway crew scheduling and now also for rostering the catering crew on the Thalys High Speed Train.

3. Description of the High Speed Train case

The Thalys is the High Speed Train that connects Amsterdam, Brussels, Cologne, Paris and Geneva. It provides fast connections between the major cities of northwest Europe and is a service provided jointly by the Belgian, French, Dutch and German railways. Besides drivers and conductors there is also catering crew present on these trains. The company that accommodates the catering is different from the company that operates the Thalys trains. In this section we discuss the specific situation and work processes of the catering crew.

In this case, we do not consider long-term crew planning, while the realization and evaluation consists roughly of standard functionality, which was described in the previous section.

The catering company employs approximately 150 catering crew and assigns some 425 duties on a weekly basis. Generally, these 150 catering crew are not always sufficient to carry out all duties. Therefore, the company hires external crew whenever this is necessary. Another aspect is that the catering activities on the Thalys are divided in two classes, where crew can be restricted to carry out work of one class only.

According to planners' practice, several standby rosters for a whole week are created to improve the robustness of the set of rosters. These standby rosters are assigned cyclically to a crew and are quite heavily used. There are two types of standby rosters. The first type of standby aims to resolve e.g. sickness of a crew. In this case one or more duties of one crew are entirely transferred to the crew on standby. The second type of standby aims to resolve disruptions such as delays, where a standby crew replaces a delayed crew a part of a duty. One can imagine that, the tasks in this second type of standby roster are not that well matched.

A planner manually creates duties that represent tasks for one day. An important objective here, besides efficiency, is to start and finish as many duties as possible in the same location. As, in this case, it is impossible to have the same start and end locations of all duties, a crew needs to lay over somewhere away from his or her homebase. When this occurs, the crew has to return to his or her homebase the day after this layover. It is thus not allowed to plan two consecutive layovers for a specific crew.

While creating the rosters it is important that the workload is distributed as evenly as possible, of course taking the part-time and full-time contracts into account. In addition, it is also important that a crew on average works approximately as many hours as indicated by his contract. Balancing of the workload is implemented using a history of a fixed number of weeks (say 4) for the crew.

Finally, there are also several rules that a roster has to comply with. Here we name some of the most important ones:

(1) A maximum number of duties that can be assigned to a crew.
(2) A maximum number of duties that can be assigned consecutively to a crew.
(3) A maximum number of working hours for every crew.
(4) A minimum period of rest between two consecutive duties for a crew.
(5) A crew has to have one weekend off in every two weeks.

Of course, there are also rules that deal with the construction of the duties. The planner takes these rules into account while creating the duties.

With this background, we are able to start the discussion of the automatic roster generator that we developed.

4. The automatic roster generator for this application

Crew scheduling and rostering problems are usually modeled with set partitioning or set covering type of formulations. These formulations are then solved using a column generation technique, see e.g. [5], [6] for a crew scheduling setting and [7] for a crew rostering setting. Such an algorithm is also implemented for Harmony CDR (see e.g. [2]) but we decided to implement a different algorithm for this specific application. This algorithm is based on successively solving Linear Assignment Problems (LAP), which performed quite well although the algorithm is less powerful and less flexible then a column generation approach.

We first introduce a variant of this mathematical model and thereafter we discuss how we apply it in our setting:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \qquad (1)$$

subject to:

$$\sum_{j=1}^{m} x_{ij} \leq 1, \qquad \forall i = 1, \ldots, n \qquad (2)$$

$$0 \leq x_{ij} \leq 1, \qquad \forall i = 1, \ldots, n, j = 1, \ldots, m \qquad (3)$$

In this formulation, the index *i* represents the duties that have to be assigned and the index *j* represents the available crew. The decision variables x_{ij} thus indicate whether or not duty *i* will be assigned to a crew *j*. If this is true it results in costs c_{ij}. The objective (1) tries to minimize the costs, while the constraints (2) restricts the feasible solutions to solutions where at most one crew will be assigned to every duty. Because of the structure of this problem, it suffices to model the decision variables as continuous on the interval [0, 1]. The costs emphasize the workload distribution as well as penalties for not assigning work to a crew.

In the following flowchart we depict the steps of the automatic roster generator. After the flowchart we describe the different steps in more detail.

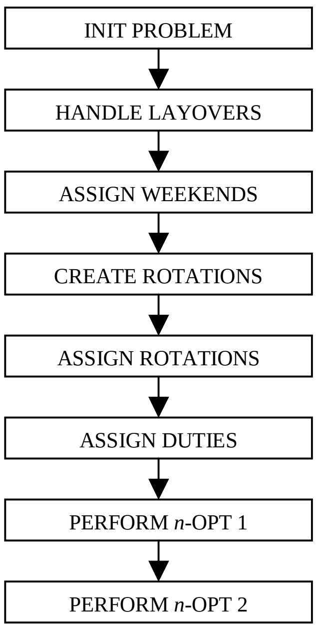

Figure 2: A flowchart of the automatic roster generator

We start with initializing the problem. Here, we determine the necessary input for each crew (e.g. the workload in the history, and fixed assignments in the week of planning). Furthermore, we determine which crew should be assigned to the standby week. Following the initialization, we handle the current layovers. Although all duties still have to be assigned, it might be that someone has a layover out in the period of planning. This can be caused by the last duty of the previous planning week or by fixed duties in the current week. We assign duties to crew such that all crew are at their homebases when they do not have to work. The assignment has to comply with the rules and regulations. After this step, we plan weekends for the crew that did not have the previous weekend off.

Typically, some duties that the planner has created do not start and end in the same location, but you are able to create rotations of two duties on consecutive days that do start and end in the same location. Because these rotations consist of two duties, they are harder to plan. As a result they are given a higher priority than duties and are planned first. The objective of this LAP is to assign rotations to crew in such a way that the period between the previous layover and the current is evenly distributed. Of course, the rules and regulations have to be respected.

The following step in the algorithm is to assign the remaining duties to the crew. Fixed duties, weekends off and rotations have already been assigned. This assignment takes place on a day-by-day basis. The objective is to assign as many duties as possible and to minimize the deviation between the actual working hours and the hours in the contract of all crew. Rules and regulations have to be met. Typically, some duties remain unassigned.

Now, we perform an *n*-opt strategy on a day-by-day basis to try to assign some more duties, while respecting rules and regulations. Because in principle the whole roster is known, swapping the duties of two crew may result assigning one previously unassigned duty more. As always, the rules and regulations have to be respected. This way as many duties as possible have been assigned to crew.

In a last step, we try to distribute the workload evenly among the crew given the assignments of duties from the previous step, again complying with the rules and regulations.

5. Analysis of the automatic roster generator

This algorithm reflects the practice of the planners when they manually create the rosters. Therefore, it is very intuitive for them to understand what happens. Furthermore, the resulting set of rosters is displayed on the planboard, where the planner is able to analyze and manipulate the result of the automatic roster generator.

In general, one focuses on an even distribution of the workload for crew rostering. In this case, however, it is possible that several duties remain unassigned and extra crew need to be hired from outside. Therefore, the objective to use a minimum number of crew is also very important in this setting.

A typical case for the catering crew consists of around 150 crew and 425 duties that have to be assigned to them. Given the duties, the algorithm described in the previous section takes approximately 90 seconds in total.

Dependent on the setting, the automatic roster generator is able to reduce the number of crew with 2%-5%, which directly translates into cost reductions. Of course, there is also a significant decrease in the needed time to create a set of rosters. This enables planners to explore different scenarios and to manually manipulate the generated set of rosters, while still gaining time with respect to the old situation.

6. Conclusions and future research

In this paper, we described Harmony CDR, which is a flexible and user-friendly crew management system and part of the ORTEC Harmony® product line. The system has been applied to several different problems, such as crew scheduling in railway industry and crew rostering in railway as well as airline industry. It is based on a sound philosophy on crew planning and results in an efficient interaction between the computer system and the human planner.

Harmony CDR contains an automatic roster generator that takes duties, created by the planner, as well as information on the crew as input and sequentially applies several variants of the Linear Assignment Problem to create a set of rosters. It is able to save 2%-5% on the number of duties compared to a human planner. This directly turns into financial benefits because the catering organization typically needs to hire external crew for carrying out some of the duties.

Currently, we are investigating the possibilities of a duty generator that can assist the planner in creating the duties, which is at the moment done manually. We expect to find a set of duties, which is at least as good as a manually constructed set, according to certain objectives of course. Furthermore, we should be able to construct such a set in a fraction of the time that the planner needs. This way we can support the planner even better in creating different scenarios for the total set of rosters.

In addition, we are trying to analyze the generated set of rosters with the planners as well as the catering crew. This analysis should point out aspects for a higher improvement of the "welfare" of the catering crew.

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