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The problem of scheduling surgery room with approach of maximizing preferences of hospital management and surgeons: A case study in Saadi Hospital of Isfahan

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Abstract

In present age, medical system is changing and transforming in terms of position and these changes include increasing speed of patients and population aging and in its respect, increasing the elderly. Regarding technical barriers and limitations of human resources at hand in hospitals, major part of patients cannot be treated immediately and respectively, how longer time patients wait for treatment, their satisfaction about hospital services will decrease. In other hand, hospitals and especially state hospitals suffer a massive budget deficit. This limitation led to this matter that hospitals look for increasing medical service efficiency and decreasing cost of medical services. It should be pointed that the purpose of these hospitals is nothing but balancing and integrating budget. Based on obtained results, 70% of referrals to hospitals were aimed to surgery operations and more than 15% of wasted time in hospitals was related to surgery rooms and this instance clears importance of surgery room and its proper benefit more than before. Surgery room and generally surgery department has a special sensitivity and it is considered as the most vital section in hospitals. Therefore, the smallest deficiency or disregarding specified plan and pre-determined standards result in problems. Hence, hospital surgery room can be resembled with hospital motor because many hospital resources such as managers of surgery room planning, anesthesia specialist surgeons, nurses and others whom probably have different and sometimes conflicting goals are dependent on surgery room and eventually surgery room planning. The goal of this paper is the problem of surgery room scheduling with approach of maximizing surgeons and devoting surgery time based on hospital preferences and each of surgeons. Therefore, a model is provided to their scheduling in order to preferences and decreasing overtimes. In such a way that each surgeon operates in a surgery room specified for the same type of surgery regardless of surgery teams and based on predicted times for each surgery. This proposed model is solved in shape of a problem using obtained data from Saadi hospital of Isfahan and using Lingo software.

Keywords: surgery room, linear planning, time period, TOPSIS method, scheduling

Introduction

Planning of related activities to surgery is developed using research models in recent three decades. The cause of this matter is very high cost of development and facilities management of operation and surgery roomand effect of these activities on amount of hospital service demand and waiting time. Surgeries' planning is not easy to do due to multiplicity decision variables, uncertainty resulted from emergency patients' entrance, surgery time duration and using time of other sources such as hospital bed which should be considered (Ketabi, 2009).

In present age, medical system is changing and transforming in terms of position and these changes include increasing speed of patients and population aging and in its respect, increasing the elderly. Regarding technical barriers and limitations of human resources at hand in hospitals, major part of patients cannot be treated immediately and respectively, how longer time patients wait for treatment, their satisfaction about hospital services will decrease. In other hand, hospitals and especially state hospitals suffer a massive budget deficit.

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This limitation led to this matter that hospitals look for increasing medical service efficiency and decreasing cost of medical services. It should be pointed that the purpose of these hospitals is nothing but balancing and integrating budget (Liu, Chu , and Kanliang , 2011).

One of places or in other words, one of units in hospital which is considered important in years of this decade is surgery room of hospital. More than 70% of referrals to hospitals are aimed to operations in surgery room and this increases importance of optimal benefiting from capacity of surgery rooms (Ketabi, 2009).

Surgery room and generally surgery department has a special sensitivity and it is considered as the most vital section in hospitals. Therefore, the smallest deficiency or disregarding specified plan and predetermined standards result in problems. Hence, hospital surgery room can be resembled with hospital motor because many hospital resources such as managers of surgery room planning, anesthesia specialist surgeons, nurses and others whom probably have different and sometimes conflicting goals are dependent on surgery room and eventually surgery room planning (Liu, Chu , and Kanliang , 2011).

Therefore, surgery room which makes highest income for hospitals results in time waste and intense costs such as important and key resources. Hence, hospital managers interest in increasing efficiency and using effective methods of surgery room managing; because it leads to improvement in quality and efficiency of their hospitals (Liu, Chu, and Kanliang, 2011).

Whereas in many countries, scheduling surgery room is in such a way that any number of work-days which are composed of several time periods are allocated to a surgeon and assignment of this days is based on records which surgeons have needed them in previous periods. This method has no defect spontaneously, but it is possible that a operation relevant to a surgeon will be canceled in some work-days and other surgeons will not able to using this time period. It results in wasting hospital resources and we had to make overtime hours eventually. So, we can increase efficiency of surgery rooms by proper scheduling of operations and adjusting patient requirements with surgery rooms and surgeons (Liu, Chu, and Kanliang, 2011).

In a surgery room unit in hospital which operates based on open strategy scheduling, it is tried to scheduling operations in such a way which results in maximizing preferences of hospital and surgeons and also decreasing overtime hours.

Studied hospital in this research is Saadi hospital of Isfahan. This hospital includes general surgery, obstetrics and gynecology, cosmetic, urology, ear, nose and throat, orthopedics, neurology, oral and maxillofacial and dental departments and 9 surgery rooms which faced to problems resulted from lack of regular and clear scheduling plan.

Totally, surgery room scheduling has many benefits which include:

1.for costumer (patient): (patient satisfaction, sooner operation of patients, reducing waiting time, reducing mental and psychic effect)

2. for doctors and surgery agents: (knowing accurate time of operation, better and more precise planning of each surgery and optimal use of each surgery time, more optimal use of human resources and reducing their vacation times)

3. for surgery room equipments: (reducing operating of each surgery room, reducing being unused cost for each device)

4. for hospital owners: (caring patient with high quality, excellent service to patients, ensuring patient safety in high level because of operating in usual times of hospital, reducing overtime costs, maximizing efficiency of using available times to intended operations)

5. for society: (reducing metal and psychic effects)

Literature review

Scheduling, resources assignment in over time is for performing a set of tasks. This definition entails two different concepts: fist, scheduling is a kind of making decision and it is a process which in time plan is defined. Second, scheduling is a theoretical topic which comprises a set of principles, models, methods and logic results and this set prepares a deep sight about scheduling act for us (Ghasemi and Fatemi Qomi, 2004).

Scheduling means defining start and end times of one or several activities on a source in serial or parallel form. However in manufacturing industries, this concept is used for many years but recently, it attracted attention of many manufacturing and service industries including healthcare industry (Ghasemi and Fatemi Qomi, 2004).. Issues such as nurses scheduling, prioritization and scheduling of patients and surgery room scheduling are important issues in healthcare industry. In surgery room scheduling, waiting time for each patient is defined depending on type and severity of disease and doctor diagnosis. Exceed of this defined time can lead to side risks for patients.Assignment of patients to surgeons and surgery rooms is doing in such a way which in loss due to delay of patients' operation is minimized regarding patients' multiplicity, their requirements and work calendar of different sections' surgeons. Beside of these goals, other goals such as increasing benefits of surgery rooms, reducing waiting times, increasing hospital income and similar subjects can be pointed (Fei, Meskens, and Chu, 2003).

The most prevalent procedure which is used in many hospitals to planning and scheduling surgery rooms is accomplished in 2 main stages named assignment and sequencing. Related problem to each one is showed respectively in forms of SCAP and SCSP (Testi, Tanfani, and Torre, 2007)

Generally in literature, there are 3 different policies to performing stage of assignment as following:

1 .open strategy scheduling

This strategy is known as every work-day strategy (Ghezelbash, 2010). It means surgeons can choose every work-day for each surgery. This strategy can be also defined as first entrance-first serving (Fei, Chu, and Meskens, 2008).

2.Block strategy scheduling

This refers to those strategies which in surgeons or a team of them are assigned to a set of time periods which in they can schedule and regulate their surgeries. Theoretically, this time periods are periods which are reserved for each surgeon beforehand and planning cannot be assigned to another surgeon in that period even if some of these periods remain unused (Fei, Chu, and Meskens, 2008).

3. modified block strategy scheduling:

In fact, block or periodic strategy scheduling can be modified in two forms for more flexibility. In such a way that those surgery room hours which are reserved or unused time periods fill by surgery of other surgeons adaptively. Block or modified scheduling is used in hospitals in widespread level practically (Fei, Chu, and Meskens, 2008).

According to conducted studies, scheduling and surgery planning are variable between techniques and goals. Therefore, it is used in techniques for defining a date for the surgery and it is used for improving surgery scheduling in second instance (Dexter *et al.*, 2007).

From management approach, scheduling and planning of surgery room is divided to 4 levels of long-time, medium-time, offline short-time and online short-time. It states interaction between 4 control levels in the hospital. In each level, several decisions are made in different periods of time. Based on provided framework, these decisions are classified into 4 categories: educational planning, planning of resources capacity, medical coordination and financial planning (Hans, 2006).

Research Background

Arenas *et al.* developed an ideal planning model as a information system which its main goal is planning and managing optimally. This optimization is conducted for surgery operations in a hospital in Spain. This linear model consists of a set of dynamic limitations which show the monthly evolution of waiting time for each process. According to this matter that the most important priority for planning in the given hospital is reducing patients' waiting time to less than 6 months in the waiting list, the goal of the hospital is definition of maximum level of activities and amount of extra activities with considering prediction of patients' entrance and available resources. In order to this, two models of GP are presented for solving these two problems. The first ideal in the first model is this matter that we should be ensured that no patient stays in the waiting list more than 6 months. The second ideal is about level of extra activities which this level should not exceed from a particular level. In second model, waiting time is reduced to 4 months and the effect of this reduction from the waiting list is surveyed to defining excess requirements or amount of needed extra activities. Used strategy in this hospital is block strategy. Assigned time to each surgery team is not re-distributable and it is the most important limitation of this system (Cardeon, Demeulemeester, and Belien, 2009).

Vissers presented a one-month planning model for patients in their research and they defined their decision variable different than other researches. In this research, selected patient are categorized according to rate of resources which they use and the model specifies that in each day, how many patients from each specific type should be scheduled to optimizing 4 limited resources of studied surgery centers. According to considered priorities, these resources are: limited time, surgery hall, beds of general units and the number of ICU nurses. This scheduling is designed in such away which in all patients are scheduled in surveyed time and using considered resources does not exceed determinate allowable limit. The model is formulated as MILP and solved using MOMIP solver. Finally, different scenarios are presented to examining effect of the model using and results are compared to each other. In this paper, real data of a heart center in Rotterdam is used (Arenas, and Bilbao, 2002).

Jebali presented scheduling surgery operations during a 2-stage process assuming the date of surgery is determinate for each patient.In first stage, surgery operations are assigned to surgery rooms and in second step, sequencing of surgery operations is presented.

The aimed goal in stage of assignment is reducing patient cost, reducing overtime and under-time of surgery room. In first stage modeling, limitations of ICU beds' capacity, surgeon availability, capacity of surgery room and date of operating surgery of each patient is considered. To sequencing patients aimed to minimizing surgery room overtime, a two-stage flexible FS model is presented which in m of first machine consists of surgery rooms and n of second machine consists of recovery beds. In this stage, two strategies are examined: in first strategy, the results of scheduling stage are given to the second model as parameters and then, sequencing is done. But in second strategysequencing is conducted regardless of first stage results. Results show that first strategy is had a better efficiency. In this problem, multiple assumptions are considered to simplification. For example there are all required resources for surgery operation (technician, equipments, nurse and etc) except surgeons in all hours and without any limitation. This model is not examined with real data. Because of considered assumptions for simplification, this model is far from reality (Vissers, Adan, and Bekkers, 2005).

Cardeon presented a comprehensive classification in regard to surgery room scheduling and planning (in all three stages) and he examined published papers from a different perspective.This classification is conducted based on 7 descriptive criteria:

1. Patient type
2. Performance type
3. Certainty and uncertainty of the issue
4. Solution technique type
5. Performed analysis type
6. Made decisions description
7. Being the issue practical or not

In this review paper, patients are divided to two categories of selective patient (including outpatients and inpatients) and non-selective patients (including emergency and urgent patients). Outpatients are those who do not need to hospitalization after surgery operation and they are discharged, while hospitalized patients need more care after surgery operation and they should be hospitalized one or more days. Urgent patients are those who need urgent treatment and they should be operated immediate after entrance. But emergency patients have a better condition in comparison to urgent patients and they can wait a few hours for treatment. The entrance of urgent and emergency patients is accidental and to this cause, considering these patients in planning and scheduling makes a accidental and uncertain state and it makes the problem very complex (Jebali, Alouane, and Ladet, 2006)

In assignment stage, Lamiri considers each time block from each surgery room to determining a set of patients. This work is performed through definition of a cost matrix. In this respect that assignment cost of each patient to one day and a special surgery room is considered as the model input. In this research, Lamiri used perpendicular manufacturing method to solving the model. In this model selective and emergency patients are considered and decision variable which is used is determining the day and surgery room for patients. Surgery unit is considered completely distinct and its goal function is in multiple forms for balancing rate of benefits from surgery rooms and reducing related costs to patients (Lamiri, Xie, Dolgui, & Grimaud, 2006)

Methodology

Research process of this study is as follows:

1. Recognition phase: referral to different hospitals for receiving primary information and familiarization with outlined terms in literature

1.1.Literature review: librarian study for examining types of available processes, limitations and considered criteria in literature

1.2.Recognizing available processes, limitations and criteria of hospital surgery room scheduling with daily presence

2. Phase of modeling and model implementation

2.1. Formulating proper primary model for scheduling according to obtained data from librarian and field study

2.2. Developing data and information in Excel software

2.3. Implementation in Lingo software

3. Completion and modification phase of presented model

3.1. Implementation of the model on model completed input data using experts' opinions

4. Model assessment phase

4.1. Assessment of presented model using data and comparing obtained results with present conditions

5. Presenting scheduling table for each surgeon

In this research, we are going to define scheduling surgery rooms effectively and efficiently to increasing preferences of surgeons; and at the first, we predict the number of surgery operations in any type for any surgeon in planning period. Also, we will define effective factors on surgeons rating and in this regard, we provide a linear planning model to assignment of surgery room day to each surgeon.

Basic model of surgery room scheduling

Anastasia Romanyuk& Alexandra Silva used this model for minimizing difference between assigned hours and required hours of each surgery teams in week. In this model, they paid attention to reducing predicted assigned hours and real used time. Also, according to this matter that required used time may be more than assigned time, we consider between zero value and maximum negative value (if it will be created). The goal function and limitation of this model is as follows:

$$MINf(x) = \sum_{j=0}^{N_{gropup}-1} \max(0, t_j - \sum_{i=0}^{N_{types}} \sum_{k=0}^{k=6} (d_{ik} \cdot x_{ijk}) \quad (1)$$

$$\sum_{j=0}^{N_{group}-1} x_{ijk} \leq a_{ik} \quad (2)$$

$$x_{ijk} \leq p_{jk} \quad (3)$$

$$LDType_{ijk} \leq x_{ijk} \leq UDType_{ijk} \quad (4)$$

$$LDall_{jk} \leq \sum_{k=1}^{k=12} x_{ijk} \leq UDall_{jk} \quad (5)$$

$$Lweek_{ij} \leq \sum_{k=1}^{k=12} x_{ijk} \leq Uweek_{jk} \quad (6)$$

In this model X_{ijk} is an integer variable which is assigned for assignment of type i surgery rooms which are for type j surgery teams in day k.

Index j shows type of surgery team and each surgeon operates in related room specified for that team.

Indicator k shows a specific shift. It is assumed that in studied hospital, the number of shift is 21 and every day consists of 2 morning and afternoon shifts (it continues from Monday morning to Saturday afternoon).

Index d_{ik} shows the number of hours of type i surgery which is operated in its specific surgery room and in day k of the week.

Index t_j shows the number of basis hour for surgery team type j.

Index a_{ik} shows type of surgery room type i in day k.

Equation number 2 (first limitation) shows that the number of surgery room type i which are assigned to all surgery teams in time k (related shift and day) should be less than or equal with the number of surgery rooms type a in time k.

Equation number 3 (second limitation) shows that the number of surgery rooms from all types which are assigned to team i in time k in the week should not be more than the number of surgeons in team p.

Equations number 4, 5, 6 (limitations number 3, 4 and 5) are surgery room limitations which are assigned to each surgery unit.

Equation number 4 (limitation number 3) shows that the number of all surgery rooms, from any type, can be assigned to group j in day k.

Equation number 5 (limitation number 4) shows limitations of surgery rooms type I which can be assigned to team j in day k.

Equation number 6 (limitation number 5) shows limitations of the number of all surgery rooms type i which can be assigned to team j in week.

Proposed model

In this model, maximizing hospital and surgeons' preferences about time of surgery operating and assignment of surgery room which is related to this type of surgery, in addition to prediction of required number of individual surgeons.

Structural characteristics of this mathematical model are as follows:

The sets

J: the set of clinicians

G: the set of surgery teams

I: the set of surgery operations

K: the set of week days

S: the set of work shifts per day

Model parameters

$t_{j:}$ average time of surgery i

h_s: available time in shift s

r_s: number of available surgery rooms in shift s

n_{ij}: the number of surgery type j which is predicted for surgeon j in planning period (a week)

$P_{j,k,s}$ = {0,1}: surgeon tendency to operating surgery in day k and shift s

$C_{j,k,s}$: priority of surgeon j to operating surgery in day k and shift s from hospital management view

$_j$: The number of related surgery room to surgery team jØ:

Decision variables

$X_{j,k,s}$ ={0,1} assignment of surgery room to surgeon j and day k and shift s

Hypotheses

Surgery rooms are professionalized for each surgery teams.

The number of surgeons is 64.

The surgery operations are performed from Saturday morning shift until Friday afternoon shift (1 and ... 21).

The total number of surgery rooms is 8 and they are assigned according to each surgery team.

The goal function and its limitation

$$f(x) = \max \sum_{j} \sum_{k} \sum_{s} x_{jks} * c_{jks} \quad (1)$$

Limitations

$$\sum_{k} \sum_{s} h_s * x_{jks} \leq \sum_{I} t_i * n_{ij} \qquad \forall j \in J \quad (2)$$

$$\sum_{J} x_{jks} \leq r_s \qquad \forall k \in K, s \in S \quad (3)$$

$$\sum_{K} \sum_{S} \sum_{J \in g} x_{jks} \leq \varphi_j \qquad \forall g \in G \quad (4)$$

$$x_{jks} \leq P_{jks} \qquad \forall j \in j,\ \forall k \in k,\ \forall s \in s \quad (5)$$

$$x_{jks} = \{0,1\} \qquad \forall j \in J,\ k \in K,\ s \in S$$

In this model, C_{jks} shows preferences of hospital management and it is assigned in according to present priorities to each surgeons. X_{jks} shows whether or not surgery is operated and numbers one and zero are assigned to it.

Equation number 2 (first limitation) shows limitation of allowable margin of total time of surgeries in each shift.

Equation number 3 (second limitation) shows that for each surgeon if he/she has no tendency to a specific shift or absence of that surgery in his/her plan, that surgery will not be planned on that shift.

Equation number 4 (third limitation) shows specific surgeries are operated in related specific surgery rooms.

In order to solving this model in form of mentioned problem in Saadi hospital, we can use Excel and Lingo software. According to the number of variables and accessing to optimal and more precise solution, Lingo software is used.

$$J = \{1,....64\}$$
$$I = \{1,....38\}$$

The sample of scheduling table which is Lingo output is for all surgeons (first number on the right) and all available shifts to scheduling assignment (number in left, it continues from 1 to 21 according to shifts and week days). Also, existence of zero and 1 value shows operate or do not operate about related surgeon in outlined shift. This is expressed in accordance with following table.

Discussion and research findings

In this problem, scheduling is planned based on hospital management opinion and their preferences and also it is based on surgeons' opinion in association with time of operating surgery. This is conducted in such a way which in it is tried to filling all surgery room hours in coordination with type of surgery room. The amount of surgery room occupation level shows increasing effectiveness of surgery room scheduling and reducing overtime hours. The difference between basis hours for each surgeon and their filling hours is reduced and reached to less than predicted value.

Conclusions

In this paper, a mathematical model is considered to the problem of surgery rooms' scheduling and planning with goal function of maximum preferences of surgeons and hospital management. Afterwards, Lingo software was used to solving this problem. Main findings show that using this method led to improving occupation level of surgery rooms from 87% to 85% and value of difference between assigned times to each surgeon and their filled hours reached to less than predicted value.The most important advantage of this model is attempt to considering hospital preferences about time of operating surgery and preferences of each surgeon.

This research, such as other researches, has limitations including not considering all parameters and hospital limitations from limited viewpoint that researches cannot highlight planning aspects using financial data and amount of planning effectiveness on financial performance of the hospital. Also, researches can use meta-heuristic methods to solving proposed model in solving problems.

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Table1. Assignment of surgery times for each surgeon

X(1, 18)	1	X(45, 14)	1	X(30, 11)	1	X(74, 7)	1
X(1, 19)	1	X(45, 15)	1	X(30, 12)	0	X(74, 8)	1
X(2, 2)	1	X(45, 19)	1	X(30, 16)	0	X(74, 12)	1
X(2, 6)	1	X(46, 2)	1	X(30, 20)	0	X(74, 16)	1
X(3, 21)	1	X(47, 17)	1	X(32, 14)	0	X(76, 10)	1
X(4, 13)	1	X(48, 9)	1	X(33, 6)	0	X(77, 2)	1
X(4, 15)	1	X(48, 11)	1	X(33, 8)	0	X(77, 4)	1
X(5, 7)	1	X(49, 3)	1	X(33, 21)	0	X(77, 17)	1
X(5, 10)	1	X(49, 6)	1	X(34, 3)	1	X(77, 20)	1
X(7, 1)	1	X(50, 18)	1	X(35, 15)	0	X(79, 11)	1
X(7, 13)	1	X(51, 9)	1	X(36, 6)	1	X(80, 2)	1
X(8, 2)	1	X(51, 19)	1	X(36, 16)	0	X(80, 12)	1
X(8, 8)	1	X(52, 4)	1	X(37, 1)	0	X(80, 18)	1
X(9, 2)	1	X(52, 19)	1	X(37, 16)	0	X(81, 12)	1
X(9, 4)	1	X(52, 21)	1	X(37, 18)	0	X(81, 14)	1
X(10, 18)	1	X(54, 14)	1	X(39, 11)	0	X(83, 7)	1
X(10, 19)	1	X(54, 15)	1	X(39, 12)	0	X(83, 8)	1
X(11, 3)	1	X(54, 20)	1	X(39, 17)	0	X(83, 13)	1
X(11, 13)	1	X(55, 9)	1	X(40, 6)	0	X(84, 2)	1
X(12, 6)	1	X(56, 2)	1	X(40, 20)	0	X(84, 16)	1
X(12, 17)	1	X(56, 13)	1	X(41, 10)	0	X(85, 6)	1
X(13, 3)	1	X(56, 20)	1	X(41, 17)	0	X(85, 13)	1
X(13, 11)	1	X(57, 7)	1	X(42, 4)	0	X(85, 21)	1
X(14, 18)	1	X(58, 14)	1	X(43, 11)	0	X(87, 7)	1
X(15, 10)	1	X(59, 6)	1	X(44, 3)	0	X(87, 20)	1
X(16, 18)	1	X(60, 14)	1	X(45, 11)	0	X(89, 7)	1
X(17, 4)	1	X(60, 21)	1	X(95, 20)	0	X(89, 14)	1
X(18, 2)	1	X(61, 19)	1	X(96, 18)	0	X(90, 12)	1
X(19, 15)	1	X(63, 11)	1	X(98, 10)	1	X(92, 4)	1
X(20, 19)	1	X(64, 15)	1	X(99, 14)	0	X(93, 8)	1
X(21, 11)	1	X(65, 7)	1	X(27, 9)	1	X(71, 5)	1
X(22, 19)	1	X(66, 15)	1	X(28, 17)	0	X(72, 13)	1
X(23, 15)	1	X(67, 11)	1	X(29, 13)	0	X(73, 9)	1
X(24, 2)	1	X(67, 19)	1	X(27, 3)	1	X(70, 20)	1
X(26, 11)	1	X(70, 7)	1				

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