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Daily Operating Room Schedule Taking into Account the Preferences of Hospital Physicians (Case Study of Imam Khomeini Hospital)

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Abstract

The issue of allocating the capacity of operating rooms to different departments of surgery is done by observing the decisions made at the strategic level of hospital decisions. Therefore, operating room scheduling plays an important role in increasing their productivity and reducing hospital costs. On the other hand, due to various uncertainties in operating room activities, this issue can be very challenging. In this case, according to the defined objective function and also the existing limitations, the capacity of operating rooms is allocated to different surgical groups. Therefore, in this model, the daily schedule of surgeries in two stages of surgery and recovery and considering all the real limitations in hospitals has been investigated. This issue determines the sequence, start time of each surgery and allocation of resources required in each stage with the aim of minimizing the total cost of employing surgeons according to the differences in their skills, performance and preferences.

Keywords: Operation sequence, Operating room scheduling, Surgical staff allocation, Physicians' preferences, Mathematical modeling.

1. Introduction

In today's developed world, the need for new ways of providing services in health systems is increasing, so that while paying attention to the level of satisfaction of patients and clients, the economic benefits for the hospital. The share of health expenditures in total GDP increased from 3% in 1948 to 9.7% in 1997. According to the World Health Organization in 2013, more than 17.9% of GDP in the United States is allocated to health and is projected to reach 20% of GDP in 2021. On the other hand, due to the special position of hospitals in the field of health, proper management in the field of health is not possible without proper management of hospitals and medical centers. According to the World Health Organization in Iran, a large part of the cost of treatment is paid by the government. This figure was about 37% in 2000, about 43.5% in 2001, about 46.7% in 2007 and more than 40% in 2012 (Shafaei,2015). Considering the double emphasis of the government this year on increasing the budget in the field of health in the coming years, the need for proper management in this field seems more than ever.

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One of the most challenging issues for a hospital is making the right decision about how to assign surgeries to existing specialists. Obviously, mathematical modeling can be instrumental in this decision.

The purpose of developing the mathematical model is to find the optimal allocation according to factors such as the amount of daily access to physicians, surgery costs, overtime hours and post-surgery care, etc. Also, due to the uncertainty in the duration of each surgery according to the patient's condition, different scenarios have been considered for the allocation model and the mathematical model has been modeled in the form of a stochastic optimization model. In addition to the above, another issue in hospital planning is to consider emergency situations. For this purpose, one of the approaches of this research is to provide a solution to improve the situation for emergency patients.

As mentioned, in this study, a model for achieving the best allocation in a hospital is presented. Based on this, at first, by studying the existing literature in this field and also by considering the existing conditions in Iranian hospitals, a mathematical model has been developed. Then, in order to ensure the operation of the model, it was discussed in small dimensions. After ensuring the operation of the mathematical model, the mathematical model and validation have been solved in Gams software. The final validation is performed through sensitivity analysis on the most important parameters of the model.

Statement of the problem

In this research, an optimization model of daily operating room scheduling is presented. The basis of the model introduced in this section is modeling with the BIM approach. The concept of BIM in an operating room problem means the breakpoints of the schedule. According to what was mentioned, one of the approaches of this model is to provide a solution for surgery of emergency patients. Schedule breaks, or BIMs, are the points at which an operation in a room is completed and the next operation has not yet begun. Since no surgery can be left unattended, in the event of emergency surgery, only an intermittent schedule can be disrupted between BIM points, as only during this time can an emergency patient be admitted. There is. Therefore, in order to create better performance in the schedule, arrangements should be made to reduce the distance between BIM points as much as possible to increase the possibility of responding to emergency surgeries. Figure 1 intuitively shows the time taken to receive an emergency patient.

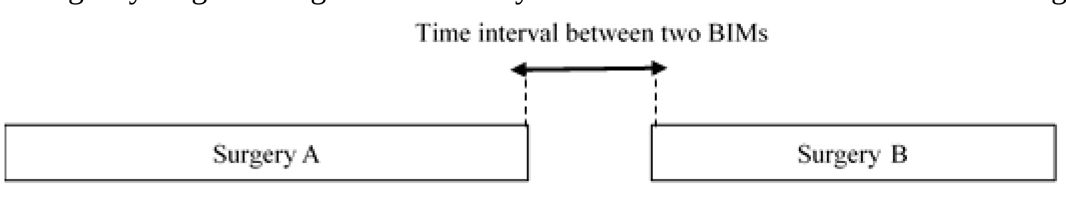

Figure 1. Time interval between two planning breakpoints

As shown in Figure 1, the greater the distance between the BIM points, the longer the operating room idle time. In this case, although the possibility of accepting an emergency patient increases, but on the other hand, if the emergency patient does not come, the system incurs a huge cost.

Therefore, to improve this situation, the solution of the BIM-based model is to increase the number of BIM points in close distances. In this case, both goals have greatly reduced the possibility of admitting an emergency patient as soon as possible, as well as reducing the length of time it takes to operate operating rooms and the amount of overtime.

On the other hand, considering the capacity of the operating room alone to maximize the quality of services (minimizing the waiting time for patients) does not lead to a proper schedule. Lack of downstream resources can prevent patients from moving forward and significantly reduce operating room utilization. Therefore, surgical planning should also take into account the capacity of operating rooms, the availability of recovery beds, and the total workload. When the surgery is over, the patient is transferred to a recovery room that includes recovery beds. If the recovery beds are full, the patient stays in the operating room and blocks the operating room until a recovery bed is available. The patient is then cared for until complete recovery. In other words, the path to be taken by the patient will be that the patient is admitted first and if the need for surgery is diagnosed, the patient's name is announced to the operating room management, the operating room finalizes the list of surgeries the next day and Informs the surgeons and assigns rooms and shifts to the surgeries, the patient is transferred to the operating room at the appointed time, after the operation is transferred to the recovery rooms and ICU according to the conditions (Figure 2). Therefore, lack of access to a bed in the recovery ward increases unused time in the operating room and reduces the hospital's economic efficiency. Also, if not enough ICU beds are available to receive patients, some patients will have to stay in the operating room. Accordingly, in this study, at first, a method has been developed to calculate the rate of exposure to shortages in the acceptance of recovery boards, and then by considering the penalty for the shortage rate, the shortage in this sector has been minimized.

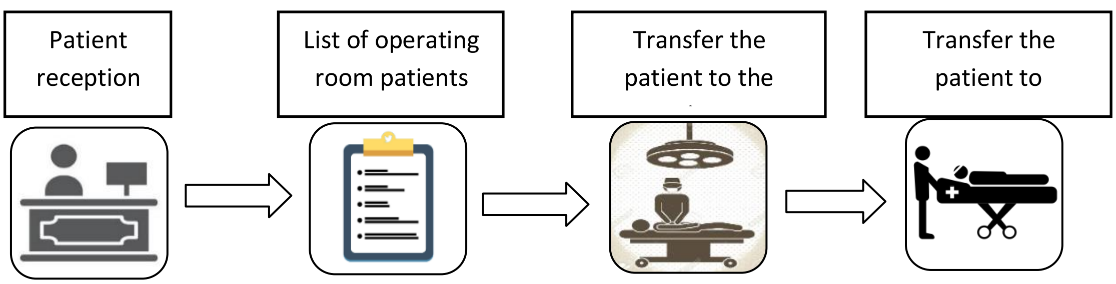

Figure 2. The surgical process of patients in the operating room

In this research, the model is initially considered in the form of a two-stage stochastic optimization. In stochastic optimization, there are two categories of first and second stage variables. The variables of the first stage are those variables that are calculated independently of different scenarios. The variables of the first stage in this study are the allocations of surgeries to rooms and people, as well as the sequence of surgeries in each room. The variables of the second stage are those variables that are determined after the occurrence of each of the scenarios. Certainly, the problem studied in this study is the different conditions of a patient, including normal, optimistic and severe, and consequently the duration of his surgery and the time spent in the recovery wards will depend on the scenario of the event, so variables such as the end time of each surgery is considered random.

Literature Review

Theoretical foundations

Research Background

Operating room scheduling and planning began with Adair's work in 1953. Research in this field has been on the rise, so that in the 60s, many researchers, such as Blaye and Goldman, joined the ranks of researchers in operating room scheduling and planning, and studies on the optimal number of operating rooms and policy evaluation and They paid the schedule. These issues have been evolving since 1977; But over the past hundred years, the number of articles published in this field has increased exponentially. Studies have divided surgical scheduling into two sub-stages, arrival timing and scheduling. In 1977, Blake and Carter developed this classification and added a third process, called external resource scheduling, in which the process of reserving and determining the resources required before and after each surgery is specified. Each of these stages was examined at three levels: strategic, executive and operational (Wang,2005).

- Cardoen et al. (2010) provided a comprehensive overview of operating room planning and scheduling issues along with their classification from different dimensions (Cardoen et al, 2010).
- In 2012, Hens et al. Categorized the framework of hospital management issues into three levels: strategic, tactical, and operational. Materials coordination and financial planning are done (Hans, 2012).
- After them, Samudra et al. (2016) reviewed published articles in the field of operating room planning and scheduling between 2000 and 2014, and outlined the challenges and shortcomings that researchers in this field face. are. In these studies, some researchers have considered the modeling of the problem in a definite state (Samudra,2016).
- For example, Xiang et al. (2015) considered the three-stage modeling of the surgical process (preoperative, intraoperative, and postoperative) to be definitive, and after presenting a complex integer programming model for the problem, the Ant Colony Optimization Algorithms (ACO) were developed to solve it (Xiang, 2015).
- In the real world, too, there are various uncertainties in the process of scheduling operating rooms. Cochran and Roche (2009) review the existing articles and state that for the problem of operating room scheduling, different objective functions have been defined. The long wait for the operation is one of the most frequent complaints of patients. Prolonged waiting time for medical services in hospitals, including surgeries, in addition to the fact that the patient may be harmed due to time constraints, may be prevented from receiving services due to time delays and his problem may become more acute (Cochran,2009). For this reason, reducing patient waiting time can be a criterion for diagnosing a better schedule.
- In addition to completing previous research, Mesken et al. (2013) point out that the hospital pays for all the hours that the operating room and surgical staff are ready to

perform surgery; Therefore, if these resources remain idle for part of these hours, additional costs will be imposed on the hospital. Therefore, the ideal mode of scheduling for the operating room is to eliminate this idle time. Obviously, this is not possible in practice, because on the one hand, the probability of the time of surgery does not allow the schedule to remain unchanged, and on the other hand, the planning of a large number of operations in one day in order to reduce unemployment is incomplete. Staying in operation during working hours results in resources having to stay longer in the hospital. It is clear that operating room overtime increases hospital costs, and since the costs of both unemployment and overtime are overhead costs, hospitals seek to reduce both costs simultaneously. On the other hand, the salary that the hospital pays to the staff for the surgical hours can not be reduced, but the costs of being unemployed or overtime in the operating rooms can be reduced with the right timing. Therefore, reducing unemployment and overtime hours of operating room staff is an important criterion in evaluating a scheduling model (Meskens, 2013).

- Meanwhile, in recent years, relatively extensive studies have been conducted by Iranian researchers on the issue of planning and scheduling operating rooms. For example, Atiqechian and Sepehri (2012) examined the issue of daily scheduling of surgeries in the case of having multiple sources and considering the probability of the duration of surgeries (Atiqeh Chian, 2012).
- Ghazal Bash et al. (2012) have also investigated the issue of planning the allocation of patients to operating rooms in definite conditions (Ghazalbash,2012).
- Akbarzadeh et al. (2013) have also studied the issue of planning and scheduling of operating rooms at the operational level (Akbarzadeh,2013).
- Zhang et al. (2014) considered the uncertainty factor during surgery times and presented a two-stage probabilistic planning model to model the problem (Zhang,2014).
- Sagnol et al. (2016) considered uncertainty both during surgery and in the arrival of emergency patients and solved the problem using possible multi-stage model planning (Sagnol,2016). In recent years, efforts have been made to take these research uncertainties closer to the real-world situation and make them more practical.

Timing operating rooms is challenging for two main reasons:

1. The allocation of resources (operating rooms, surgical staff, etc.) to tasks (surgeries and their sequencing is a matter of combined optimization;
2. There are significant uncertainties in many activities of this department, such as the duration of each surgery (Denton, 2009).

Operating room scheduling issues are categorized from different aspects, including the following categories can be mentioned:

1. Selective or non-selective patients: Selected patients are pre-programmed, while non-selective patients are usually unexpectedly admitted during the day and added to the existing schedule.
2. Surgery Scheduling Levels: There are three levels to scheduling surgeries:

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- Strategic level: This stage determines the number and type of operating rooms, working hours of the rooms and the capacity allocated to different surgical specialties, individual surgeons or surgical groups.
- Intermediate (tactical) level: At this level, the allocation of different surgical specialties to operating rooms is done in one time window, which is also called the "main surgery scheduling issue."
- Operational level: At this stage, each surgical case is planned in the operating rooms. This process is divided into two sub-stages of planning surgeries on a weekly basis and assigning surgeries to operating room blocks and daily scheduling of operating rooms.

3. Operating room scheduling strategies:

– Block strategy: In this strategy, an operating room time block is maintained for a surgeon or surgical team. The surgeon may hold several different time blocks over the course of a week and remain constant from week to week.
– Open strategy: In this strategy, no operating room is reserved for a specific surgeon; However, there may be a weekly schedule for the surgeon.
– Modified block strategy: It is a combination of two open and block strategies in which several time blocks are left open, thus increasing the flexibility of the block strategy (Cardoen, 2010).

Problem solving method is another issue that should be considered in research methodology. Mathematical programming and its exact solving methods, innovative and meta-innovative methods as well as simulation, are the methods that have been used so far to solve the surgical scheduling problem. Obviously, according to the research approach, the dimensions of the problem and the data collected, it is necessary to choose an appropriate method to solve the problem; For example, using simulations for scenario analysis is usually more appropriate. It is also possible for a research to use more than one approach or method for the problem; For example, due to the possible nature and complexity of the mathematical model of the problem, the use of simulation along with other methods is common. Therefore, the solution method can also be considered as one of the innovations to solve a problem.

In general, the innovations of the present study are:

1 .Considering the preferences of physicians in order to be present in the hospital and perform surgeries.

2. Dynamic consideration of the capacity of the hospital intensive care room in order to recover patients after surgery.

2. Method

Mathematical model

In order to fully understand the proposed model, it is necessary to be familiar with the symbols, abbreviations, sets and parameters used in the main model. For this purpose, first the positive values and parameters of the model and finally the decision variables used in the model are stated:

Collections

N: A set of all possible scenarios.

K:Collection of operating rooms.

M:A set of surgeries to be performed in one day.

M_k:A set of surgeries that should be performed during the day in operating room k.

T:A set of time blocks

S:Collection of all available surgeons$(s, \acute{s})$

Parameters

P_{is}^{n}: Duration of surgery i performed by surgeon s under scenario n.

S_k:Time to start work in the operating room k.

B: The start time of the whole set, which is equal to the maximum values of the operating rooms.

E^n: End of working time under scenario n is equal to the minimum values of closing time of operating rooms.

C_s: Cost of employing surgeons per unit time.

C_{pt}^{n}: The nominal capacity of the ICU in the t time block under scenario n.

A_s:Surgeon s availability time during the day.

α: Coefficient of preference for surgeons to attend the hospital.

L: Very large number.

Av_t: The end time of the t time block.

Decision variables

X_{is}: Variable zero and one if surgery i is performed by surgeon s is equal to one and otherwise equal to zero.

O_{ijk}: Variable zero and one is equal to one if surgery i is performed by surgeon s in operating room k before surgery j, otherwise it is equal to zero.

C_{iks}^{n}: Time to complete surgery i by surgeon s under scenario n.

W_i^n: Variable zero and one in case of completion of surgery i before the end of the employment period is equal to one and otherwise equal to zero.

V_i^n: Variable zero and one if surgery i before the start of the employment period is equal to one and otherwise equal to zero.

y_{it}^n: The variables zero and one are equal to one if not available in the t time block during the day after i-bed surgery for ICU admission under scenario n, otherwise zero.

CAP_t^n: Dynamic variable of ICU capacity in the tth time interval of the day under scenario n.

GG_{ik}^s: The variables zero and one are equal to one if the surgeon i is assigned to room k and the surgeon s is equal to one, and otherwise equal to zero.

$G_{jik}^{\acute{s}s}$: The variables zero and one are equal to one if operation i by $\acute{s}$ occurred before operation j by s in room k, otherwise equal to zero.

λ_{ik}: Variable zero and one if surgery i is assigned to room k is equal to one and otherwise equal to zero.

Problem Object Function

$$Z = \frac{\sum_n \sum_i \sum_s C_s . x_{is} . P_{is}^n}{N} \qquad (1)$$

Problem Limitations

$$C_i^n = (s_k + P_{is}^n).GG_{sik} + \sum_{s'} \sum_j P_{js}^n . G_{ss'jik} \qquad \forall k \in K,\ \forall i, j \in M_K,\ \forall n \in N\ ,\forall s \in S,\ i \neq j \qquad (2)$$

$$\sum_k \lambda_{ik} = 1 \quad \forall i \qquad \forall i \in M_k \qquad (3)$$

$$\sum_s C_{jks}^n - \sum_s C_{iks}^n \geq -L(1 - O_{ijk}) \qquad \forall k \in K,\ \forall i, j \in M_k,\ \forall n \in N,\ i < j,\ \forall n, i, j, k, i \neq j \qquad (4)$$

$$\sum_s C_{iks}^n - \sum_s C_{jks}^n \geq -L(O_{ijk}) \qquad \forall k \in K,\ \forall i, j \in M_k,\ \forall n \in N,\ i < j,\ \forall n, i, j, k, i \neq j \qquad (5)$$

$$C_i^n \leq B - \varepsilon - LV_i^n \qquad \forall n \in N,\ \forall i \in M \qquad (6)$$

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$$C_i^n \le E^n + \varepsilon - LW_i^n \qquad \forall n \in N,\ \forall i \in M \qquad (7)$$

$$\sum_i P_{is}^n . x_{is} \le \alpha . A_s \qquad \forall s \in S,\ n \in N \qquad (8)$$

$$y_{it}^n \ge 1 - \frac{C_{iks}^n}{Av_t^n} \qquad \forall i \in M_k,\ t \in T,\ n \in N,\ s \in S,\ k \in K \qquad (9)$$

$$Cap_t^n = Cp_t^n - \sum_i y_{i(t-1)} \qquad \forall t \in T,\ n \in N \qquad (10)$$

$$\sum_s x_{is} = 1 \qquad \forall i \in M_k \qquad (11)$$

$$\begin{aligned} G_{jik}^{ss'} &\le (o_{jik} + x_{js'} + \lambda_{ik} + \lambda_{jk} + x_{is})/5 \quad i \ne j \\ G_{jik}^{ss'} &\ge (o_{jik} + x_{js'} + \lambda_{ik} + \lambda_{jk} + x_{is} - 4)/5 \quad i \ne j \end{aligned} \qquad \forall s, s' \in S,\ j, i \in M_k,\ k \in K \qquad (12)$$

$$\begin{aligned} GG_{ik}^s &\le (\lambda_{ik} + x_{is})/2 \quad i \ne j \\ GG_{ik}^s &\ge (\lambda_{ik} + x_{is} - 1)/2 \quad i \ne j \end{aligned} \qquad \forall s, i, k \qquad (13)$$

Problem Relationship Description

- Equation (1) represents the objective function of the problem, which minimizes the total cost of employing surgeons due to the difference in their skills and performance.
- Equation (2) Calculates the completion time of surgical procedure i in room k under scenario n if s is assigned to surgeon. It should be noted that although this variable is dependent on the scenario, but the structure of the model requires conditions that can be done only for single values of these indices in each scenario. To the right of this constraint states that the end time of each operation is the start time of that operating room plus the duration of the operation and other prerequisite operations performed in that room.
- Equation (3) states that a particular surgery should be assigned to only one surgeon.
- Equations (4) and (5) provide the precedence and latency, respectively, as indicators for surgery.
- Equations (6) and (7) are used to count the number of points with the ability to break the planned routine of surgeries in emergency situations with the help of auxiliary variables. Under this restriction, endpoints in the busy interval (the time when all rooms are occupied) are considered a BIM because it is possible to admit an emergency patient immediately afterwards.
- Equation (8) provides limited control over the amount of access to different surgeons according to the level of preference for their presence.

- Equation (9) Assigns a bed to the 1st surgical patient in case of completion of surgery in the t time block in the ICU.
- Equation (10) dynamically calculates the capacity of the ICU. Given that in each block of time it is possible to discharge a patient or transfer a patient from the operating room to the ICU, this value changes dynamically during the day and changes depending on the relevant scenarios.
- Equation (11) calculates the variable of assigning surgeries to related surgeons. This limitation requires the model to assign each surgery to a specific individual and prevents assigning surgeries to several different surgeons simultaneously.
- Equations (12) and (13) are used to define the variables G and GG. The interesting thing about this relationship is that the variable G can only get a value if the variable GG has a value. In other words, only when the surgery is assigned to that room will be calculated to calculate the end time of a surgery in a room and according to its prerequisites in the room. Otherwise, the time of completion of that surgery in that room will be considered zero, which means that the surgery will not be assigned to that room and specialist.

3. Results

As mentioned in the previous sections, the purpose of this study is to provide a mathematical model in order to achieve the best allocation of surgery in a hospital to operating rooms and specialists in their field. Therefore, in this section, in order to evaluate the efficiency of the model presented in the previous section and the proposed solution method, the model has been evaluated and validated using the data of Imam Khomeini Hospital and the analysis and data collected to enter the mathematical model. First, the collected data are presented, then the scenarios and how they are constructed and defined, and finally, the problem is solved and the answers are evaluated and analyzed.

Since the model presented in this study is a scheduling model at the operational and daily level, in order to extract the required data, referring to Imam Khomeini Hospital, the data of one working day of the hospital were collected. Based on this, the types of surgeries in one day and the relevant surgical groups were obtained at the request of the hospital staff. The information required according to the mathematical modeling of the problem includes the following:

1 -List of surgeries by surgery group,

2 -List of emergency patients who have referred to the hospital on the desired day,

3 -The program of doctors' presence in the hospital and their specialty

4 -Schedule set in one day by the hospital for different surgical groups

After collecting the above data from the hospital officials, it was observed that the hospital scheduling was done in the form of tables in the form of manuscripts without any special prioritization. By classifying the data of surgical operations and scheduling, Table 1 was obtained:

Table 1. Types of surgeries by group

Group code	1	2	3	4
Surgery code / Name of surgery	General surgery	Plastic Surgery	Orthopedic surgery	Thoracic surgery
1	Appendectomy	Jaw fracture	Washing and wound healing	Achalasia
2	Foreign body exit	Gynecomastia and mammoplasty	Catheter	Wound abscess
3	Cryotherapy	Bladder lipoma	Perineal and anal abscess	Wound exposure and washing
4	TBNA	Flexor digitorum sublimis FDS	Peritonitis	Finger amputation
5	Hard bronchoscopy	septorinol	Changing the dressing	Septic arthritis
6	Simple bronchoscopy	Tissue expander	Ingestion of abscess	Knee lesion
7	-	Burns and grafts	Close the fascia	Necrotic fasciitis
8	-	SCC , BCC	Pilonidal abscess	Remove the External object
9	-	Forehead lift	Mesenteric Eskimo	Repair and wash the amputee hand

Also, by reviewing the schedule lists for different surgeries, the specialists related to each surgery and the time they spent for the desired surgery were obtained (Table 2).

Table 2. Introduction of departments and their capacity

Surgery group	Number of operating rooms	Number of specialists	Number of surgeries
General surgery	4	3	10
Plastic Surgery	5	4	9
Orthopedic surgery	3	3	11
Thoracic surgery	4	3	9

By completing the data collection process and problem parameters, the mathematical model has been implemented in Gams coding software and the schedule has been optimized taking into account the preferences of physicians and the absence of operating rooms. The results obtained from solving the model in the optimal state of each of the surgical groups are shown in Tables 3 to 6.

Table 3. Schedule of general surgeries

Surgical code	Surgery	Code for Surgeon	Time to start surgery	End of surgery	Room Number
1	appendectomy	1	9:00	10:00	4
2	appendectomy	1	8:00	9:00	1
3	appendectomy	2	11:00	12:00	1
4	Simple bronchoscopy	2	10:00	11:00	2
5	Simple bronchoscopy	3	11:00	12:00	2
6	Hard bronchoscopy	2	9:00	10:00	3
7	Hard bronchoscopy	1	10:00	12:00	3

Table 4. Scheduling of plastic surgeries

Surgical code	Surgery	Code for Surgeon	Time to start surgery	End of surgery	Room Number
1	Bladder lipoma	3	9:00	11:00	2
2	septorinol	2	10:00	11:00	1
3	Burns and grafts	2	12:00	13:00	1
4	Jaw fracture	1	9:00	10:00	3
5	Gynecomastia and mammoplasty	1	8:00	9:00	2
6	SCC , BCC	2	9:00	10:00	4
7	Forehead lift	1	10:00	12:00	4

Table 5. Schedule of orthopedic surgeries

Surgical code	Surgery	Code for Surgeon	Time to start surgery	End of surgery	Room Number
1	Washing and wound healing	1	8:00	10:00	1
2	Washing and wound healing	2	8:00	10:00	2
3	Catheter	1	10:00	12:00	1
4	Perineal and anal abscess	3	10:00	13:00	3
5	Pilonidal abscess	1	12:00	14:00	1
6	Pilonidal abscess	3	13:00	16:00	3
7	Hernia	1	14:00	16:00	1
8	bronchoscopy	2	13:00	15:00	2
9	bronchoscopy	2	15:00	17:00	2

Table 6. Schedule of thoracic surgeries

Surgical code	Surgery	Code for Surgeon	Time to start surgery	End of surgery	Room Number
1	Achalasia	1	12:00	14:00	4
2	Wound abscess	3	10:00	12:00	3
3	Finger amputation	2	10:00	11:00	1
4	Septic arthritis	1	8:00	9:00	2
5	Wound abscess	2	11:00	12:00	2
6	Wound abscess	2	9:00	10:00	4
7	Remove the External object	3	11:00	12:00	1
8	Repair and wash the amputee hand	2	12:00	13:00	1

Model sensitivity analysis

In this section, in order to evaluate the efficiency of the model, the sensitivity of the basic parameters of the model is analyzed. An efficient model is one in which the variables associated with that parameter change logically in exchange for changes to some parameters of the problem. Since cost is one of the basic factors of any mathematical model, one of the important parameters of this issue is the cost of employing surgeons and operating room medical staff. It is expected that with the increase in the average cost of surgeons' salaries, the amount of costs imposed on the entire system will also increase. It is worth noting that three scenarios have been considered to solve the model, these three scenarios evaluate the model in normal, critical scenario and ideal scenario. The effect of the change in the average wage cost on the cost objective function under all three scenarios is clearly seen in Figure 1.

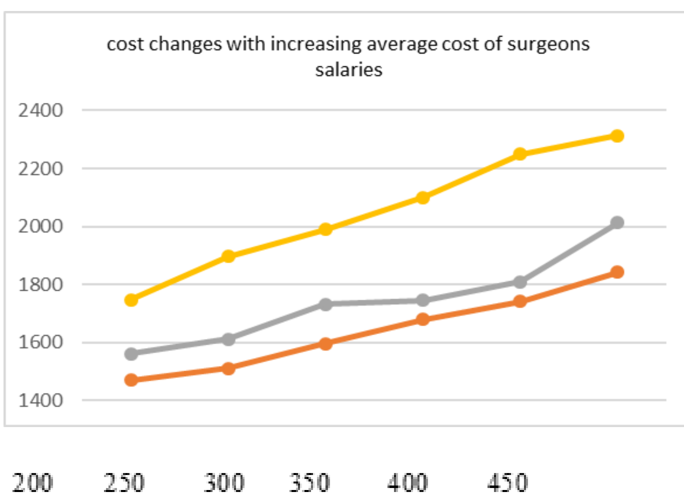

Figure 1. Changes in total cost, with increasing average cost of surgeons' salaries

4. Discussion

Today, one of the most important issues that has occupied the minds of managers of various service systems, including health systems, is to provide services in such a way that the level of customer and client satisfaction on the one hand and economic efficiency for the system on the other. In a hospital system, one of the most challenging issues is deciding on the timing of surgery. Proper and timely response of clients in need of surgery is of particular importance, because it overshadows the level of patient satisfaction more than other departments. Also, mistakes in scheduling surgeries can lead to irreparable damage that may be less common in other parts of the system. In the present study, a model was presented with the aim of minimizing hospital costs and taking into account the preferences of physicians as well as dynamically considering the capacity of the intensive care unit. These results were obtained in the context that in this study, only part of the complexity of the actual operating room compared to the mathematical model was considered; While more complexity of the operating room can be considered without a significant reduction in tool performance. However, adding these complexities to the mathematical model is not easily possible without reducing the speed of solving the model.

Future suggestions

According to the literature review in the field related to this research, an attempt has been made to cover the identified research gaps as much as possible. However, due to limitations, some more advanced aspects were postponed for further research. Potential research areas that can be explored in order to complete the research topic are suggested as follows:

- Use of artificial intelligence algorithms and neural networks to more accurately identify uncertainty-related scenarios;
- Consider patient and operating room preparation times depending on the type of surgery;
- Considering the limited access to specialized personnel such as anesthesiologists, etc., depending on the type of surgery;

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