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**RESEARCH ARTICLE**

# LINEAR PROGRAMMING APPLIED TO NURSES SHIFTING PROBLEMS FOR SIX CONSECUTIVE DAYS PER WEEK

***[1]Satheeshkumar, B., [2]Nareshkumar, S. and [3]Kumaraghuru, S.**

[1]Dr.N.G.P. Arts and Science College, Coimbatore, Tamilnadu, India
[2]SriGuru Institute of Technology, Coimbatore, Tamilnadu, India
[3]Chikkanna Government Arts College, Tirupur, Tamilnadu, India

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**ABSTRACT**

Hospital's key primary mission is to ensure continuous ward care service with appropriate number of nursing staffs and the right mix of nursing skills. The planning and scheduling is done to avoid additional non essential cost for hospital. Nurses' preferences are taken into considerations such as the number of night shift and consecutive rest days. To present a mathematical modeling technique by means of linear programming as an efficient tool to solve problems related to optimization in healthcare. Hospital must be staffed 24 hours a day by a limited number of nurses. This paper illustrates how a linear programming solves the nurses scheduling problems. This paper illustrates how linear programming has been effectively used in Nurses scheduling at a multi-speciality Hospital in Coimbatore.

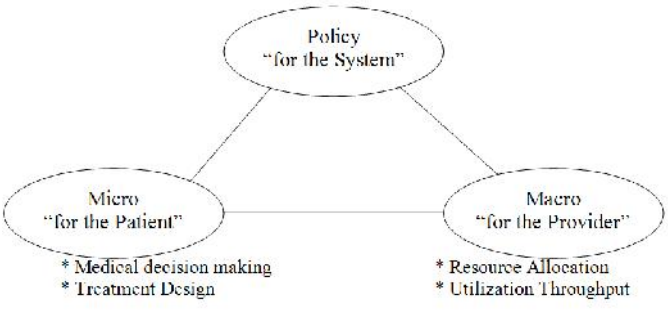


## INTRODUCTION

Nurse scheduling is a multi-objective problem. Systematic approach for nurse allocation is needed to ensure continuous and adequate level of patient care services while maintaining the legislative requirements as well as internal policies. This problem becomes complex when addition factors such as patient admission, nurse qualifications or license to practice, type of disease as well as unforeseen accidents. The personal needs of the nurses such as vacation or work shift preferences add a new dimension to the scheduling problem. The need to balance all the various dimension of the problem makes nurse scheduling a particularly daunting manual task. perations Research is a science designed to provide quantitative tools to decision-making procedures. It comprises a set of mathematic optimization and simulation methods and models, such as linear programming, non-linear programming, combinatory optimization, theory of queues, dynamic programming, theory of decisions, etc. There are various grades of nurses ranging from registered nurse to junior nurse. Some the nurses might be trained to manage certain medical conditions or skilled in certain area such as intensive care. Due to the varied trainings and specializations, certain type of nurses has to be staffed for wards requiring those skills. These varied conditions cause manual nurse scheduling to consume a significant amount of time. Even when the schedule has been planned manually, it does not necessarily guarantee the fairness of distribution of work such as the number of night shifts or weekend shifts. While the nurses might have indicated their preferences, the planner might not have taken all these into consideration resulting in poorly designed schedules which has to be modified by the nurses swapping duties or working under undesired conditions. Occasionally, the plans did not attempt to efficiently utilize the manpower properly.

***Corresponding author: Satheeshkumar, B.,***
*Dr.N.G.P. Arts and Science College, Coimbatore, Tamilnadu, India.*

### OPERATION RESEARCH APPLICATIONS IN HEALTHCARE – THREE CATEGORIES




### Linear Programming

Linear programming techniques are considered as mathematics based decision-making tool. Such technique requires two fundamental types of functions, objective and constraints, that

is developed to generate closed-form solution. In a typical OR problem, the objective function, often expressed as Z, is formulated to determine the maximum profit while minimizing cost with given set of rules or constraints such as business policies, resource availability, preventive maintenance schedule, transportation distance or time and capacity.

**Literature Review**

Nursing scheduling has been widely studied since 1960s. Prior to the development of mathematical programming, most nursing scheduling approaches were based on cyclical modeling. Cyclic models consist of regular patterns which can be rotated across multiple time periods. The pattern will only repeat after one cycle. These types of models are highly repetitive and regular. Even though such models are considered to be fair in terms of distribution of work, the modeling process ignores the preferences of the nurses. Howell's approach (1966) provides the first cyclical scheduling approach which takes into considerations the behavior and preferences of the individual nurse. Subsequently, nurse scheduling began to adopt heuristic models which are able to consider all the requirements at the planning stage (Maier-Rothe and Wolfe, 1973; Isken and Hancock, 1991). This enables the models to attempt satisfying all the requirements. The development of mathematical programming also gave rise to various approaches to solving the nurse scheduling problem especially the non-cyclical problem (Harmeier, 1991; Ozkarahan, 1989; Ozkarahan, 1991; Tobon, 1984; Warner, 1976b). Norde rescheduling aims to minimize changes to be original schedule while minimizing costs, rebuilding the schedule with current staff is usually be cheaper option as there is no extra wage to pay, but altering the schedule will alter other nurses schedules as well.

$$\text{Min } z = \sum_{i=1}^{7} x_i \quad \text{subject to } x_i \geq b_i \text{where } i = 1 .. 7$$

where $x_i$ is the number of nurses assigned to day1, day2, etc. and $b_i$ is the demand of nurses for day1, day2, etc.

**Problem Definition**

Consider a hospital that is open seven days a week. Based on past experience, the number of nurses needed on a particular day is given as follows.

| | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ | $x_1$ |
|---|---|---|---|---|---|---|---|
| **Day** | **Mon** | **Tue** | **Wed** | **Thu** | **Fri** | **Sat** | **Sun** |
| **No. of Nurses** | **200** | **150** | **250** | **90** | **160** | **300** | **100** |

Every nurse works six consecutive days, and then takes one day off, repeating this pattern indefinitely. How can we minimize the number of nurses that staff the hospital?

**Model**

A natural first attempt at this problem is to let $x_i$ be the number of people working on day i.
Let $x_1$ be number of nurses starting duty on Sunday (Sunday – Friday)
Let $x_2$ be number of nurses starting duty on Monday (Monday – Saturday)
Let $x_3$ be number of nurses starting duty on Tuesday (Tuesday – Sunday)
Let $x_4$ be number of nurses starting duty on Wednesday (Wednesday – Monday)
Let $x_5$ be number of nurses starting duty on Thursday (Thursday – Tuesday)
Let $x_6$ be number of nurses starting duty on Friday (Friday – Wednesday)
Let $x_7$ be number of nurses starting duty on Saturday (Saturday – Wednesday)

The demand for the number of nurses in the hospital on Sunday: 100, Monday: 200, Tuesday: 150, Wednesday: 250, Thursday: 90, Friday: 160 and Saturday: 300 respectively.
Let $x_i$ be the number of workers who begin their six day shift on day i. Our objective is

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$$

Consider the constraint for Sunday staffing level of 100. Those who start their shift on Sunday ($x_1$), they will work for consecutively 6 days, that is, Sunday to Friday. Those, who start their shift on Monday ($x_2$), they will work for consecutively 6 days, that is, Monday to Saturday. Similarly, those who start their shift on Tuesday ($x_3$), they will work Tuesday to Sunday and so on.

We can formulate the following table

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ | $x_7$ |
|---|---|---|---|---|---|---|---|
| Sunday Shift | * | * | * | * | * | * | - |
| Monday Shift | - | * | * | * | * | * | * |
| Tuesday Shift | * | - | * | * | * | * | * |
| Wednesday Shift | * | * | - | * | * | * | * |
| Thursday Shift | * | * | * | - | * | * | * |
| Friday Shift | * | * | * | * | - | * | * |
| Saturday Shift | * | * | * | * | * | - | * |

Similar arguments give a total formulation of

$$\text{Minimize } z = \sum_{i=1}^{7} x_i \quad \text{subject to constraints}$$

$x_1 + x_3 + x_4 + x_5 + x_6 + x_7 \geq 100$
$x_1 + x_2 + x_4 + x_5 + x_6 + x_7 \geq 200$
$x_1 + x_2 + x_3 + x_5 + x_6 + x_7 \geq 150$
$x_1 + x_2 + x_3 + x_4 + x_6 + x_7 \geq 250$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_7 \geq 160$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 \geq 90$
$x_2 + x_3 + x_4 + x_5 + x_6 + x_7 \geq 300$
$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 \geq 0$; / $x_i \geq 0$ for all i

**Solving the Model**

Since this model has 7 variables, we cannot solve the problem manually. Hence, we can solve the LPP by using solver. If we solve the LPP, we will get the feasible solution (Min Z = 303.3333). But, unfortunately minimum demand of nurses will not be in decimal point.Hence, we have to solve the above LPP by Integer Programming Problem (possibility of extension).

## Conclusion

Nurses shifting allotment is a well developed area. Note that our model has only one type of shift, but the model is easily extended to other types of shifts, with differing shift costs. The resulting schedule includes balanced schedules in terms of the distribution of shift duties, fairness in terms of the number of consecutive night duties and the preferences of the nurses. This is an improvement over the traditional manual approach which is costly in terms of labor as well as inefficient in producing a good schedule. Nurse rostering is a complex scheduling problem that affects hospital personnel on a daily basis all over the world. The need for quality software solutions is acute for a number of reasons. In particular, it is very important to efficiently utilise time and effort, to evenly balance the workload among people and to attempt to satisfy personnel preferences. A high quality roster can lead to a more contented and thus more effective workforce.

## Future impact of this study

In the present day scenario, the ratio of the nurses available to serve the ever-increasing number of patients is very less. The finding of this research enables optimum utilization of the available resources, increase in the efficiency of the services provided by the nurses and maximum profit with minimum resources. The research work undertaken for this paper helped in understanding the existing shifting problems in Nursing as a whole and facilitated in making the right decision about the requirement of the nursing staff at the different hours of the day.

This research paper can be further extended to all the other fields of work which pursue shift system. This paper has solved the problem using Linear Programming, however, the same problem can be solved using Integer Programming. Employing Integer Programming method will also fetch better results.

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