DEVELOPMENT OF IT SOLUTION FOR OPTIMIZATION OF NURSE ROSTERING

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Abstract- Effective use of working time and the allocation of resources are important activities to enable competitive business performance. The main challenge in majority of Slovenian hospitals is to provide efficient, quick and equitable distribution of working time of the employees. Since the nurse roster is being created physically on paper the need for a special software for nurse rostering emerged. Commercial solutions for nurse rostering are not adjusted for Slovenian environment thus this research proposes an IT solution, developed for the University Medical Centre Ljubljana (UMCL) in Slovenia. Results of preliminary testing have shown that in the quality of nurse rostering was importantly improved. We have also shown the economic viability of the proposed solution.

Keywords- Health Information system, Work Performance, Human Resource Management

I. INTRODUCTION

In order to improve business process and increase competitiveness of the organization the management should be focused on personnel development and effective exploitation of human resources [1, 2]. The main challenge in majority of Slovenian hospitals lies in providing efficient, quick and equitable distribution of working time of the employees. Hence rostering can be described as determination of activities within a specific time period with specific human resources [3]. In Slovenian hospitals it is typically created manually within individual departments.

As shown in [4] the employees at UMCL, specifically nurses, are not motivated for work and constantly feel that they are being on the verge of burnout. One of the major reasons for such situation lies in recent financial crisis that caused the emergence of restriction on new employments. This has a negative effect on the quality of patients' health. However, such situation could be avoided by the use of specific computer software for optimization of nurse rostering.

Rostering problems could be solved by the use of several methods that are available in the literature [5, 6]. In general there exist integer programming methods [7, 8] and heuristic approaches [9], among which the majority of methods rely on mathematical programming, branch and bound techniques or goal programming [10], while the rest of them are based on iterative algorithms [11]. For the purposes of solving the nurse rostering problem also several simulation models could be used [12]. However, there exists no solution for nurse rostering at UMCL hence the nurse rostering is still done manually on paper.

To gain insight on the discussed topic we have conducted several interviews with relevant employees and observed the rostering process and its implications for the personnel. We have recognized several problems that arise from manual rostering:

- Manual preparation of roster is time consuming process. In average the head nurse spends 4 to 8 hours per month to prepare roster for nurses, who work in three shifts.
- Manually prepared rosters need to be manually entered into application for recording working time, for which in average the head nurse spends 2 to 3 hours per month.
- Rosters are not assuring equal distribution of working time for employees. The number of night-time, full-day and afternoon shifts and the number of overtime hours of personnel deviate considerably on a monthly basis. Such rostering can lead to burnout and bad mood of the employees and undermines the relationships among them.
- The process of making a roster manually is uneconomical.
- Professional staff is overloaded with administrative work.

Based on the abovementioned we can estimate the total elapsed time to be 7,5 hours on average per month. On the market there are some specific solutions for hospitals that enable automatic rostering but are not adjusted for Slovenian environment and are thus not suitable for use at UMCL. Therefore we introduce the development of computer software for roster optimization to mitigate identified problems at UMCL. This paper has four sections. Section 2 defines the methodology, section 3 presents the results and economic analysis and section 4 provides conclusion.

II. METHODOLOGY

To determine and examine the current and desired state and to identify specifics of the anticipated computer application the method of system analysis

was selected. For development of algorithms a combination of exact and heuristic methods was used. To implement and preliminary test the solution the prototyping approach was used. The economic viability of the proposed IT solution was considered by the cost-benefit analysis.

We have designed the functionalities of computer application in two phases. The first phase considers answering the question what the application will do and what should be the inputs and outputs of the application. The second phase considers answering the question how and with what algorithms it is possible to achieve the desired transformation of inputs into outputs. The identified software functionalities are:

- Compliance with laws and internal rules of the UMCL.
- Planning of night shifts in packages of 2, 3 or 4 consecutive days. Every package of night shifts must be followed by one rest day.
- No deviation is allowed for matching the actual number of staff with planned one within individual shift.
- The minimum and maximum number of night shifts among employees can differ by no more than 2, which is the minimal package of night shifts.
- The minimum and maximum number of whole-day shifts among employees can differ by no more than 2 since the whole-day shift in general come in packages of 2.
- The minimum and maximum number of afternoon shifts among employees can differ by no more than 2.
- The number of overtime hours may deviate for max 20.
- The number of work-free weekends may deviate for max 2.
- The level of automatization can be defined by user (entirely automatically, entirely manually or in combination).
- Facilitation of monitoring of planned and realized working hours within individual shifts for each employee and for any period.
- Data should be exported in a form, which enables automatic import into databases used by other applications.
- Data must be appropriately protected. Only authorized users can access the application.

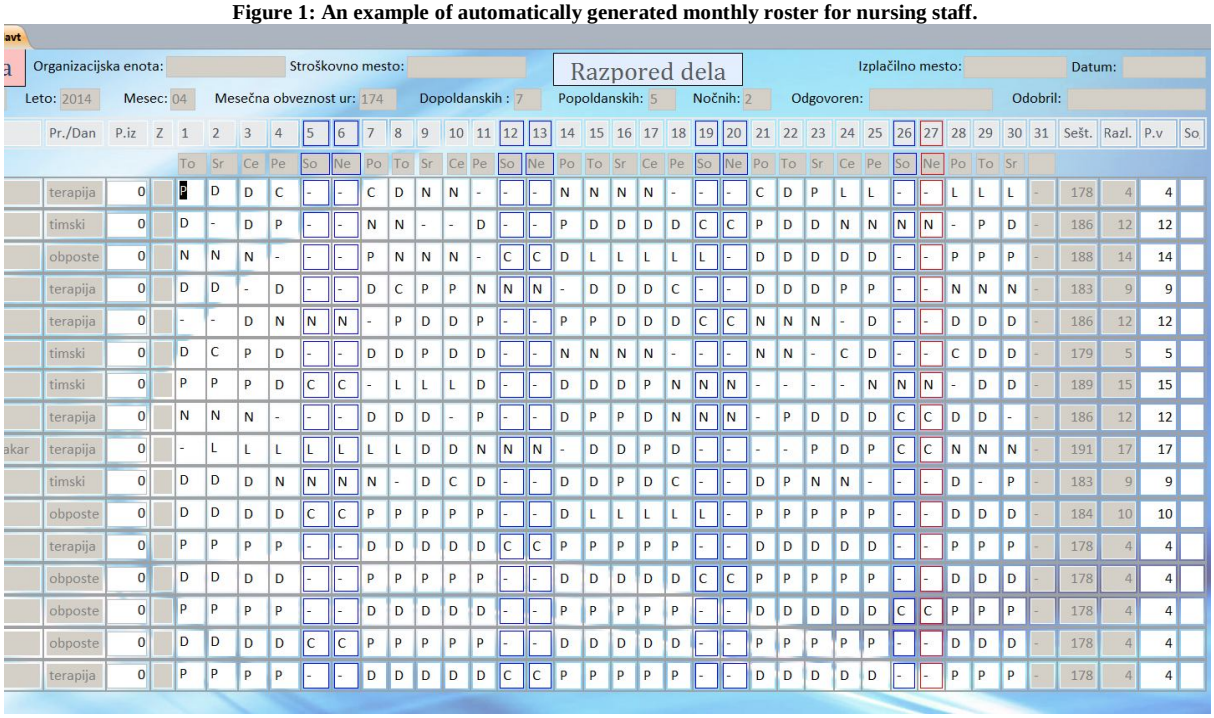
The development of application, which was based on prototyping method, first tackled the design of the initial sample of prototype solution. Prototype was then progressively improved on the basis of the feedback from user testing. The development of proposed application took about two years.

III. RESULTS

The example of fully automatically generated monthly roster for nursing staff in a selected department is shown in

Figure1. The names of employees have been deleted.

Figure 1: An example of automatically generated monthly roster for nursing staff.



Preliminary testing of proposed IT solution performance was implemented in Department 1 at Clinic for Otorhinolaryngology (ORL) at UMCL by comparing the computer generated solutions with manually designed rosters. Considered criteria (on monthly basis) and the comparison are shown in Table 1.

Table 1: The comparison between manually and automatically designed roster in the department 1 at ORL clinic.

Criterion	Manual roster	Automatic roster
Maximum difference in night shifts between personnel	5	2
Maximum difference in daily shifts between personnel	4	2
Maximum difference in afternoon shifts between personnel	8	2
Was number of night shifts allowed exceeded?	No	No
Number of blocks with more than 4 sequential night shifts	3	1
Number of deviations of morning shifts from desired ones	6	0
Average time needed for preparation of roster	4-8 hours	½ hour

In ORL clinic they have problems with high number of absences thus maximum difference in night shifts between personnel, maximum difference in daily shifts between personnel and maximum difference in afternoon shifts between personnel are the most important criteria for them. Empirical results show that the developed application significantly outperforms manual design.

Economic analysis was conducted by a cost-benefit analysis, where only tangible benefits were taken into account. On the basis of the interviews we estimate that the number of users for proposed solution at UMCL equals 100. The average time needed to manually prepare the roster is estimated to be 6 hours. In average the automatic roster is prepared in 30 minutes. Thus the time reduction is 5,5 hours on average, which amounts 5,5 (hours) x 100 (users) = 550 working hours per month. Taking into account that the minimal hourly rate of graduate nurse equals 8,54 EUR we can estimate the tangible benefits of the proposed solution to be 4.697 EUR per month. The yearly savings would thus amount 56.364 EUR.

On the basis of monthly licensing prices of computer applications that are comparable to solution proposed in this research, we can estimate the cost of one licence per user per month to be 30 EUR. Hence the total annual cost of the proposed solution at the UMCL would amount 100 (users) x 30 (EUR) x 12 (months) = 36.000 EUR.

Thus the total economic benefits can be estimated to be 56.364 – 39.000 = 17.364 EUR. As shown above the annual cost would not exceed predicted benefits therefore the introduction of proposed computer application would be economically justified.

CONCLUSION

The goal of presented research was to develop an effective IT solution for nurse rostering at UMCL. Introduced application enable monitoring of planned and realized working hours of personne. It strive to equalize planned and actual number of employees in the morning, afternoon and night shifts.

Taking into account the identified criteria for comparison it is possible to conclude that automatically designed roster performs better than manual one. The automatic solution is generated in 30 minutes, which is, in comparison with 5,5 hours needed on average for manual design, app. 91 % faster. Additionally, the solution uniformly distributes working shifts among employees which consequently affects the increase of their satisfaction at work.

By cost-benefit analysis we have shown that the implementation of the proposed solution into UMCL would be economically justified.

In the future we will thoroughly test the developed IT solutions in several departments at UMCL and, if necessary, add some refinements. The solution could also be modified for use by other users in the health care system (i.e. physicians, ambulances drivers, kitchen staff, etc.). Some analytical functionality could be added as well, such as module for analysing daily deviations from required values or an overall view of the employees' rosters for specific users.

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