Nurse Scheduling Optimation with Various Assignment Pattern at ABC Hospital Using Goal Programming Method

Sigit Ananda Murwato[1] dan Abdullah Shahab[2]
[1]Department of Technology Management, Sepuluh Nopember Institute of Technology, Surabaya
[2]Department of Mechanical Engineering, Sepuluh Nopember Institute of Technology, Surabaya
e-mail: sigit.ananda@gmail.com

***Abstract*—In fulfilling health services in hospitals, the availability of human resources (HR) which includes doctors, nurses, midwives, and so on, plays a very important role. In terms of amount and dominant existence in the hospital in providing health services to patients is a nurse. The role of hospital management in maintaining the availability of nurses is to plan a good schedule. Without a good resource scheduling plan, the services will not be optimal and the costs will hard to control. This research aims to optimize the nurse scheduling. Existing schedule did not pay attention to specific time that have different load to another. Management feels that a lot of idle time is experienced by some nurses. Therefore, from the data that occurred in the past there will be observations that every 4 hours will occur how many services performed and how many nurses needed. Furthermore, by using Goal Programming method, several priority objectives are made, such as how to minimize the deviation of nurses needed in one shift or slot. Then how to minimize the excess target number of nurses who work in one week. And then minimize the excess number of nurses who work on the night shift. The suggested mathematical model has been implemented using Lingo Software. Work patterns have been suggested to improve schedules quality based on different load of services that occur in specific time. The suggested approach can be used for any similar staff scheduling problem in the next research.**

***Keywords*—Lingo Software, Priority Objectives, Staff Scheduling, Work Patterns.**

I. INTRODUCTION

A hospital is an organization or company that operates in the field of health services, which generally consists of outpatient services, inpatient services, and emergency services. Maintaining human resources become essential because they have contributed significantly to meet the increasing demands of public health needs [6]. Organizing is one of the important key of management function that allow stakeholders to keep the good quality of services. With the high amount of nurses if not supported by good scheduling planning, the costs may arise both tangible costs such as employee wages, or intangible costs such as work fatigue due to heavy scheduling. It is important to observe several points in determining nurse scheduling decisions such as the distribution of shifts, nurse work hours, vacation requests, also the number of nurses needed in each shift. Keep in mind that the aim of nurse scheduling is to minimize the total cost to be spent. Management teams need to find the scheduling plan by placing the number of nurses as optimal as possible.

This research was conducted at ABC Hospital located in Surabaya City. This hospital serves groups of patients such as BPJS users, General, and VIP. At the moment, management teams were considered to improve service quality by making efficient scheduling patterns according to the needs per day. The addition of nurse resources was also included to be considered if the number of demands is not proportional. A goal programming model is developed in this paper for nurse scheduling with the aim to minimize the cost.

Table 1.
Conditions of the assignment pattern in one day

*day	Monday					
*slot	0812	1216	1620	2024	2404	0408
	1	2	3	4	5	6
*1st pattern	A1*X1111	A1*X1112	A1*X1123	A1*X1124	A1*X1135	A1*X1136
*2nd pattern	A2*X1231	A2*X1212	A2*X1213	A2*X1224	A2*X1225	A2*X1236
*3rd pattern	A3*X1331	A3*X1332	A3*X1313	A3*X1314	A3*X1325	A3*X1326
*4th pattern	A4*X1421	A4*X1432	A4*X1433	A4*X1414	A4*X1415	A4*X1426
*5th pattern	A5*X1521	A5*X1522	A5*X1533	A5*X1534	A5*X1515	A5*X1516
Target number of nurses needed	25	30	45	40	35	50

II. PROBLEM DESCRIPTION

The staff (nurse) scheduling problem is one of the most popular forms of scheduling among practitioners. Hospitals have challenges in how to be able to fulfill all the demands and also provides the efficiency of nurse assignments at the same time. The assumptions can be summarized as follows:

a. Hospital staffs are specific to nurses.
b. Nurses works well.
c. Three shifts in one working day (24 hours): (morning, afternoon, and night).
d. Each shift lasts for 8 hours.
e. Nurses can only work as much as 1 shift in 1 working day.
f. Nurses have the possibility of working the night shift at least 1 time a week.

This research is about to deliver optimum nurse scheduling with the intent to minimize cost related to staff resources. Hopefully we can give alternative solution for the hospital to make a decision about nurse scheduling.

III. ASSIGNMENT PATTERN

In order to give more possibilities to find the optimum schedule, we need to produce scheduling that has variations

Table 2.
Scheduling pattern from mathematical calculation using Lingo

Day	Monday						Tuesday					
Slot	0812	1216	1620	2024	2404	0408	0812	1216	1620	2024	2404	0408
	1	2	3	4	5	6	1	2	3	4	5	6
Pattern 1	-	-	1	1	-	-	-	-	1	1	-	-
Pattern 2	-	1	1	-	-	-	-	1	1	-	-	-
Pattern 3	-	-	-	-	-	-	-	-	-	-	-	-
Pattern 4	1	-	-	-	-	1	1	-	-	-	-	1
Pattern 5	1	1	-	-	-	-	1	1	-	-	-	-
K	45	7	12	1	0	24	44	8	13	1	0	24

Day	Wednesday						Thursday					
Slot	0812	1216	1620	2024	2404	0408	0812	1216	1620	2024	2404	0408
	1	2	3	4	5	6	1	2	3	4	5	6
Pattern 1	-	-	1	1	-	-	-	-	-	-	-	-
Pattern 2	-	1	1	-	-	-	-	1	1	-	-	-
Pattern 3	-	-	-	-	-	-	-	-	-	-	-	-
Pattern 4	1	-	-	-	-	1	1	-	-	-	-	1
Pattern 5	1	1	-	-	-	-	-	-	1	1	-	-
K	45	9	11	1	0	25	38	8	10	1	0	24

Day	Friday						Saturday					
Slot	0812	1216	1620	2024	2404	0408	0812	1216	1620	2024	2404	0408
	1	2	3	4	5	6	1	2	3	4	5	6
Pattern 1	-	-	1	1	-	-	-	-	-	-	1	1
Pattern 2	-	1	1	-	-	-	-	1	1	-	-	-
Pattern 3	-	-	-	-	-	-	-	-	-	-	-	-
Pattern 4	1	-	-	-	-	1	1	-	-	-	-	1
Pattern 5	-	-	-	-	1	1	-	-	1	1	-	-
K	33	7	7	1	0	25	31	6	6	1	0	19

Day	Sunday					
Slot	0812	1216	1620	2024	2404	0408
	1	2	3	4	5	6
Pattern 1	-	-	1	1	-	-
Pattern 2	-	-	-	1	1	-
Pattern 3	-	-	-	-	1	1
Pattern 4	-	-	-	-	-	-
Pattern 5	1	1	-	-	-	-
K	3	2	2	1	0	1

in pattern selection. In Table 1 will illustrate the conditions of the assignment pattern that are used to find the optimal number of nurses based on field observations.

The condition of the assignment pattern is explained as follows:

1. Table 1 is an example of the working patterns in one day.
2. First, the pattern grouped into slots that each slot has 4 working hours. So in 1x24 hours of total service operation in one day will have 6 slots.
3. Second, grouped into shifts that each shift has 2 working hour slots. In one day only have 3 shifts.
4. To provide more possibilities and choices of nurse assignment in one slot, there are 5 patterns that have different shift start times. The example in Table 1 that is filled in red is the first shift in each pattern.
5. Number in the bottom of the table in Table 1 is the target number of employees to meet services needs within the span of one slot. In later mathematical model will look for the possibility of the many choices of shifts, slots, and which patterns will be filled that is the most optimum.

IV. THE MATHEMATICAL MODEL

A mathematical model is formulated to find the assignment patterns that gives minimum number of nurse needed. The sequence of making a mathematical model process will be described below.

A. Decision Variable

The following binary decisions variable is used.

$$X_{ijkl}\begin{cases}1 & if\ nurses\ work\ in\ day\ i, pattern\ j, shift\ k, and\ slot\ l.\\ 0 & otherwise.\end{cases} \quad (1)$$

With indexes as follows:

i : days (i = 1, …, 7)
j : pattern (j = 1, …, 5)
k : shift (k = 1, …, 3)
l : slot (l = 1, …, 6)

B. Formulating Model Constraint

1) Each slot is given a target number of nurses needed.

$$\sum_{j=1}^{5}\sum_{k\in K} A_j X_{ijkl} - d_{il} = C_{il} \qquad \begin{matrix} i = 1,\dots,7 \\ l = 1,\dots,6 \end{matrix} \qquad (2)$$

2) Maximum nurses available to work in a week.

$$\sum_{j=1}^{5} A_j + dm - dp = B \qquad (3)$$

3) Amount of nurses work in a night shift.

$$\sum_{i}^{7}\sum_{k\in K}\sum_{l=5}^{6} A_j X_{ijkl} - dk = K \qquad j = 1,\dots,5 \qquad (4)$$

4) Each nurse is given at least one slot night shift.

$$A_j - \sum_{i}^{7}\sum_{k\in K}\sum_{l=5}^{6} m X_{ijkl} < 0 \qquad j = 1,\dots, \qquad (5)$$

5) Work hour each day is 8 hours or 2 slots.

$$X_{ijkv} - X_{ijkw} = 0 \qquad \begin{matrix} i = 1,\dots,7 \\ j = 1,\dots,5 \\ k = 1,\dots,3 \\ (v,w) \in l \end{matrix} \qquad (6)$$

6) Each nurse only work 1 shift each day.

$$\sum_{k=1}^{3} X_{ijkv} < 1 \qquad \begin{matrix} i = 1,\dots,7 \\ j = 1,\dots,5 \\ v \in l \end{matrix} \qquad (7)$$

C. Objective Function

1) Goal 1

Minimize deviation from the target number of nurses needed each slot.

$$min\ Z = \sum_{i=1}^{7}\sum_{l=1}^{3} d_{il} \qquad (8)$$

2) Goal 2

Minimize deviation from the nurses available to work in a week.

$$min\ Z = dp \qquad (9)$$

3) Goal 3

Minimize deviation from the amount of nurses work in a night shift.

$$min\ Z = dk \qquad (10)$$

V. IMPLEMENTATION AND RESULT

As described from previous section, this mathematical model has 3 goals to meet the objective function. Those goals need to run sequentially and cannot be skipped because the next goal has dependency value from previous goal. The result indeed met all the constraint. Using Lingo software, the optimum solution is obtained. Table 2 show the optimum schedule. Nurses are on rows while a column is dedicated to slots, shifts, and days. The number of demands shows in the bottom of each slot. Work patterns for nurses are illustrated in grey area.

VI. CONCLUSION

Nurse scheduling optimization result in this research produce scheduling pattern that can cover number of nurses needed in each time slot. This pattern also addressing the work balance that every nurses can have at least one night shift every week. To gain better result in both for the hospital and for the next research regarding nurse scheduling, there is several things that can be added into the decision variable. Cost element can be added with the purpose to have better view of scheduling optimization.

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