



## Optimization the number of nurses in the emergency department using linear programming technique

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### ABSTRACT

**Introduction:** Aim of current study is determination of optimal number of nurses in the emergency department of Shiraz Ali Asghar Hospital.

**Method:** Current study is an applied study and belongs to operational research (OR) studies. The population has been studied in this research, includes records of referred patients to the emergency department of hospital in 2008. Sampling was performed in the forms of stratified (monthly) and simple for all of the records and each of months respectively. Required data collection was performed from statistics notebook and also patient's records using data collection forms. After average determination of entering patients in a day at eight period in three hours, determining the type of provided services and also the period of offering nursing services (with using time information) determine optimum number of required nurses in different periods of hospital with using of linear programming technique by lingo 8 software.

**Results:** The minimum number of nurses needed in emergency department of Ali Asghar hospital regarding to desired services to the patients were obtained 1 and 3 nurses for each shift and a day respectively.

**Conclusion:** According to the results the used number of nurses in the emergency department was more than optimum number. It seems that, obtained number of nurses from quantitative methods such as linear programming technique is much less than the calculated number experimentally by the directors of nursing.

**Keywords:** Linear programming, Nursing services, Emergency department, Number of nurses

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### Introduction

The manpower in the set of capitals of any organization has a special role, because it is not only necessary along with other sources, but also it is considering as the special condition for improving organization and in spite of the other sources it can be promoted(1).

Hospital personnel scheduling problems particularly personnel of emergency department have been considered from 1980 due to their importance in quality of services for emergency patients and their satisfaction(2).

Long waiting time in the medical services delivery system can result in dissatisfaction of patients from medical care system. Many researchers and managers of hospitals are interested in solving this problem with optimum using human resources. Previous studies have been shown that shortage of nursing personnel affects on

care delivery and nursing outcomes. From the perspective of nurses, inadequate staff and heavy workload have been considered as the effective factors on the poor quality care, job dissatisfaction and workflow(3, 4).

Most of the studies have been focused on ratio of nurses to the patients. In this area, obtained results by a previous study has showed that enhancement in number of nurses working in the public wards and where cardiovascular surgery patients are treated has relation with significant decrease in mortality in the hospital(5).

In addition, as any unnecessary enhancement of personnel leads to significant enhancement of the cost of treatment, determination of optimum number of personnel particularly nurses who form major percent of total personnel is important. Indeed, great number of personnel can be both a sign of better services and excessive density of personnel(6).

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Linear programming is a mathematical model for resource allocation (capital, raw material, manpower and equipments, ...) in order to achievement of a specific goal while existence of several approach for application of resources(7).

Linear programming model consists of parts or inputs as follows(7-9):

1. The decision variables: variables that have unknown values and decision maker trying to find appropriate values for them.

2. The objective function: a mathematical function which includes the decision variables so that shows the relationships between variables and indicates the desired goal. The goal is usually maximization or minimization.

3. Profit or cost coefficients (parameter): Coefficients of decision variables in the objective function are profit or cost coefficients. These coefficients indicate values that a decision variable has in an objective function.

4. Constraints: System of equations that shows model limitations in order to achievement of the objectives. Constraints indicate limited resources for making a decision. According to the problem, Constraints may have three forms so that are shown with three symbols of  $\leq$ ,  $=$ ,  $\geq$ .

## Methods

The current study is applied research and belongs to the operational research(OR) studies. In the present study, population included records of all patients referred to the emergency department of Ali Asghar hospital (outpatient and inpatient) in 2008. In order to generalizing sample results to the population, Instead of a simple sampling stratified sampling was conducted for all of population referred to the emergency department in 2008. Then, 10% of patient records were selected as simple sampling in each month. The average number of referred patients per month in 2008 was 240 so that 24 records have been chosen randomly. Required data from the records of patients referred to the emergency department were collected using data collection forms. These data that consist of referral time to the department and received nursing services were collected from nursing note paper and physician order sheet. Using emergency department statistics notebook, the average number of patients arrival was calculated in 8 periods. Then, using data collected from records, nursing care received by patients and Percentage of patients who have received services in this department was determined. Using time study information carried by the hospital nursing management in the emergency department, the average time for performing each nursing service was calculated. Given the above information, Services delivery times were determined in each period and then the numbers of nurses needed per hour were calculated. Finally optimum number of nurses per shift using linear programming by lingo 8 software was determined. Due to making a linear programming model, the first step is to identify shifts in the hospital.

Division of work shifts of nurses was 6-hours in the Ali Asghar hospital as shown at Table1. In order to development of linear programming model, a 24-hour

period was divided into eight periods as shown in Table 2. Based on work shifts in this hospital, and also time periods of this model, a shift can include nurses from different time periods.

**Table 1.** The shift scheduling of nurses in Ali Asghar Hospital

Time	Shift
Morning	8-14
Afternoon	14-20
Night	20-8

**Table 2.** The time scheduling due to modeling

Period of time	Time
First	8-11
Second	11-14
Third	14-17
Fourth	17-20
Fifth	20-23
Sixth	23-2
Seventh	2-5
Eight	5-8

Services times and the number of nurses needed per an hour from each time period was determined using the average of patients arrival in eight time period, nursing services, service time and the percentage of patients who used these services ( Table 3) in emergency department of Ali Asghar hospital in 2008 as shown at Table 4.

In this study, different parts of model for solving the problem are as follows:

1. Decision variables:

X1: The number of nurses that their shift starts at 8.

X2: The number of nurses that their shift starts at 11 (zero).

Considering that the morning shift started at 8 and ends at 14 in this hospital, the number of nurses that their shift starts at 11 is zero.

X3: The number of nurses that their shift starts at 14.

X4: The number of nurses that their shift starts at 17 (zero).

Considering that the afternoon shift started at 14 and ends at 20 in this hospital, the number of nurses that their shift starts at 17 is zero.

X5: The number of nurses that their shift starts at 20.

X6: The number of nurses that their shift starts at 23 (zero).

X7: The number of nurses that their shift starts at 2 (zero).

X8: The number of nurses that their shift starts at 5 (zero).

Considering that the night shift started at 20 and ends at 8 in this hospital, three variables of x6, x7 and x8 are zero.

2. Objective function:

Min  $Z = x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8$

The target is obtaining the number of nurses needed.

3. constraints:

a. Limitations of time period (demand): these

limitations show the number of nurses needed in each time period.  $X1 \geq 0.81$

$$X1+x2 \geq 0.96$$

$$X3 \geq 0.59$$

$$X3+x4 \geq 0.73$$

$$X5 \geq 0.55$$

$$X5+x6 \geq 0.73$$

$$X5+x6+x7 \geq 0.33$$

$$X5+x6+x7+x8 \geq 0.30$$

b. Supply constraints: the hospital was not faced with supply constraint of nurse.

c. Restrictions of non-negativity of variables:

$$x1, x2, x3, x4, x5, x6, x7, x8 \geq 0$$

0.73 nurses in the afternoon shift ( 14-20) and 0.73 nurses in the night shift ( 20-8). Also the number of nurses needed for desired nursing services was calculated 2.42 for emergency department of Ali Asghar hospital.

Given that the number of nurses is discrete variables and less than one nurse cannot be exist, so the number of nurses needed is one and 3 nurses in each work shift and a day respectively.

### Discussion and Conclusion

Ketabi and monzavi (2006) in the Tehran doctor Chamran hospital estimated the number of required nurses for delivering services in the emergency department is 27nurses using linear programming model.

This estimation was performed using expected percentage

**Table 3.** Nursing Services, the average of services time and the percentage of patients who received these services

	Nursing Services	The Average of Service Time (min)	The Percentage of Emergency Patients Who Received These Services(%)
1	Taking ECG	7	70
2	Taking injecting drug, IV	8	100
3	Taking oral drug	6.5	64
4	Taking blood samples and follow-up its result	8.5	82
5	Checking out the vital signs(V/S)	4	100
6	Putting oxygen	2	47
7	Patient preparation for chest x-ray (CXR) and radiology request form	3.5	42
8	Installing chest lid for cardiac monitoring	3	23
9	Intramuscular injection (IM)	5	3
10	Take related work to patient transfer to other departments	24	90
11	Information to doctor for patient visit	3	100
12	The history of the patient	9	100
13	Completing the patient records	11	100
14	Writing the patient profile in the statistics notebook	2	100
15	Writing nursing note	7.5	100
16	Replacing the patient bed sheets	4	100
17	Separating device and serum and.....	6	100
18	Checking out devices, narcotics, and laryngoscope and.....	7	100
19	Oral training and pamphlet to the patient	7	100

### Results

Final result of the number of nursing personnel needed in the different work shifts in the emergency department of Ali Asghar hospital in 2008 were determined using linear programming method ( Table 5).

The final result was determined using linear programming simplex method; 0.96 nurses in the morning shift (7-9),

of referred patients and the average amount of time required due to servicing in the emergency department(10).

In the current study, also using the similar method, the number of nurses needed was estimated 3 nurses. The causes of existing differences in final outcomes of these two studies can be due to the difference in the number of their referred patients.

**Table 4.** The number of nurses needed per an hour in each period

Time period (hour)	The average number of referred patients	The average of referring per hour	Required nursing services(min per hour)	The number of nurses needed per hour
8-11	1.32	0.44	48.5	0.81
11-14	1.56	0.52	57.5	0.96
14-17	0.96	0.32	35.5	0.59
17-20	1.16	0.39	43.5	0.73
20-23	0.88	0.30	33	0.55
23-2	1.16	0.39	43.5	0.73
2-5	0.52	0.17	19.5	0.33
5-8	0.48	0.16	18	0.30

**Table 5.** Final outputs of model optimization

Variables	Output
Z	2.42
X1	0.96
X3	0.73
X5	0.73

Sinerich and jabali (2007) with the development of a linear optimization model and a simulation model have reached similar conclusions so that with having less manpower, of course with reduced length of stay of patients, have the same therapeutic outcomes(11).

Wijewickrama and takakuwa (2006) applied a linear programming model due to determination of the optimized number of physicians for outpatients in Nagaya teaching hospital in Japan. The aim of the study was to minimize the waiting time for patients. As a result, this model defined an optimal scenario that the average of waiting time was reduced up to 26%. This program had the advantage in contrast to the other scenario that it is possible to saving waiting time for patients in a day using 29 physicians instead of 31 physicians exist in the current system(12). As a result of this study that shows the number of doctors is not optimal, in the present study, also the number of nurses needed in the Ali Asghar hospital was more than the optimal number.

Centeno et al (2003) estimated the number of nurses needed with simulation using data collection about probability distribution of patients arrival times and also care times. They also indicated that the number of nurses obtained using this method, are much smaller than the experimentally calculated ones(2). This finding is consistent with our results. In 2008, six nurses were working in the emergency department of Ali Asghar hospital in such a way that two nurse's work per shift (morning, afternoon, night). Given that in each shift only one nurse is in charge or responsible as supervision and managing the emergency works, it seems that the number of nurses had been optimized. This means that three nurses were in charge for three different shifts and also three nurses were applied to service to the patients.

Considering that in charge of emergency department unlike other clinical departments should help the other nurses for direct and indirect services for patients while an emergency and during high patients referring in addition to managing of department and Also the emergency department of Ali Asghar hospital is relatively small and the average of referring patients is low so the nurse who is responsible in the department has largely off time and consequently the optimal number of nurses needed to service was determined less than 3, It can be concluded that the number of nurses working in Ali Asghar hospital emergency department in 2008, was more than the optimum number.

The following suggestions are offered for optimal use of nurses:

1. According to the results, although the number of nurses used in this department in 2008, was more than the required number but, considering the current shifts and no changing of them, and also regarding to that emergency services has a critical role in each hospital and it is not acceptable to risk about the number of nurses to service so the number of nurses cannot be decreased. In this case a solution is to increase the demand for medical services and nursing in this hospital by different methods. Applying this solutions, with having the current number of nurses and no change in numbers and shifts, human resources can be used optimal in this department. For example, due to enhancement of the number of referring patients to this hospital it can be negotiated with the Namazi hospital for its patients with excess of capacity. Considering that Namazi hospital has pediatric department like as Ali Asghar hospital, and also considering that in most times, the number of referring patients to the emergency department of Namazi hospital is more than its capacity, Ali Asghar hospital can receive some of them and service them with a contract with hospital Namazi.

2. While in the current study, the average numbers of patient inputs was applied to investigate the optimal number of nurses, demand for hospital emergency services in this hospital is varied in different months. So in this regard a flexible program can be used. This means that using variable number of nurses in different months. Hence, in this area, it can be used part-time nurses and nursing students.

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