Nurse Scheduling Model with the Work Sift and Work Location

L Harlina¹, O S Sitompul², S Nasution³

¹,³ Department of Mathematics, Universitas Sumatera Utara, Medan, 20155, Indonesia
² Department of Computer Science, Universitas Sumatera Utara, Medan, 20155, Indonesia

* liyaharlina@gmail.com

Abstract. This paper discusses the nurse scheduling model with work shifts and work locations. In general, scheduling is a very complicated problem and often occurs in agencies that operate 24 hours a day, one of which is a hospital whose mission is to provide maximum patient health services. Scheduling nurses with work shift and work location can have a positive impact, namely the efficiency of time and work effectiveness so that it is very important in optimizing human resources to be able to improve their quality. The goal is to design a nurse scheduling model with work shift and work location with the objective function of minimizing the number of nurses working in the hospital by paying attention to the constraints associated with the regulations of the hospital so that the nurse's schedule is fair. This model is solved by the Integer Linear Programming (ILP) method, it is hoped that it will be better and can overcome the difficulties in manually scheduling.

1. Introduction

Scheduling is a very complicated problem and often occurs in agencies that operate 24 hours a day, one of which is a hospital. The hospital is a social institution engaged in the field of public health services that must be run optimally. Nurses as providers of nursing services are the spearhead of hospital services, because nurses are 24 hours in providing nursing care. Nurse scheduling is one of the problems in health organizations that is difficult to solve because it can be a difficult and task time-consuming, and often complicated. Judging from the number of patients, the seriousness of the patient's illness, absences and personal requests for holidays, and the nurse's qualifications and specialization itself become several factors why nurse scheduling is difficult, including making schedules for each nurse into different working hours in the short term.

Nurse scheduling in Indonesia is classified in the guarding or shift service scheduling system, namely the morning guard service, the afternoon guard service and the night watch service. Usually nurses at the hospital at the beginning of each work period for 8 hours in one day and 40 hours in one week. The hospital can determine the minimum number of nurses to be employed so that there will be enough nurses available for each period, Kumar et al [4].

Previous research on nurse scheduling has been carried out by Yilmaz [8], namely the problemscheduling shift of nurses'with the aim of minimizing the total nurse time for a week. Bard and Purnomo [1] present nurse scheduling in the imbalance of supply and demand shift-by-shift. Kumar et al [4] examined nurse scheduling problems by analyzing the practice scheduling process, the
goal is to get a fair schedule. Trilling research et al [7] focuses on the problem of scheduling nurse anesthesiology (ANSP) to maximize a fair schedule. Lin et al [5] to create an equal and fair nurse's shift schedule, Lin et al [6] to make shift schedules for nurses and holidays. Capan et al [2] to optimally assign a nurse's shift by fulfilling a special scheduling policy for Neonatal Intensive Care Unit (NICU).

In operations research, many nurse scheduling problems have been formulated into mathematical models. But there are still many who handle the problem of employee scheduling manually. The mathematical model that is common in this scheduling problem is a linear programming model that is a model that has an objective function and constraints in the form of linear equations or inequalities. Recent advances in integer programming and continued to increase computing power have facilitated good quality solutions to many nurse scheduling problems. In the literature, several studies have used optimization methods to solve nurse scheduling problems. Like Integer Programming Lin et al [6], Bard and Purnomo [1]. Integer Linear Programming Yilmaz [8]. Mixed-Integer Programming Capan et al [2]. Genetic algorithm Lin et al [5].

In this paper will be discussed nurse scheduling models with work shift and work location using the method Integer Linear Programming (ILP) by minimize the number of nurses.

2. Research methods
The stages of completion are:

2.1. Determining assumptions
The beginning of this modeling begins with determining the assumptions that apply in terms of nurse scheduling. Assumptions that are identified are pre-conditions that have been carried out before calculating

2.2. Decisions on decision variables.
At this stage determined the decision variables that apply mathematically. All types of decision variables will be identified in an integer form.

2.3. Determine contrains
At this stage the problem boundaries are set on nurse scheduling.

2.4. Determine objective functions
In this stage an objective function is determined in mathematical form by combining all existing constraints / constraints.

2.5. Implementing calculations
After all stages and components have been determined and modeled mathematically by using Integer Linear Programming (ILP) so that a nurse scheduling model has been obtained with work shifts and work locations.

3. Result and Discussion
Each nurse is allocated to daily shifts and gets assignments on a predetermined shift. Work shift is divided into three namely morning shift (08.00-15.00), afternoon shift (15.00-21.00), night shift (21.00-08.00). It is assumed that there is no special day for holidays except holidays on the day determined by the head nurse. The other assumptions that can simplify the problem in this paper are:

1. A nurse works not at most one shift in one day
2. A nurse does not work exactly 6 working days a week
3. Waiting time between shifts is ignored
The notation to be used in making mathematical models is as follows:

- \( i \) = Index for working days \((i = 1, 2, ..., I)\)
- \( j \) = Index for shift work \((j = 1, 2, ..., J)\)
- \( m \) = morning shift \((08.00-15.00)\)
- \( a \) = afternoon shift \((15.00-21.00)\)
- \( n \) = night shift \((21.00-08.00)\)
- \( k \) = index for nurses \((k = 1, 2, ..., K)\)
- \( L \) = Index for work location \((l = 1, 2, ..., L)\)
- \( d_{ijkl} \) = Number of nurse work for shift \( j \) in day \( i \) location \( l \)

Parameters used:

- \( X_i \) = Number of nurses \( k \) needed in morning shift on day \( i \)
- \( Y_i \) = Number of nurses \( k \) needed on shift afternoon on day \( i \)
- \( Z_i \) = Number of nurses \( k \) what is needed on the night shift on day \( i \)
- \( I \) = Number of working days \((I = 1, 2, ..., 6)\)
- \( J \) = Number of work shifts \((J = 1, 2, 3)\) workers
- \( K \) = Number of nurses \((K = 20)\)
- \( L \) = Number of location \((L = 1, 2, 3)\)
- \( T \) = Total number of working days \((T = 7)\)

To get the nurse scheduling model in this study using the Integer Linear Programming method. This decision variable is an integer number 0 or 1. An integer problem 0-1 relates to a situation where the decision variable is yes or no. This paper seeks optimal decisions about whether a nurse \( (k) \) is scheduled, on day \( (i) \), shift to \( (j) \), and location \( (l) \). So that the decision variable in this linear programming integer formulation is \( x_{ijkl} \).

\[
X_{ijkl} = \begin{cases} 
1, & \text{if nurse } k \text{ work for shift } j \text{ in day } i \text{ location } l \\ 
0, & \text{otherwise} 
\end{cases}
\]

Based on Hillier [3], the general form of a linear program model is

\[
\max (\min) \ Z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots + c_nx_n \tag{1}
\]

So, nurse scheduling is proposed as follows:

\[
\min Z = \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \sum_{l \in L} x_{ijkl} \tag{2}
\]

Objective function (2) minimize the number of nurses.

Constraints

\[
s.t \sum_{k=1}^{K} m_{ikl} \geq X_i, \forall i \in I, k \in K, l \in L \tag{3}
\]

Constraints (3) the number of nurses who work for the shift morning on the day \( i \) location \( l \) must meet the needs

\[
\sum_{k=1}^{K} a_{ikl} \geq Y_i, \forall i \in I, k \in K, l \in L \tag{4}
\]
Constraints (4) the number of nurses who work for the shift afternoon on the day i location l must meet the needs
\[
\sum_{k=1}^{K} n_{ikl} \geq Z_i, \forall i \in I, k \in K, l \in L
\]  
(5)

Constraints (5) the number of nurses who work for the shift night on day i location l must meet the needs
\[
\sum_{j=1}^{J} x_{ijkl} = 1, \forall i \in I, k \in K, l \in L
\]  
(6)

Constraint (6) that each nurse k only gets one shift j for each day i
\[
\sum_{i=1}^{I} \sum_{k=1}^{K} x_{ijkl} = 6, \forall j \in J, l \in L
\]  
(7)

Constraint (7) to limit the number of working days assigned to nurses k and each nurse works 6 days a week.
\[
x_{i3kl} + x_{(i+1)kl} \leq 1, \forall i \in I, k \in K, l \in L
\]  
(8)

Constraints (8) for nurses k who work on shift j the night is not assigned to the morning shift the next day.
\[
\sum_{k=1}^{K} x_{ijkl} \geq d_{ijl}, \forall i \in I, j \in J, l \in L
\]  
(9)

Constraint (9) scheduling that must meet the minimum number of nurse in each shift, day and location
\[
x_{ijkl} \in \{0,1\}, \forall i \in I, j \in J, k \in K, l \in L
\]  
(10)

Constraint (10) that the boundaries are not negative and integer.

4. Conclusions
Nurse scheduling with work shifts and work locations of this research is modeled with the Integer Linear Programming method with the objective function of minimizing the number of nurses working in the hospital so that the needs of each shift and work location of nurses are fulfilled. Nurse scheduling problems can be developed also by adding to the objective function such as the cost for the needs of nurses who work with long working hours.

References
[1] Bard J F and Purnomo H W 2005 Hospital-Wide reactive scheduling of nurses with preference considerations Ieee Transactions On Software Engineering, SE-11 9 589–608
[2] Capan M, Hoover S, Jackson E V, Paul J D and Locke R 2017 Integrating nurse preferences and organizational priorities into nurse schedules – application to the neonatal intensive care unit Industrial and Systems Engineering Conference 19-24
[3] Hillier F S 2012 Introduction to Operations Research (Tata McGraw-Hill Education)
[4] Kumar B S, Nagalakshmi G and Kumaraguru S 2014 A shift sequence for nurse scheduling using linear programming problem Journal of Nursing and Health Science. 3 6 24-28
[5] Lin C C, Kang J R, Chiang D J and Chen C L 2015 Nurse scheduling with joint normalized shiftand day-off preference satisfaction using a genetic algorithm with immigrant scheme *Journal of Distributed Sensor Networks* Article ID 595419 1-10

[6] Lin C C, Kang J R, Liu W Y and Deng D J 2014 Modelling a nurse shift schedule with multiple preference ranks for shifts and days-off *Mathematical Problems in Engineering* Article ID 937842 1-10

[7] Trilling L, Guinet A and Magny D L 2006 Nurse scheduling using integer linear programming and constraint programming *Hal.Archives-Ouvertes* 651-656

[8] Yilmaz E 2012 A mathematical programming model for scheduling of nurses’ labor shifts *J Med Syst* 36 491–496