Minimizing an important part of hospital costs through the optimal allocation of the number of nursing force to different days of the week using linear programming model
Case study in hospital emergency department (A) in Isfahan

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Abstract

Introduction: the hospital as the largest health care center of the society allocates a bulk of the sources and credits assigned to the health sector of the country. Several studies carried out by the researchers indicate that the manpower cost of each hospital constitutes over sixty per cent of its resources. Due to the relevance of the personnel in the quality of services provided to the patients and its costs for hospital, determining the number of optimal needed employees of hospital complex departments is a problem; it has not had a specified standard. Therefore, this research has been carried out for reducing the hospital costs to minimum through the optimization of the nursing force allocation using the Linear programming model in the hospital emergency department. This case study was conducted in 2015.

Method: this is a scientific-applied and cross-sectional-descriptive study that has been done in a public health training Centre in 2015; the emergency department was randomly selected as a sample. At the beginning a model was made based on the Linear programming and then the information was collected from the hospital reception during the months of April to September. After calculating the average patients in each day of the week, the optimal number of nurses of different days of the department was determined by the use of Win QSB software.

Findings: according to the obtained results, the optimal number of the required nurses by days of week and on the whole is as follows: $6+3+7+2+6+4+8=36$

Conclusion: the Linear programming model can be used as a useful tool for timing and determining the optimal number of employees needed by the various departments of a hospital and reduce costs to minimum.

Keywords: Linear programming model, optimal number of nurses, timing, cost, hospital

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Introduction

Nowadays, the pressure on hospitals for making efficient the costs of treatment has been increased (1). Also many industrial and service organizations face up to the planning problems of manpower (2). Among the industrial and service organizations, hospitals face up to the different levels of expertise of their remedial personnel (3). Therefore, one of the main challenges in the field of long-term planning of the hospital personnel is resulted from the different skills and specialties of the remedy stuff (3). Hence one of the main tasks of management is to determine the proper number of employees regarding each level of experience and specialty (1, 4).

A wide range of issues related to the planning of the service institutes employees is appropriated to the manpower planning. Solving these issues is of very high importance for the service organizations; that is why regarding the type of companies and their need for employing personnel, the researchers have provided the issues according to these desires and needs and solved them with a variety of common tools. The purpose is to use the minimum workforce needed in each shift in order to complete the predetermined goals. Factors such as "Days of holidays", "Type of specialty", "Skill degree", "Employees' experience level" or their tendency to serve in a particular shift, play an effective role in the timing of manpower. The schedule of manpower predicts regularly the organization's future supply and demand for employees. With estimating the number and type of the required employees, the department of human resources can plan better the absorption, selection, training, career planning and other activities; as a result, it enables the department of human resources to reduce costs and in the meantime equip the organization at the time with the suitable individuals (5).

The issue of timing and planning is the harmonization of a set of entities such as events, activities, individuals, tools and devices, vehicles, places etc. in a pattern of time distance. The aim in such problems is that the available resources are exploited in a best manner. Also, the existing conditions and limitations must be considered and will be estimated (6). Therefore, the planning of personnel is the process of setting up the task schedules for the employees in order to estimate the time-dependent demand and the persons' working preferences (2).

The remedy sectors planners (for example: head nurses or senior nurses) should determine the number of nurses per shift with respect to the number and the required skill levels, so that at any time a balance is created between nurses' workload and their preferences. This can be hard when the employees' work flow is high. Nurses are usually divided "according to skill levels and the size of the patients". However, on some of the working shifts due to the shortage of skilled nurses, some limitations are applied to work shifts for maintaining a certain level of skill (7).

In the meantime, according to studies conducted in developing countries, Thailand, Lebanon, Japan and Turkey, the results showed that in private and public hospitals some units encounter

with a lack of manpower like nurses or with the improper distribution. Planning the nursing workforce is raised as a kind of the resources allocation problem with regard to their high workload and some limitations and requirements (8). The problem of nursing planning is a combined one with several aims that each one is probably different with other ones (9). Therefore, in the nurses' letter of duties, there exist a large number of changes in the legal regulations and individual preferences, depending on the different countries and institutions. The most major concern is related to the issues associated with demand coverage, the requirements related to the weekend, the requirements associated with the holidays and the minimum and maximum of manpower (8).

In the last decade some studies have been conducted regarding the timing of manpower. The study of Chung et al (2003) and Burke et al (2004) was oriented to investigate the nursing planning problems and provide the solution to existing problems. Maenhout, B., and Vanhoucke, M (2005) classified the problems of nursing planning based on the size and complexity (10). In Japan, planning of the nursing timing is done often without a timing algorithm and this has caused the compression of time and work (7). In other study, with expanding the planning model that includes three working shifts with 30 nurses, considering the weekly working pattern, nursing teams and head nurse, . Aickelin has solved indirectly the issue through the genetic algorithm; then he has compared the obtained results with the results of the prohibited search that in terms of answer it has been close but distant in terms of flexibility (11). With considering the planning for a period of 4 weeks, three degrees for nurses and 4 shifts for each day, another researcher has solved the problem of planning of nurses by using the genetic algorithm (12). Also in other study, the results indicated that one-third of hospitals of U.S. have implemented the strategy of reducing their manpower in order to reduce their personnel costs (3).

According to the above cases, we can mention that in recent decades the demand for health care has increased; which led to the reorganization of the health system. Hence at the macro level, the reduction of the number of care providers has attracted serious attention (13). Therefore, organizations need to develop the effective planning methods for improving the supply and demand (3, 9); Because, to express the tasks of human resources, achieving knowledge about the effectiveness of existing human resources in the activities associated with the different projects is necessary, because the results of an effective activity depend on the resources assigned to it (14).

For many organizations, the manpower planning is considered as the determining factor in customers' satisfaction and the efficiency of the organizational services (2). In the modern world, the salient manpower system is regarded as an important factor in a competitive system of every organization. The manpower development is a factor in increasing the manpower quality improvement, organizational productivity and organizational benefit (15). Therefore, the timing system applications are oriented to increase the use of manpower, medical equipment and reduction of waiting time (13). Also today, timing systems are known as an efficient tool to

optimize the health care services (13). Considering the above cases, for removing such difficulties a planning for the development of the timing algorithm of nurses is effective. Hence the present study aimed to "minimize the nursing costs as a major class of personnel costs through optimizing the allocation of nursing workforce using the linear programming model in emergency department of hospital under case study in 2015".

Method of investigation

This research is a scientific-applied and of cross-sectional-descriptive type of studies. The research population was a public educational and remedial center whose emergency department was randomly selected as a sample. At the beginning a model was made based on the linear programming and then the information was collected from the hospital reception in a period of 180 days during the months of April to September in 2015. After calculating the average patients in each day of the week, the optimal number of nurses of different days of the department was determined by the use of model and Win QSB software. Based on the information obtained from the hospital reception and archive, the average patients in each day of week are provided in table 1.

Table 1: average number of patients during the days of a week

Days of week	Number of patients
Saturday	25
Sunday	27
Monday	29
Tuesday	25
Wednesday	24
Thursday	22
Friday	26

With regard to the care needs of patients that include the daily activities, public health, emotional education & support and drug & remedy, we recognized five levels, as table (2) shows.

Table 2: service levels and required time

Level of services	Patient state	Care hours during day
Self-care	Without a need to help or the partial help – he/she needs a time to remedy less than 10 minutes	3
Minimal care	He/she needs a minimal help – 20 to 30 minutes for medication and remedy and supervision	5
Moderate care	A difficulty in eating and walking - to 60 minutes for the medication, remedy and supervising the effectiven	8
Extensive care	He/she cannot eat – He/she needs more than 60 minutes for care	13
Intensive care	ds to observe one by one or investigate exactly and constantly on each s	19

The done investigations on patients during the mentioned 6 months show that on average 30% in the first group, 20% in second group, 25% in third group, 15% in the fourth group and 10% in the fifth group require the nursing services.

With respect to the average number of patients and also considering the service time required for each group of patients according to the table 2 and also by taking 8 hours working per shift into consideration, the services required for each day of the week and ultimately the average number of nurses required for service in each day of the week have been presented in table (3).

Table 3: service time and the number of required nurses

Days of week	patients average	Amount of the needed nursing services (hour)	Number of needed nurses
Saturday	25	202	25.25
Sunday	27	217	27.125
Monday	29	222	27.75
Tuesday	25	202	25.25
Wednesday	24	190	23.75
Thursday	22	171	21.375
Friday	26	209	26.125

Modeling

For making a model, we use the case study. On this basis, if in the intended hospital (N) number of nurses has been employed so that each one works (m) consecutive days of week (e.g. 5 consecutive days) and utilizes 2 consecutive days of rest, the statistic of patients referring to the hospital in the days of week will fluctuate and the number of nurses, accordingly, depends on what a day of week is.

If the number of nurses is considered in order of weekdays n_1, n_2, n_3, ..., n_7 individual and the hospital's planning unit decision has the intention of reducing the number of nurses to the minimum as possible, we can design its linear programming model as follows:

X_i = the number of nurses beginning to work at days of week

i= 1, 2, …, 7

N = total number of employed nurses of the desired department

Min $Z = X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7$

Subject to: $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq N$

$X_1 + X_4 + X_5 + X_6 + X_7 \geq n_1$

$X_1 + X_2 + X_5 + X_6 + X_7 \geq n_2$

$X_1 + X_2 + X_3 + X_6 + X_7 \geq n_3$

$X_1 + X_2 + X_3 + X_4 + X_7 \geq n_4$

$X_1 + X_2 + X_3 + X_4 + X_5 \geq n_5$

$X_2 + X_3 + X_4 + X_5 + X_6 \geq n_6$

$X_3 + X_4 + X_5 + X_6 + X_7 \geq n_7$

$X_i \geq 0$ (i= 1, 2, 3, 4, 5, 6, 7)

Modeling of case study

Based on the above designed general model and also with regard to 45 employed nurses in hospital's emergency department, the model is taken shape as follows:

Min $Z = X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7$

Subject to:

$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq 45$

$X_1 + X_4 + X_5 + X_6 + X_7 \geq 25/25$

$$X_1 + X_2 + X_5 + X_6 + X_7 \geq 27/125$$
$$X_1 + X_2 + X_3 + X_6 + X_7 \geq 27/75$$
$$X_1 + X_2 + X_3 + X_4 + X_7 \geq 25/25$$
$$X_1 + X_2 + X_3 + X_4 + X_5 \geq 23/75$$
$$X_2 + X_3 + X_4 + X_5 + X_6 \geq 21/375$$
$$X_3 + X_4 + X_5 + X_6 + X_7 \geq 26/125$$
$$X_i \geq 0 \quad (i = 1, 2, 3, 4, 5, 6, 7)$$

Findings

With regard to 45 employed nurses in hospital's emergency department, the optimal answer of the minimum nurse needed for each day of week and in total for the desired department after solving the model by the software Win QSB is as follows:

$(X_1 = 6) + (X_2 = 3) + (X_3 = 7) + (X_4 = 2) + (X_5 = 6) + (X_6 = 4) + (X_7 = 8) = 36$

Discussion

With regard to the optimal answer to the problem, it is determined that there is 9 surplus nurses; by taking into consideration the average monthly salary and benefits of nurses that in 2015 was which in 2015 was equivalent to 2200000 Toman(629 Dollars) and also for paying festal and bonuses, if the duration of the calculation is considered to be equal to 13.5 months per year, in accordance with the following calculation about 267300000 Toman(76372Dollars), that is to say, 20 percent of personnel costs of Emergency Department are reduced. This is a significant percentage and can be generalized to the costs of the salary of nurses in other departments as well.

Sum of salary and benefits of nurses of emergency department (in present conditions) = 45×13.5×2200000 = 1336500000 Toman $\approx$ 381857\$

Sum of the economized salary and benefits of nurses of emergency department = 9×13.5×2200000 = 267300000 Toman $\approx$ 76372\$

$$\textbf{Economizing percent} = \frac{267300000}{1336500000} \times 100 = 20\%$$

If you have sufficient data, the use of average values gives a suitable estimation in relation to complex issues. In this study, also, for estimating the amount of the daily need to nurse, the expected amount of patients during the days of week, the average value of time required for caring as well as average wages and salaries have been used.

Centeno et al in 2003 in their research about the probable distribution of arrival time of patients and the care time, calculated the amount of need to nurse through the simulation. They also found that the number of thus obtained nurses by the help of this method is much less than the experimental method; this is consistent with the present research (16).

With designing a linear programming model, Jabali and Sinreich in 2007 could achieve to the similar results in the different departments of several hospitals; that with having less manpower and reducing the time of patients stay, they achieve the same therapeutic result (17).

Ketabi et al in 2006 with a study in Isfahan through designing a model for the Emergency Department shifts, could cause to reduce the personnel and consequently the costs (18).

Conclusion
Because the costs of the salary constitute one main group of three groups of costs of every unit of provided services, so the optimal allocation of the manpower number to every shift, every workstation or every section of organization is essential in order to reducing the costs to minimum; this is achievable through the linear programming model. So far as with making the model and the use of hospital emergency department information the case study shows 20% reduction in the costs, and it is evident that this increases influentially the purchasing power of the health services by people.

Resources

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