A SCHEDULING PROBLEM FOR HOSPITAL OPERATION THEATRE

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This paper provides a classification of real scheduling problems. Various ways have been examined and described on the problem. Scheduling problem faces a tremendous challenges and difficulties in order to meet the preferences of the consumer. Constructing the scheduling problem is complicated, inefficient and time-consuming. This study aims to develop mathematical model for scheduling the operation theater during peak and off peak time. Scheduling problem is a well known optimization problem and the goal is to find the best possible optimal solution. In this paper we used linear programming model for scheduling problem in high level of synthesis. An additional to time constrained scheduling and resource constrained scheduling. An optimal result was fully obtained by using software called GLPK/AMPL. This model can be adopted to solve other scheduling problem such as for the Lecture Theater, Cinemas and Work Shift.

Keywords: Linear programming, Optimization, Scheduling Problem.

1. INTRODUCTION

Hospital Operation Theater (OT) scheduling involves arrangement of several operation rooms to the medical surgeons in a period of time. In health service sector such as government or private hospitals, the scheduling of Operation Theater plays an important role towards achieving their goals. Their main goal is to meet patients' satisfaction by minimizing their total waiting time before undergo major or minor operation [3]. Poor scheduling of Operation Theater may cause longer waiting time and can also worsen the patient's disease. In this case, an effective schedule has to be developed in order to improve the reputation and performance of government as well as private hospitals.

Another objective is to minimize the cost involved with Operation Theater such as staffing cost or known as overtime cost which cost greater than regular working hour [3]. For example, hospital needs to hire part-time medical specialist to perform major operation during weekend or outside office hour. As a result, the hospital has to spend more to satisfy the need of the patient. This has lead to the need of optimizing the available operation theatre by minimizing under-allocation of each operation rooms. Several recent researches focus on both objectives of minimizing the overtime cost and maximizing the utilization of operating theater [1], [2], [3], [5], [9] and [10].

Scheduling of Hospital Operation Theater can be divided into several types of strategies which are open scheduling, block scheduling and modified block scheduling [4]. Open scheduling allows surgical cases to be assigned to an operating room available at the convenience of surgeons [6] and [3]. Meanwhile, for block scheduling, specific surgeons or groups of surgeons are assigned a set of time blocks, normally for some weeks or months, into which they can arrange their surgical cases. In the pure form, the surgeon or group "owns" their time blocks. None of those time blocks can be released [4]. “Modified block scheduling” is modified into two ways to increase its flexibility. Either some time is blocked and some is left open, or unused block time is released at an agreed-upon time before surgery, for instance 72 hours [4].

Implementation of different types of operation theater scheduling is based on the complexities of real situation in the hospitals. There are several techniques have been used by past researchers in order to achieve their objectives and constraints such as linear programming [5], heuristic algorithm [6], hybrid genetic algorithm [4] and mixed integer linear programming [7].

In this study, a procedure to optimize the utilization of operating theater by minimizing the total deviation from the weekly target hours and relative amount of under-allocation of rooms to different departments is pretested. Using small data set, a linear programming technique was used to find the optimal operation theater schedule in one week period with open scheduling strategy.

The rest of the paper is organized as follows. Section 2 describes the numerical example and model formulation. Section 3 presents the result obtained to evaluate the performance of integer programming technique. Section 4 concludes the paper.

2. NUMERICAL EXAMPLE AND MODEL FORMULATION

This study is a simplified version of the real operation scheduling problem. Consider a hospital that has 10 staffed operating rooms serving 6 departments; surgery, gynaecology, ophthalmology, otolaryngology, oral surgery and emergency. There are 8 main surgical rooms and 2 elective outpatient surgery (EOPS) rooms. An operating room is either “short hours” or “long hours”, depending upon the daily number of hours the room is in use. Because of the socialized nature of health care, all surgeries are scheduled during work days only from Monday to Friday.

Table 1. Surgery Room Availability.

Availability hours Weekday	Main short (hours)	Main long (hours)	EOPS short (hours)	EOPS long (hours)
Monday	7.5	9.0	7.5	8.0
Tuesday	7.5	9.0	7.5	8.0
Wednesday	7.5	9.0	7.5	8.0
Thursday	7.5	9.0	7.5	8.0
Friday	7.5	9.0	7.5	8.0
Number of rooms	**4 per day**	**4 per day**	**1 per day**	**1 per day**

Table 2. Weekly Demand for Operating Rooms Hours.

Department	Weekly target hours	Allowable Limits of Under-allocated hours u_j
Surgery	187.0	10.0
Gynaecology	117.4	10.0
Ophthalmology	39.4	10.0
Oral surgery	19.9	10.0
Otolarynoglogy	26.3	10.0
Emergency	5.4	3.0

Table 2 summarizes the daily availability of the different types of rooms and Table 3 provides the weekly demand for operating room hours. The limit on the under-allocated hours in Table 3 is the most a department can be denied relative to its weekly request. We can devise a daily schedule that most satisfies the weekly target hours for different departments. We set target hours for each department as a goal. The given situation involves 6 departments and types rooms.

Let say,

x_{ijk} = number of rooms of type i assigned to department j on k days {k=1, 2,...5}
u_j = maximum number of under-allocated hours allowed in department j
h_j = requested ideal target hours for department j
a_{ik} = number of rooms of type i available on a day
d_{ik} = duration availability in hours of room type i on day k

2.1 Fitness Function

The objective of the model is to minimize the total deviation from the weekly target hours and relative amount of under-allocation of rooms to different departments. The problem says that the ratio $\frac{s_j}{h_j}$, measures the relative amount of under-allocation for the department *j*.

$$Minimize \sum \frac{s_j}{h_j} \quad (1)$$

where s_j is the number of under-allocated hours and hourly occupied in each department.

2.2 Constraints

We need to assign each department with a constraint:

$$s_j \leq u_j \tag{2}$$

where the number of under-allocated hours has to be less or equal than the allowable limit. For each type of room i assigned to department j on each day k, we set the constraint as:

$$\sum x_{ijk} \leq a_{ik} \tag{3}$$

where the sum of the rooms that assigned to each department on a particular day has to be less or equal of the number of rooms of type i available on that day. We add up another restriction:

$$s_j \geq \sum d_{ik} x_{ijk} \tag{4}$$

in order to reached the weekly target hours. All parameters and variables are positive:

$$s_j,\ x_{ijk},\ h_j,\ u_j,\ a_{ik},\ d_{ik} \geq 0 \tag{5}$$

This present study involves small decision variables, constraints and parameters. The model searches for an optimal solution using an integer programming algorithm. The coding was programmed using GLPK/AMPL and the optimal solution for a 5 days schedule was obtained less than 2.0 seconds running on a 2.26GHz PC. This is very fast compared to other approaches such as heuristic Genetic Algorithms that have been used elsewhere [8]. The efficiency of the Linear Programming approach in solving the scheduling problem has been mentioned in many past studies [5].

3. NUMERICAL RESULTS

The results are presented in Table 3 (integer approach) and Table 4 (real number approach). Each table satisfies the goal and details allocation of rooms by type to different departments during working week which from Monday to Friday.

Table 3. Room Allocation in Integer Solution.

	Main short					**Main long**					**EOPS short**					**EOPS long**				
	M	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**
Surgery	0	0	4	2	4	0	4	4	0	3	0	0	0	0	0	1	0	0	1	0
Gynaecology	4	4	0	1	0	1	0	0	2	0	1	0	1	0	0	0	0	1	0	0
Ophthalmology	0	0	0	1	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0
Oral surgery	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1
Otolayngology	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emergency	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Table 4. Room Allocation in Real Number Solution.

	Main short					Main long					EOPS short					EOPS long				
	M	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**	**M**	**T**	**W**	**T**	**F**
Surgery	0	4	4	4	0	0	0	0	1.79	4	0	0	0	1	1	1	1	1	1	1
Gynaecology	0	0	0	0	4	0	1	4	2.21	0	1	1	1	0	0	0	0	0	0	0
Ophthalmology	4	0	0	0	0	0.48	0.79	0	0	0	0	0	0	0	0	0	0	0	0	0
Oral surgery	0	0	0	0	0	0	2.21	0	0	0	0	0	0	0	0	0	0	0	0	0
Otolaryngology	0	0	0	0	0	2.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emergency	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0

From table 3 and 4, each room meets the requirement per day and fulfills the weekly target hours. Integer solution shows better result than real number solution because it produces a better and logical used of the available room. The percentages of departmental allocation by integer solution are; surgery 100%, gynaecology 100%, ophthalmology 100%, oral surgery 106%, otolaryngology 103% and emergency 139%. The logic of the model is that it may not be possible to satisfy the target hours for department j without applying the surplus. The objective is to determine a schedule that minimizes the relative amount of under-allocation of rooms to the different departments. The nonnegative variables s_{-j} and s_{+j} represent the under and over allocated of hours relative to the target for department j. The ratio $\frac{s_{-j}}{h_j}$ measures the relative amount of under-allocated slack to department j. Table 5, shows the actual value of surplus that used in the problem and compared it to the allowable limits of under-allocated hours.

Table 5. Surplus and Allowable Limits of Under-allocated hours.

Department	**Surplus (hours)**	**Allowable Limits of Under-allocated hours u_j**
Surgery	0.0	10.0
Gynaecology	0.1	10.0
Ophthalmology	0.1	10.0
Oral surgery	1.1	10.0
Otolarynoglogy	0.7	10.0
Emergency	2.1	3.0

4. CONCLUSION

This problem is very common in managing operating room for government and private hospitals. Many studies have been done to find the best schedule which able to meet patient's satisfaction and minimize the total cost of operating theater. This paper uses linear programming approach to solve operating theater problem with open scheduling strategy. This study is concern more on optimal utilization of available operating theater. Results show that integer linear programming technique managed to obtain optimal schedule that meet the objective of the study and also related constraints. Moreover we can provide extra treatment on oral surgery, otolaryngology and emergency if needed based on the availability of the rooms. The scheduling procedure is really efficient where we manage to meet all the requirements and gives a major impact on the productivity of the hospital treatment. It's greatly outperformed older manual scheduling methods and optimizes real-time workloads. Further study can be done by focusing on both objectives to maximize the utilization of Operation Theater as well as minimize the total cost with large set of sample data that represent the real situation in the hospitals. Also, different approach can be used such as heuristic algorithm technique which able to solve NP-hard scheduling problem for other related area.

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