ADVANCED DUTY ROSTER-PLANNING TOOL

BACKGROUND DOCUMENT

Duty Roster Planning Optimization Using Mathematical Modelling in Region Zealand (DK)

Background Document for Invitation to Market Dialogue

June 2020, Sorø, Denmark

Content

1 Introduction

In recent years, hospitals have experienced an increased focus on capacity use. A substantial part of health service expenses consists of hospital payroll costs. When the economy is under pressure, optimal allocation of clinical staff and thus good workforce management tools are of particular importance.

The Danish Region Zealand strives to improve work force management to obtain better use of available work force in its hospitals, including more just duty roster planning. Since 2016, the department for Data and Development Support in cooperation with clinical departments has worked to obtain better duty roster planning by using mathematical optimization. From the end of 2016 to November 2018, the department carried out a project 'Duty Roster Optimization' with support from the Danish Ministry of Health. As part of the project, mathematical models and related algorithms and software for decision support for duty roster planners were developed to proof of concept level.

The tool has been experimentally implemented in two clinical departments. The results show considerable potential in the application of mathematical modelling in duty roster planning: Better planning and use of resources, reduced costs for duty roster planning, transparency in availability and allocation of resources, as well as better and more just duty rosters that can take into consideration staff members' requests and preferences, as well as formal requirements such as collective agreements and other legal regulations.

2 About duty roster planning

High levels of specialization among clinical staff, multiple shift types, collective agreements and other legal regulations on national, institutional and departmental level concerning working hours, salaries, and duty roster notification time are among the high number of variables that make health care duty roster planning a complex and time-consuming task. The duty roster planner has to make sure to plan in accordance with all the formal requirements and take into consideration staff members' requests based on preferences and needs.

Very often, duty roster planners located on the individual clinical departments are responsible for working out the duty rosters with some support from centralized IT departments. Irrespective of whether such a duty roster planning process is manual in whole or in part, the relevant information is only systematized to a limited extent. At best, information is accessible in notebooks, e-mails and handbooks. However, a lot of information depends on the duty roster planner's knowledge of staff members and work routines at the department and may be applied more or less intentionally.

Region Zealand identified the large body of collective agreements as one of the most significant sets of variables complicating duty roster planning along with staff member's requests. None of the workforce management systems or specific duty roster planning systems identified in a market research by Region Zealand addressed these variables in an adequate and sufficiently simple way to meet the Region's needs. Neither as part of larger workforce management systems nor as stand-alone or plug-in solutions complementing the (semi) manual duty roster planning or digital workforce management systems.

3 Development of an advanced duty roster-planning tool

In order to increase efficiency in capacity use in hospitals, the department for Data and Development Support has tested the potential of mathematical methods to optimize duty roster planning in clinical departments. This entails a shift from a highly experience-based and intuitive

duty roster planning process to a more empirical data-driven and analytical approach, which again requires that all necessary information is available as structured and treatable data.

Due to the many complicated issues with planning in the health sector, Region Zealand has established a research and development cooperation between the Department of Data and Development Support and the Technical University of Denmark's division for Operations Management. The purpose of the cooperation is to conduct research in and develop decision support tools for a variety of planning tasks.

To ensure that mathematical methods and algorithms to solve planning problems are developed based on hospital needs, research and development is based on hospital data and organization.

The Department of Data and Development Support identifies problems in planning that are of high relevance to the hospitals, drives the development of algorithms and software and organize the implementation of the methods under development and handles the daily administration of the methods. The Technical University of Denmark uses the Region Zealand algorithms for research in health care planning with operational analytical methods and gives input to the Department of Data and Development Support; so that Region Zealand can be sure that their algorithms are up do date.

To work with the duty roster project a development team consisting of staff from the Department of Data and Development Support, the duty roster planner from a clinical department, and a PhD student from the Technical University of Denmark was established.

The development took place in three overlapping phases:

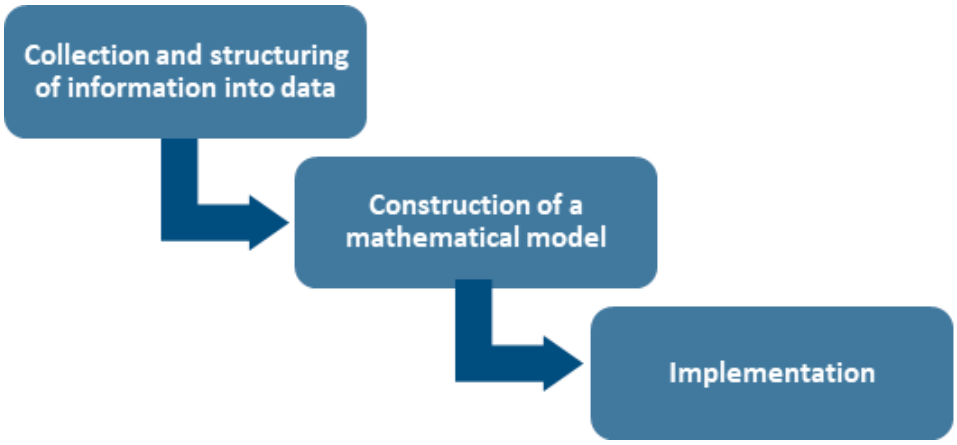

Fig. 1: Illustration of development process

3.1 Collection and structuring of information into data

The development team's first step was to methodologically analyse, categorize and structure information such as:

- Shift types incl. start and end times, days off, and other 'alternative' shifts
- Staff member data such as contractual hours, competencies and preferences
- Staffing requirements, such as number of staff and competencies needed at different times
- Staff members' wishes and demands for the duty roster
- Undesirable work patterns
- Collective agreements and other regulations regarding salaries, breaks, resting days etc.

As the purpose of the data collection was to create a digital replica of the duty planner covering all imaginable local needs, it was essential at this point in the process to uncover and understand both the formal requirements and the tacit knowledge of the current duty roster planning process. For that reason, the team identified and collected the information in close cooperation with the duty roster planner at a clinical department, which had agreed to be test partner.

The complex information packages were then analysed and restructured into categories in which all elements are either 'local' (e.g. types of shifts related to the individual staff member) or general (e.g. duty roster as a giant spread sheet). The categories consists of unambiguous data units, each data unit representing a restraint on the duty roster. The data units are characterized as either soft or hard constraints, the latter being the most critical.

Due to the ambition of covering all local needs, the selection of data constraints in the advanced duty roster-planning tool is considerably wider and more detailed compared to known systems. However, this may complicate the transformation from a local tool to a generic system. To make that transfer, it may be necessary to reduce the complexity of the tool somewhat by cutting of some options such as the possibility to make ineffective plans or limitations that are administrative demanding.

3.2 Construction of a mathematical model

Based on the new uniform set of structured data, the team developed a tool designed to transform data input from the clinical departments into applicable duty rosters that comply with the restraints in the data set and hence with the formal and informal requirements to the duty roster. The core of the tool is an optimization code based on a set of algorithms for calculation and preparation.

In the code, all data concerning an individual staff member are collected in a staff member object. Constraints that are not to be altered (e.g. length of shifts) are embedded in the code.

The goal was to explore how mathematical optimization models can contribute to the duty roster planning work and ensure optimal capacity use. One of the first realizations obtained was that the shift towards data-driven duty roster planning does not only challenge how data is structured and treated. It also entails important changes in the way the duty roster planner must view and work with the planning. Therefore, the team had a very close dialogue with the duty roster planner throughout the process to achieve a common understanding of duty roster planning in practice and be able to turn it into an applicable software tool.

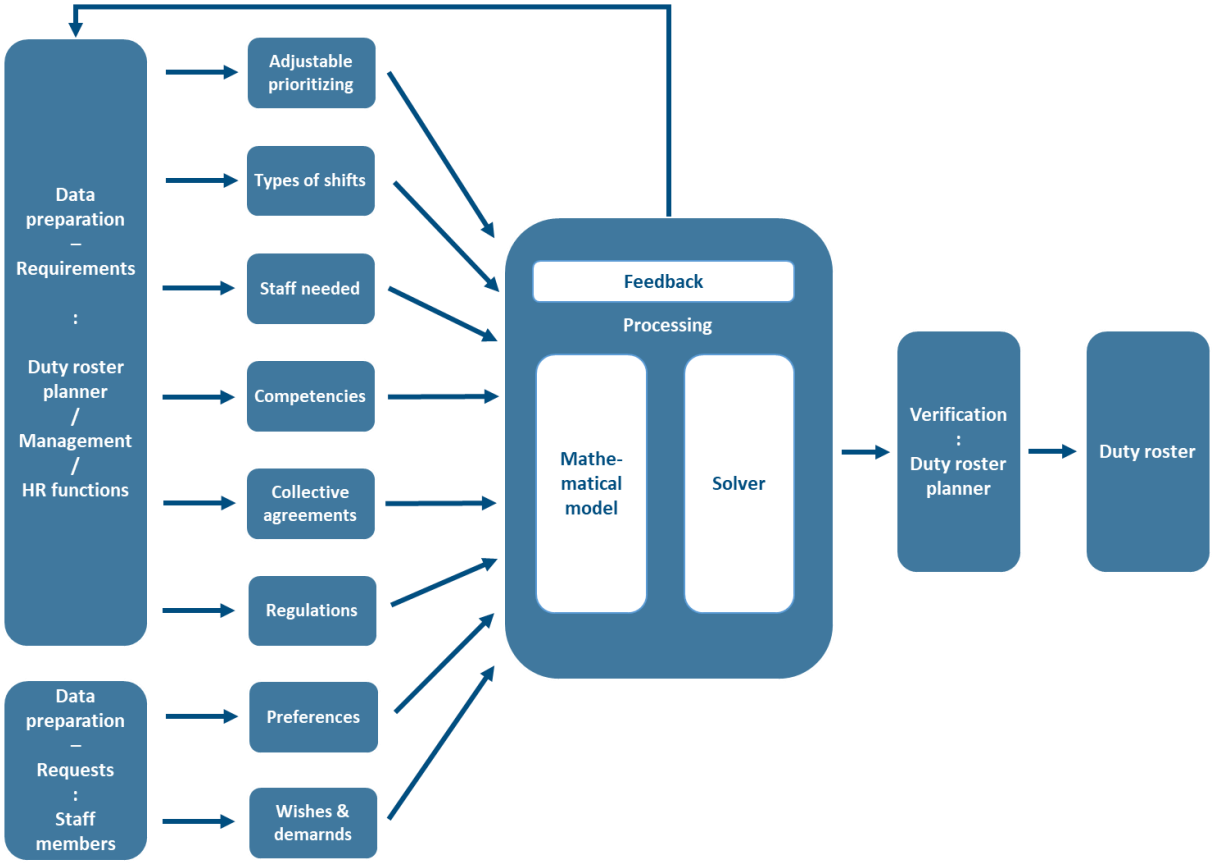

Figure 2: Illustration of duty roster process – detailed data constraints

3.3 Implementation

The duty roster tool is developed, tested and implemented on a proof of concept level and has delivered viable duty roster planners for more than 36 working months (all together).

Two clinical departments in Region Zealand hospitals have implemented the duty roster-planning tool. The department for intensive nursing at Nykøbing Zealand hospital was the first ward to test the duty roster-planning tool as a support decision tool in an iterative process of implementation, evaluation and improvement. Subsequently, the department for internal medicine at the hospitals in the three towns Næstved, Slagelse and Ringsted implemented the duty roster-planning tool in October 2018 for the production of duty rosters.

Like in the data collection and structuring process, the implementation was carried out in close dialogue between the duty roster planner and the development team. This time concerning the duty rosters produced in order to reduce possible inconveniences and minimize the amount of time needed by the duty roster planner for the final adjustments to the duty rosters.

The processes of data collection, construction of the mathematical model, and implementation were overlapping and continuous as each part influenced what was needed in the others as they progressed. Before the full implementation, the development team and the first test department had a test period, during which ‘shadow duty rosters’ were produced and quality assured by the duty roster planner to catch inexpediencies.

4 Current status

4.1 Technical set-up

The Region Zealand duty roster module consists of three elements:

- A web portal in which the staff members can enter their wishes and needs. Information from the web portal is transfered into the commercial workforce management system used in Region Zealand (currently OPUS, provided by KMD) along with information from duty roster planners (mainly local information) and the central HR department (general regulations and standard staff information).
- .CSV templates for structuring of data constraints (= the different categories in Figure 2 above, e.g. wishes, regulations and types of shifts). The workforce management system then transfers input data from the web portal, duty roster planners and HR to the relevant .CSV files.
- A modeller in which the algorithms are coded in Python: the core of the advanced duty roster-planning tool.

In order to solve the mathematical optimization models, a mathematical optimization solver is needed. The development team used Gurobi as it fulfilled all the technical needs at project level. The solver produces an automatically generated duty roster in a .CSV file, which is quality assured by the duty roster planner – if necessary in dialogue with staff members concerning adjustments. Once the duty roster is finalized, the duty roster planner enters the .CSV file into the workforce management system, which then provides the duty roster planner in its own format to the duty roster planner and the staff members.

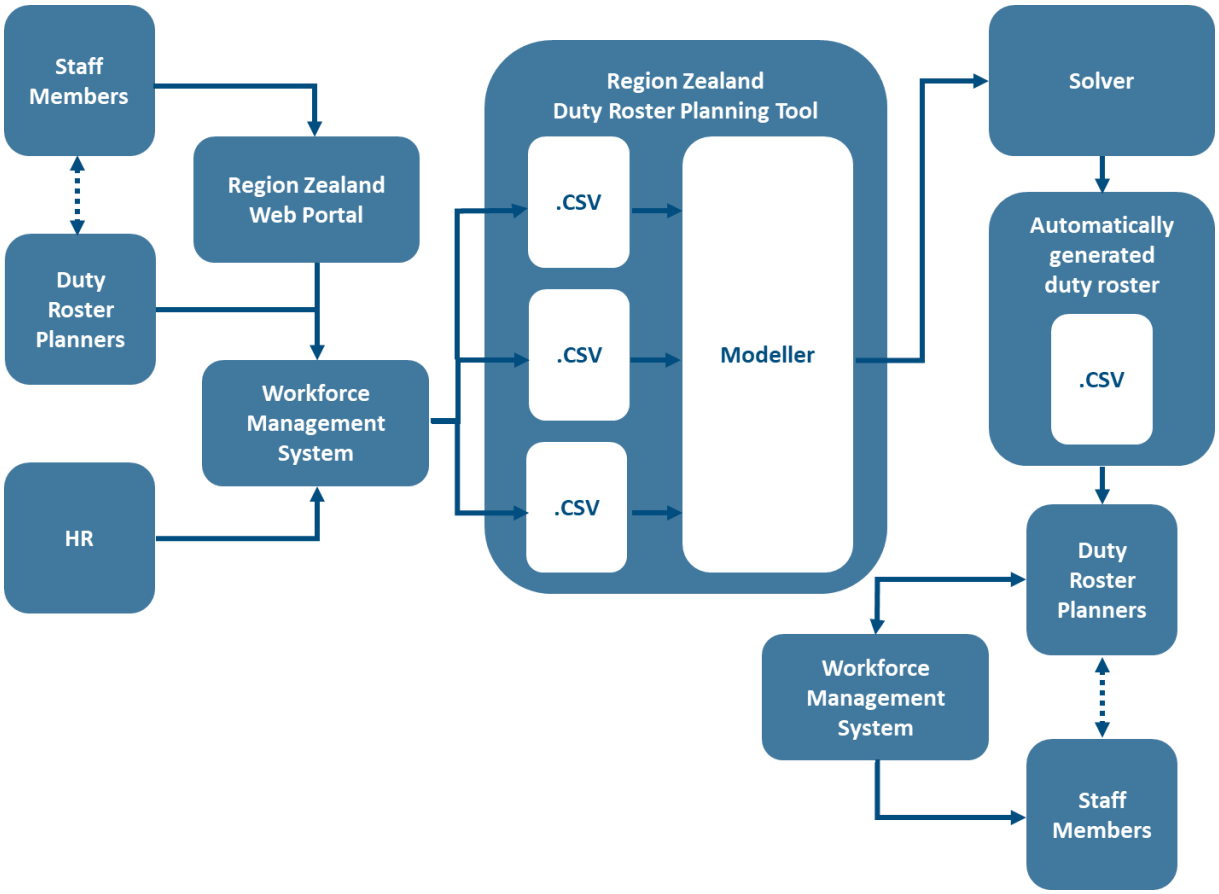

Figure 3: Illustration of duty roster process – detailed workflow

Depending on the local processes and institutional needs, the duty roster planner can also distribute the duty roster as simple .CSV files or other relevant format without going through the workforce management system.

4.2 A new proces for duty roster production

The pilot tests of the use of mathematical models as duty roster planning decision support tools have led to changes in the production of duty rosters. The process can be separated into three phases:

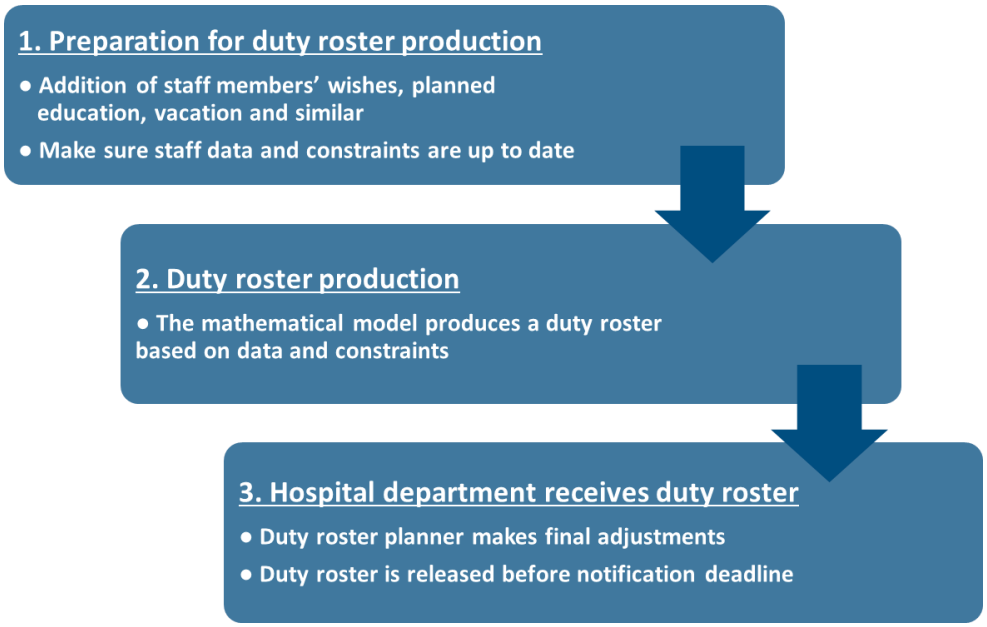

Figure 4: Illustration of the duty roster production process

After the end of the development project, the two departments continued using the duty roster-planning tool.

5 Results, learnings and potential

5.1 Results

By developing and implementing a tool based on algorithms that process large amounts of structured data, Region Zealand has demonstrated that a data-driven approach to duty roster planning can contribute significantly to optimization of duty roster planning.

The test departments have identified several remarkable results:

- Easier duty roster planning as collective agreements and other legal regulations, staff requirements, staff members' wishes and other constraints are automatically taken into account
- Improved transparency in duty roster planning as such as well as resource needs and allocation
- Better use of staff resources, as staff members and shifts are distributed based on mathematical models for optimal distribution.
- Transparency about and overview of data input and constraints for a duty roster, including that the duty roster planners must actively consider and take a stand regarding the information on each staff member such as competencies and holiday requests.

- Improved exposure of duty roster quality due to objective performance indicators for meeting of staff members' requests, number of staff called in and / or other selected constraints.
- Guarantee for compliance with collective agreements and other legal regulations, as the tool does not produce a non-compliant duty roster.
- Focus on staff perspective because of the possibility to take into account individual circumstances and needs.
- Increased degree of shift allocation fairness for staff members as duty rosters are based on general rules for a uniform distribution of shifts combined with consideration of individual wishes and preferences.
- The duty rosters reveal shifts and functions with extra strain.
- The web portal for entering information and wishes facilitates communication between staff members and duty roster planners as it is developed with both groups in mind.

One of the expectations for the project was that the mathematical models would reduce time spent by duty roster planners' on planning. This expectation is met in both test departments. After a few months of running in, the duty roster planner at the department for intensive nursing at Nykøbing Falster Hospital reduced the time spent on producing a four-week duty roster from 16 hours to 8 hours. The results at Næstved, Slagelse and Ringsted also show significant reductions of about 50 % of time spent on duty roster planning.

Good and fair duty rosters contributes to the creation of an attractive workplace with better chances of successful staff retention. The duty roster planner at the department of intensive nursing at Nykøbing Falster Hospital specifically stresses the increased degree of fairness in the duty rosters as one of the advantages.

5.2 Learnings

The process of developing and testing the advanced duty roster tool has provided important learnings. The most fundamental being that use of mathematical modelling requires and entails a fundamental change in the methodological approach to duty roster planning both at systemic and duty roster planner level.

The identification and transformation of formal as well as tacit knowledge into applicable data was a long and iterative process. Some necessary information was only pointed out during the test and implementation phases when the duty roster planner evaluated examples of duty rosters and identified shortcomings and inexpediencies resulting from a lack of information.

A precondition for maximum use of the advanced duty roster-planning tool in active management of capacity and resource planning by the duty roster planners is that they understand how the model acts and how the data input influences a duty roster. The duty roster planners involved in the project have experienced a process of transformation that have been critical to the development of the mathematical models.

5.3 Potential

The project has demonstrated multiple gains in the use of mathematical models for duty roster planning and the Region Zealand estimates that this approach has a considerable potential, especially when it comes to larger departments with many employees and departments where management has clear targets and a focused approach to the use of duty roster planning possibilities. The main experiences and knowledge gained on duty roster planning and

mathematical modelling will be included in the future work with duty roster planning in the region in general.

Furthermore, several requests from other hospital departments in Region Zealand and other Danish regions and well as market research has indicated a significant commercial potential for an advanced duty roster-planning tool that uses mathematical modelling to take into account large amounts of data and constraints.

However, due to the large and locally variable amounts of data and constraints and the fundamental changes needed in the approach duty roster planning it is not possible to make a direct transfer of the tool in its current version on a larger scale. Further work is needed in order to explore the possibilities for further development and commercialization of the duty roster-planning module. The Region Zealand has entrusted FIERS, the Foundation for Innovation and Business Promotion in Region Zealand, with this task.

Alongside continuous market research, the first step of FIERS was a novelty search/patentability assessment. The examination showed that even though patenting is not an option due to the nature of the tool, it does seem to constitute a more realistic and useful improvement to duty roster planning than known methods.

Next step is to carry out the present market dialogue with the purpose of:

- Pursue further optimization - from decision support tool to a fully automated duty roster-planning tool with need for only checking and minor changes by duty roster planner.
- Ensure adjustability to different settings / scaling possibilities
- Identify correct business model and qualify business case
- Identify next steps, e.g. Private Public Partnership, Innovation Partnership, direct commercialization.
- Identify potential commercial / development partners

6 Prior Market Research - Timeline

Prior to the market dialogue, FIERS and Region Zealand has conducted the following actions for market research:

- Prior and parallel to development project: Desk research for systems offering workforce management systems carried out by researchers, Region Zealand Department of Data and Development Support and Purchase Department
- May and November 2019: Presentation for representatives from the Danish regions at two national seminars about Duty Roster Planning in a Strategic Perspective
- December 2019: Presentation of the duty roster-planning tool at a meeting in a network for health care workforce management IT facilitated by the Welfare Tech cluster, Denmark.
- Spring 2019: Patent assessment carried out by Zacho (intellectual property consultancy house)
- Spring / summer 2019: Consultancy about market situation for workforce management systems with Rato.Blue consultant
- Spring 2019: Meeting with KMD for initial testing of market relevance
- 2019 and 2020: Continuous desk research by FIERS and Region Zealand staff

7 Disclaimer

We assess that the information released in English with this invitation to market dialogue provides true and adequate information and ensures transparency and equal treatment, and that translation of the further information from Danish into English will not provide significant additional information.

The material in this market dialogue is published subject to errors and omissions.