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Optimization of Nurse Numbers in Emergency Department of a District Hospital in a Developing Country Iran, 2014

Ali Janati[1], Djavad Ghoddoosi Nejad[2], Mehdi Ariafar[3], Seyyedeh Roghayyeh Mirshojaee[4], Mohammad Mahdavi Moghaddam[5], Saaied Ghodousi Nejad[6], Majid Ghodousi Nejad[7], Morteza Arab Zozani[8] Ali Vafaee[9] & Elham Baghban Baghestan[10]

[1] PhD in Health Services management, Iranian Center of Excellence in Health Management, School of Management and Medical Informatics, Tabriz University of Medical Sciences, Tabriz, Iran

[2] PhD in Health Services management, health services management research center, institute for future studies in health, Kerman University of medical sciences, Kerman, Iran

[3] MSc student in health services management, Department of health services management, faculty of health, Mashhad University of medical sciences, Mashhad, Iran

[4] MSc student in health services management, Department of human sciences, Electronic Branch, Islamic Azad University, Tehran, Iran

[5] Social determinants of health research center, Birjand University of Medical Sciences, Birjand, Iran

[6] MA in MBA (master business administration), Sharif university of technology, Tehran, Iran

[7] BSc in engineering sciences, faculty of engineering, University of Tehran, Tehran, Iran

[8] Modeling in Health research center, institute for future studies in health, Kerman University of medical sciences, Kerman, Iran

[9] MSc in neonatal intensive care, Sarem fertility and infertility research center- SAFIR, Sarem women's hospital, Tehran, Iran

[10] Department of human sciences, Birjand Branch, Islamic Azad University, Birjand, Iran

Correspondence: Djavad Ghoddoosi-Nejad, PhD in Health Services management, health services management research center, institute for future studies in health, Kerman University of medical sciences, Kerman, Iran. E-mail: javad6463@gmail.com

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Abstract

Background: this study aims to optimize nurse numbers in emergency department of a district hospital in Iran using linear programming.

Material and methods: through observation and checklist data about average patient arrival, delivery time of care services needed for patients and number of nurses were obtained. Using linear programming optimum number of nurse needed for right delivery of services was calculated.

Results: optimum number of nurses was calculated as 12 nurses, but because of some issues in 3rd shift, real number of nurses needed for a 24 hours period is equal to 16 (12+4) nurses (12 as minimum needed plus nurses who stay and don't leave the 3rd shift till tomorrow morning).

Conclusion: Using LP models can be useful for estimating optimum number of nurses for different wards of hospitals, so they can reduce their costs and reach more productivity.

Keywords: linear programming, optimization, resource allocation, district hospital, Iran

1. Background

Considering rising needs of people in health and health care, especially services provided in hospitals and also diminishing budgets of health sectors, scientific methods is needed more than ever to optimize these resources. After failure in reaching the goal health for all till 2000, policy makers became more realistic and the new concept, universal health coverage was identified to optimize use of health resources and health systems can

reach their full potential. Knowing that hospitals are greatest users of health resources makes it inevitable to design scientific and applicable model to optimize use of health resources in hospitals. Managers and policy makers like to know and control costs and financial status of every health system and especially hospitals. Among all costs of every hospital, it is said that Costs of human resources comprise more than 60% of resources of every hospital. So managing and optimization of human resources can optimize a large part of health resources.

In hospitals, different departments exist. Among them some have special complexities. Like emergency department. Shift scheduling and calculating true needed personnel of departments like emergency department is one of the most important concerns of managers and administrators (4).

Emergency department is one of the key departments of a hospital. When nurses are below than needed, the chance for overload and confusion of nurses are higher and undesirable outcomes for patients who need emergency services as its name it is and also hospital and its reputation seems to be inevitable.

Since 1980s, concerns about time scheduling and appropriate number of personnel of emergency department have considered by researchers because of the importance of this issue in improvement of quality of services delivering to urgent patients and satisfaction of these group of patients. Determination of the minimum required number of nurses with Patient satisfaction of the service provided and also the number of nurses needed during each shift has been the common goal of all the studies that have been done in this area.

In Iran, however, managers of health care, especially in emergency department are often from medical staff rather than Analysts so they need easy-to-use tools to keep them flexible in different situations. It is several decades that researchers use different methods such as statistical methods, work measurement, queuing models and integer programming for scheduling problem for staff.

Isken & Hancock in 1991 developed a model for resource usage minimizing. In their study, resources were the nurses that must be allocated to various parts of hospital. They demonstrated that using a simple algorithm can have results like a simplex method. Their study showed some facts about shift scheduling of nurses in emergency department, but they failed to develop a comprehensive algorithm or model for shift scheduling and calculating number of nurses in a complicated environment like emergency department.

As said before, for optimization of resources, in past two decades the use of a simulation models as a tool for planning and decision making in the field of health care has increased considerably. Many simulation projects primarily in hospitals and emergency departments have been implemented .

Evans, Gor and Unger in 1996 used simulation for different studies in shift scheduling of nurses, technicians of emergency department and physicians for decreasing average length of stay (LOS) of patients in hospitals. They used the software ARENA for evaluation of shift scheduling of different employees in different parts of hospitals. In this model, 5 different time tables developed based on the time patient spends in hospital. Pitt in 1997 stated the PRISM(18), Presented use of simulation as a tool for resource planning. Cao & Tung in 1980 used a linear programming model to determine the need for regular nurses and overtime nurses. Ketabi and Monzavi barzaki in 2006 in Shahid Chamran hospital of Tehran calculated the optimum number of nurses for emergency department.

Considering the fact that data record of admission, service delivery and discharge of patients of emergency department is not well organized in Iran, using techniques of Operations Research (OR) like simulation and linear programming and so on is limited to determine the optimum number of personnel.

Despite this limitations and difficulties, still use of these techniques can be useful. In this study we calculated the average numbers of patients enter to emergency department in all day and night hours and also time needed for delivering nursing care services. Using results of these two steps, we could determine the optimum number of nurses for emergency department by use of linear programming.

2. Material and Methods

This is a descriptive, cross sectional study. Population of study, are patients and nurses of emergency department in summer of 2014. We used checklists for data collection. Validity of checklist was checked using expert validity. We used linear and integer programming method to determine optimum number of needed nurses in different shifts of emergency department. We used WinQSB software to solve the problem. This software is an easy-to-use and is common software in operations research.

Linear programming is a robust mathematical technique for finding optimum number in situations like allocation and combination of resources(7). This method is one of practical methods of operations research which used

frequently by researchers for decision making about allocation of limited resources. A linear programming model consists of components listing below:

1- Decision Variables: variables with unknown amount which decision maker wants to find right number for them.

2- Objective function: an objective function is a mathematical phrase that indicates relations between decision variables and target of problem we want to solve.

3- benefit/cost coefficients: are coefficients of decision variables in objective function. These coefficients indicate the value of every decision variable in objective function.

4- Subjects (limitations): constraints indicate limitations of resources for implementation of a decision. Based on problem statement, constraints can be in three types that we show it by three symbols $\geq$, $\leq$ and =.

A linear programming model is useful for determining optimum number of nurses for every shift in emergency department in this study.

To determine the average patient arrival to the emergency department, like Ketabi and Monzavi Barzaki(1), we divided a night and day (24 hours) to 8 periods. Then we calculated average number of patients in these different periods during study.

Table 1. Entry average of Patients in the 8-periods(1)

Number of patients	Time periods
22	8-11
16	11-14
13	14-17
21	17-20
28	20-23
9	23-2
5	2-5
11	5-8

Based on surveys and previous studies(1) , in order to determine delivery time of care services needed for patients (medical and nursing services), we divided patients into 3 groups and we estimated average time needed for each group (Table 2).

Table 2. Needed care services based on patient group(1)

Patient group (based on need to care service)	Medical service (minutes)	Nursing services (minutes)	Total time (minutes)
Low care	5	10	15
Moderate care	10	20	30
intensive (watch) care	20	45	65

We investigated patients came to emergency department in 3 past months (summer 2014) and we found that 40% of patients needed low cares, 20% needed moderate cares and 40% needed intensive cares.

At the moment, shifts of Chamran hospital in Ferdows are 6 hour periods (Table 3).

Table 3. Shifts periods of Chamran hospital

shifts	Hour
1st	8-14
2nd	14-20
3rd	20-2
4th	2-8

Although 4 shifts are defined for emergency department, but in fact nurses which their work time starts at 20 (8 P.M.) are continuing till 8 (A.M.) and they work in 2 shifts consecutively. Considering patients arrival average in 3-hours periods mentioned in table 1, and also considering care time needed for every group of patients mentioned in table 2, needed care for patients in every time period calculated. Finally we calculated average nurses needed for delivery of services to patients per hour (Table-4).

Table 4. Care time and number of needed nurses

Time period	Number of patients arrive	Average of patients arrival Per hour	Nursing care needed per hour*	Number of nurses needed per hour**
8-11	22	7	168	3
11-14	16	5	130	2
14-17	13	4	338	5
17-20	21	7	168	3
20-23	28	9	234	4
23-2	9	3	102	2
2-5	5	2	52	1
5-8	11	4	108	2

*= [40%- low care × (patients average) × (10 minutes)] + [20%-moderate care × (patients average) × (20 minutes)] + [40%-intensive care × (patients average) × (45 minutes)]

**= (Nursing care needed per hour/ 60 minutes)

In order to make a linear programming model, first step is to identify shifts of emergency department. In this hospital, shifts are 6 hours periods (table-3). Shifts of this hospital can have nurses of different time periods were discussed in table 1. For example first shift- from 8 to 14- can have nurses from first-from 8 to 11- and second-from 11 to 14- time period.

We use an objective function to minimize number of nurses needed in emergency department of Chamran hospital. In this study, our linear programming model is as follows:

a- decision variables:

X1: number of nurses starts working at 8

X2: number of nurses start working at 11 (zero)

X3: number of nurses starts working at 14

X4: number of nurses start working at 17 (zero)

X5: number of nurses starts working at 20

X6: number of nurses start working at 23 (zero)

X7: number of nurses start working at 2 (zero)

X8: number of nurses start working at 5 (zero)

b- Objective Function:

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

c- Constraints:

C1. Time periods (demand): these constraints are the number of nurses in every time period as follows

$X1 \geq 3$

$X1 + X2 \geq 2$

$X3 \geq 5$

$X3 + X4 \geq 3$

$X5 \geq 4$

$X5 + X6 \geq 2$

$X5 + X6 + X7 \geq 1$

$X5 + X6 + X7 + X8 \geq 2$

Considering start time of shifts, it is clear that last 3 constraints (constraints to X6, X7 and X8) are useless (13).

C2. Constraints to Supply: at the moment under study hospital has no limitation in supply of nurses for different shifts.

C3. Limitations of non-negative variables:

X1, X2, X3, X4, X5, X6, X7, X8 ≥ 0

3. Results

Using WinQSB software for solving our linear programming model, optimum number for minimum of nurses needed for emergency department is as follows:

Table 5. WinQSB results for minimization of nurses (Linear and Integer Programming model)

Nurse minimization	Decision variable	Lower bound	Upper bound	Solution variable
1	X1	0	M	3
2	X2	0	M	0
3	X3	0	M	5
4	X4	0	M	0
5	X5	0	M	4
6	X6	0	M	0
7	X7	0	M	0
8	X8	0	M	0
Current OBJ(minimize) = 12 ≤ ZU = M				

Optimum number of nurses based on table 5 (results of solving our linear programming model) are as follows:

X1= 3

X3= 5

X5= 4

And optimum number of nurses (Z) was calculated as 12 nurses. According to the explanation given on 3rd shift of this hospital, real number of nurses needed for a 24 hours period is equal to 16 (12+4) nurses (12 as minimum needed plus nurses who stay and don't leave the 3rd shift till tomorrow morning(X5)).

If we can change current shifts of this hospital and let nurses to start working at all shifts, because of lessen of constraints, minimum number will be even fewer than 16. As an example, because in LP model we solved above, nurses who start working in 3rd shift which starts at 20 cannot leave until tomorrow 8, 4 nurses who are needed just for 20-23, continuing to work till tomorrow 8 at the department and so extra costs will be imposed to the hospital.

If nurses can start working at the middle of current shifts, and we make another LP model for new situation, minimum necessary number of nurses will change as follows:

A. Decision Variables:

X1: nurses who start working at 5

X2: nurses who start working at 8

X3: nurses who start working at 11

X4: nurses who start working at 14

X5: nurses who start working at 17

X6: nurses who start working at 20

X7: nurses who start working at 23

X8: nurses who start working at 2

B. Objective Function

Min: Z = X1 + X2 + X3 + X4 + X5 + X6 + X7 + X8

C. Constraints

1. Constraints on time periods (Demand): these constraints are number of necessary nurses for each time period (Table 4) based on new shifts as follows:

$X8 + X1 \geq 3$

$X1 + X2 \geq 2$

$X2 + X3 \geq 5$

$X3 + X4 \geq 3$

$X4 + X5 \geq 4$

$X5 + X6 \geq 2$

$X6 + X7 \geq 1$

$X7 + X8 \geq 2$

2. Constraints on supply: at the moment there are no nurses who want to start working at 2, so $X8 = 0$.

3. Nonnegative Constraints:

$X1, X2, X3, X4, X5, X6, X7, X8 \geq 0$

In this situation using WinQSB, our model will be solved as follows:

Table 6. WinQSB results for minimization of nurses (Linear and Integer Programming model) in new situation

Nurse minimization	Decision variable	Lower bound	Upper bound	Solution variable
1	X1	0	M	2
2	X2	0	M	4
3	X3	0	M	1
4	X4	0	M	2
5	X5	0	M	2
6	X6	0	M	0
7	X7	0	M	1
8	X8	0	M	1
Current OBJ(minimize) = 13 ≤ ZU = M				

In new situation, Optimum number of nurses based on table 6 (results of solving our linear programming model) are as follows:

$X1 = 2$

$X2 = 4$

$X3 = 1$

$X4 = 2$

$X5 = 2$

$X6 = 0$

$X7 = 1$

And optimum number of nurses (Z) was calculated as 13 nurses. In contrast to current situation of shifts of hospital, new situation needs fewer nurses ($13<16$) and 3 nurses fewer will be necessary.

4. Discussion

Ketabi and Monzavi used a very interesting method for calculating optimum number of nurses. Adopting their method, in order to solve complicated problems, if we have enough data, using the mean values gives a suitable estimation(1). In this study, to estimate necessary nurses for every shift, we used expected percentage of patients come to the emergency department and also the average amount of time needed to care for them.

Ketabi and Monzavi in 2006 concluded that using linear programming not only optimum number of nurses can be calculated but also needed number of nurses for every shift can be reached.

Ceneto et al in their study collected information about probability of time of patients' arrival and also time of cares. They used right hand sides like our study and using simulation method determined number of necessary

nurses. They demonstrated that number of necessary nurses they estimated is fewer than what estimated by empirical methods.

Joustra et al in 2009 in a study tried to reduce access times for an endoscopy department by an iterative combination of computer simulation and Linear Programming. They showed that allocating current capacity in a more effective way, all procedures will be improved without extra resources like equipment and staff. Results of current study are in line with Joustra's.

In 1972, Warner et al declared that considering nurse shortage and cost of nursing, using a linear programming model will be necessary. In 2004 Matthews showed that Using linear programming is necessary for minimizing the cost of nursing. As we can see using linear programing for proper allocation of human resources is worldwide accepted and implemented.

In this study, although we used LP model for optimization of nurses in first model, results were not satisfying. Maybe this happened because of inappropriate shift scheduling of understudy hospital which results in more constraints. This (correcting shift scheduling of this hospital) is a solution for our objective (minimizing necessary nurses). In second situation, nurses can start working at the middle of current shifts, so same services for patients will be provided using fewer nurses.

5. Conclusion

Using LP, estimation of optimum number of nurses for emergency department can be achieved and also we can estimate number of necessary nurses for each shift.

According to results of this study, Chamran Hospital of Ferdows in current situation (with current shift scheduling) will need minimum of 16 nurses. It can be said that sing LP models can be useful for estimating optimum number of nurses for different wards of hospitals, so they can reduce their costs and reach more productivity.

Limitations

Like Ketabi and Monzavi, we considered 6 hours of every shift all net hours and if one wants to reach more practical results, the real net time of every nurse in each shift should be calculated and more precise results will be achieved.

Wider time interval for studying emergency department can help more in identifying real rate of patients' entrance to emergency department. Since we did this study in summer we may be biased toward some complaint happens more in summers like accidents of monocycles etc.

Funding

Researchers used no fund for this study.

Ethical considerations

We acquired oral informed consent from all nurses of emergency department. We acquired permission of hospital authorities for data collection.

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