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Shift Planning Problem for Cardiology Department in A State Hospital Considering Radiation Exposure of the Physicians

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Abstract – Planning the shift days of physicians is an important decision problem encountered in almost every hospital in real life. The cardiology department is a department that physicians are exposed to radiation. During angiography, physicians are exposed to high doses of radiation. As a result of radiation exposure, thyroid cancer, cataract, blood cancer and urinary diseases can be seen in healthcare workers. These diseases can be occupational diseases. In this study, shift plans are created by considering radiation exposures. A mathematical model is proposed for the shift planning problem. The proposed mathematical model for the solution of the problem is solved with CPLEX. The proposed solution method was applied in a state hospital. As a result, with the proposed solution method, physicians are assigned to shifts quickly and successfully.

Keywords – Shift Planning, Mathematical Model, Radiation Exposure, CPLEX, Space Between Two Shifts

I. Introduction

In this study, shift planning of cardiologists is carried out. In many shift planning problems in the literature, only the economic factors have been taken into account, and the necessary personnel have been assigned to the shifts at the required time with minimum cost in order to ensure the continuity of the system. Psychological, sociological and physiological boundaries are ignored while creating shift plans. However, physicians are one of the most important resources in health systems. The dissatisfaction of the workforce with the working conditions negatively affects the performance of the system. As a result, shift planning is an important process that affects employee motivation. It is not sufficient to consider only employee preferences in the shift planning problem.

The problem addressed in this study was defined through the shift planning of cardiologists. Cardiologists work in public hospitals, university hospitals, private hospitals or private imaging centers. All these departments are exposed to radiation due to the angio. Radiation exposure can adversely affect human health depending on factors such as distance from the radiation source, amount of radiation received and exposure time. The effect of radiation can be decreased by increasing the space between consucutive shift days. A mathematical model has been proposed for the solution of the problem. The proposed solution method was applied for a public hospital staff.

The first part of the study is the introduction. In the second part, literature review was made. The problem discussed in the third chapter in detail through the real life problem. In the fourth chapter, mathematical model is given. In the fifth chapter, the mathematical model is applied for a state hospital. The last section is the conclusion section. In the conclusion part, the study is evaluated and future studies is given.

II. Literature

Atmaca et al. [1], addressed shift planning of nurses. They proposed a mathematical model and used GAMS program to solve it. Öztürkoğlu and

Çalışkan [2], scheduled the working hours of Erciyes University Medical Faculty Hospital intensive care nurses. They took into account the preferences of the nurses. They solved the mathematical model using the LINDO program. Legrain et al. [3], made two types of scheduling by scheduling nurses and hospital equipment in their study. They solved their multi-objective model with CPLEX. Yanmaz [4], intended to reduce the workload of doctors in the emergency department. He proposed a mathematical model to find the most appropriate number of doctors to be found in the emergency room according to the patients admitted to the hospital and solved this model with GAMS. In the second phase of his study, he used simulation and compared the two results. Varli et al. [5], discussed physical and psychological fatigue on nurses in their studies. They developed a mathematical model for the balanced and fair assignment of nurses working in a state hospital in Kırıkkale to shifts and solved it with goal programming. They also benefited from the ILOG Cplex Optimization program in their studies. Varli and Eren [6], created nurses' monthly work plans with goal programming. They also took into account the special requests of the nurses. They solved the model they created with the help of the ILOG Cplex Optimization program. Karayel and Atmaca [7], conducted a scheduling study aiming to find the most appropriate number of nurses for the hospital in order to ensure the satisfaction of the patients coming to the hospital and to plan a fair shift for the nurses. In the solution, integer mathematical modeling was proposed and solved with the GAMS program. Aktürk et al. [8], discussed the nurse scheduling problem of a hospital in Kırıkkale. In the solution of the problem, they benefited from the goal programming model, which is one of the multi-objective optimization techniques. Bayraktar [9], scheduled the three-month shifts of nurses working in the pediatric emergency department in Denizli. Geçici and Güler [10], studied the nurse shift scheduling problem of a hospital's cardiovascular surgery service. Öztürkoğlu [11], addressed shift planning problem of the nurses. He made the scheduling in a fair and balanced way in accordance with the hospital's rules. Keskin et al. [12], discussed the nurse scheduling problem in their study. They developed a mixed integer linear programming model. They carried out their studies in the emergency and intensive care units of Erzurum Regional Training and Research Hospital.

III. Problem Definition

Planning the doctors' shift days is an important decision problem encountered in almost every hospital and department in real life. The cardiology department is a branch on duty, and unlike other branches, it is a department where physicians are exposed to radiation. During angiography, doctors are exposed to high doses of radiation in an environment with irregular radiation. The radiation dose depends on the distance between the radiation source and the staff. As a result of radiation exposure, thyroid cancer, cataract, blood cancer and urinary diseases can be seen in healthcare workers. These diseases are seen as occupational diseases. Physicians should use lead shields while working in order to minimize the effect of radiation on the body. They must take one month leave a year. In addition, for a fair workload distribution, the number of weekend shifts should be as equal as possible. In addition, the preferences of physicians should be taken into account. Maximizing the space between two consecutive shifts allows physicians to more easily remove radiation from their bodies. The application was made in the Cardiology Department of a State Hospital. There are 6 doctors in the department and the schedule is prepared monthly. The schedule is prepared manually for the next month by the department head in the current month. A physician can hold a maximum of 7 shifts per month. There should be at least 48 hours between two shifts.

IV. Mathematical Model

The constraints of the problem are as follows:
A physician have to be assigned to shift every day.
The shifts to be held on Saturday and Sunday should be shared equally among the physicians.
A physician cannot be assigned to shift for two consecutive days.
The time between two consecutive shifts should be equal to predetermined value.
Physicians' preferences should be taken into account.

Indices
i: Physicians i={1,…,6}
j: Days j={1,….,30}
Parameters

$$Pr_{ij} = \begin{cases} 1; \textit{If physician i wants to be assigned} \\ \quad \textit{a shift for day j.} \\ 0; \quad \textit{Otherwise} \end{cases}$$

$$Vj = \begin{cases} 1; \textit{ If day j is a weekend day.} \\ 0; \quad \textit{Otherwise} \end{cases}$$

Decision variables

$$Xij: \begin{cases} 1; \textit{If physician i is assigned to} \\ \quad \textit{shift for day j.} \\ 0; \quad \textit{Otherwise.} \end{cases}$$

C: Maximum shift number over all physicians

Constraints

Min Z=C (1)

$\sum_j x_{i,j}=1 \quad \forall j$ (2)

$\sum_j x_{i,j} * V_j \geq 1 \quad \forall i$ (3)

$x_{i,j} + x_{i,(j+1)} \leq 1 \quad \forall i,j$ (4)

$x_{i,j} + x_{i,(j+1)} + x_{i,(j+2)} \leq 1 \; \forall i,j \in \{1, \ldots, 28\}$ (5)

$x_{i,j} \leq Pr_{i,j} \quad \forall i,j$ (6)

$C \geq \sum_j x_{i,j} \quad \forall i$ (7)

$x_{i,j} \in \{0,1\}$ (8)

Equation (1) is the objective function, and the number of shifts of the physician holding the most shifts is minimized. Equation (2) ensures that a physician is assigned to shift every day. Equation (3) ensures that the number of weekend shifts is greater than 1 for every physician. Equation (4) prevents assigning same physician to consucutive shift days. Equation (5) ensures that the space between shift days is at least 2 days for each physicians. Equation (6) ensures that physicians' preferences are satisfied. Equation (7) determines the maximum number of shift over all physicians. Equation (8) is the sign constraint.

V. Application

Six cardiologists work at the State Hospital. Physicians' shift days should be determined on a monthly. The mathematical model has two parameters and eight constraints. In the Table 1 Pr_{ij} parameter is given. The GAMS program was used to solve the mathematical model. The problem is solved in 2 seconds. The shift plan is given in Table 2.

Table 1. Pr_{ij} parameter

Days	1	2	3	4	5	6	Days	1	2	3	4	5	6
1	1	1	0	0	1	1	16	1	0	0	1	1	1
2	0	1	1	1	1	1	17	1	1	1	1	1	1
3	1	0	1	1	1	1	18	1	1	1	1	0	1
4	0	1	1	1	1	1	19	1	1	1	1	1	0
5	1	1	1	0	1	1	20	1	1	1	1	1	1
6	1	1	0	1	0	0	21	0	1	1	1	1	1
7	0	0	1	1	1	1	22	1	1	1	0	1	1
8	1	1	1	0	1	1	23	1	1	1	1	1	1
9	1	1	1	1	1	1	24	1	1	1	1	1	1
10	1	1	0	1	1	1	25	1	0	0	0	1	1
11	1	1	1	0	0	1	26	1	1	1	1	0	0
12	1	0	1	1	1	1	27	1	1	0	1	1	1
13	0	1	0	1	1	1	28	1	1	1	1	1	1
14	1	1	1	0	0	1	29	0	1	1	1	1	1
15	1	1	1	1	1	1	30	1	1	1	1	1	1

Table 2. Shift plan

Days	1	2	3	4	5	6
1						Shift
2					Shift	
3	Shift					
4						Shift
5			Shift			
6				Shift		
7						Shift
8					Shift	
9			Shift			
10				Shift		
11		Shift				
12	Shift					
13					Shift	
14		Shift				
15				Shift		
16					Shift	
17			Shift			
18	Shift					
19					Shift	
20				Shift		
21		Shift				
22	Shift					
23			Shift			
24		Shift				
25						Shift

26				Shift		
27		Shift				
28						Shift
29			Shift			
30	Shift					

With this study shift plans are prepared quickly. Physicians do not need to devote their time to charting. Physicians' preferences and radiation exposure are taken into account for the shift planning problem. In December, the weekend was eight days. While the first and sixth physicians were assigned to shift for two weekends, the second, third, fourth and fifth physicians were assigned to one shift for weekends.

VI. CONCLUSION

In this study, shift planning problem is addressed for cardiology physicians of a State Hospital The preferences of the physicians and rules of the hospital were also taken into consideration. The prepared schedule meets the demands of both physicians and hospitals. It is aimed to increase the service quality and satisfaction of the physicians. The optimal solution can be obtained in a very short time with integer programming. In the hospital, shift scheduling was prepared manually by a physician. By solving the mathematical model in a few seconds in the GAMS program, the time loss in long manual preparation is eliminated. It takes 2-8 hours for the physician to manually prepare a shift schedule and the optimal solution can not be guaranteed. With this study, optimal shift plans can be obtained using the proposed mathematical model.

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