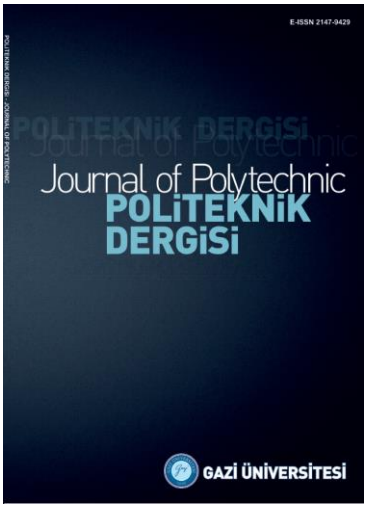

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Evaluation of operating room scheduling processes by analytic network process method

Ameliyathane çizelgeleme süreçlerinin analitik ağ süreci yöntemi ile değerlendirilmesi

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Evaluation of Operating Room Scheduling Processes by Analytic Network Process Method

Highlights

- *Operating room scheduling processes were taken into account.*
- *Factors affecting the scheduling processes were examined.*
- *These factors were evaluated.*
- *Analytical network process method was used.*
- *The points that will increase the effectiveness of the operating room schedule were mentioned.*

Graphical Abstract

The factors that are effective in operating room scheduling have been analyzed. Analytical network process method, which is a multi-criteria decision making method, has been used. Figure 1 shows the application scheme of the study.

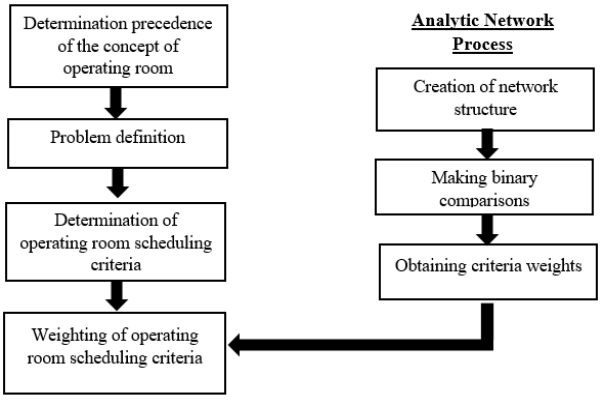

Figure. Implementation steps

Aim

It is aimed to examine the factors affecting the effectiveness of operating room schedules.

Design & Methodology

Analytical network process method, which is a multi-criteria decision making method, has been used.

Originality

Subjective analysis of the efficiency of the scheduling processes contributes to the literature.

Findings

In the results, it is seen that the criteria related to the surgeons come to the fore with rate of 31%.

Conclusion

The efficiency of the surgeons' performance is important, they are also effective in the scheduling process depending on the operations they perform.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Evaluation of Operating Room Scheduling Processes by Analytic Network Process Method

Araştırma Makalesi / Research Article

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ABSTRACT

Multiple performance criteria should be evaluated together in the operating room schedules. Therefore, the operating room scheduling problem is a complex and difficult problem. As a result, it is very difficult to get the best solution, even high-quality solutions, at a reasonable time. For this reason, the evaluation of the criteria that are effective in the scheduling and planning process of the operating room has been discussed. In this study, the analytical network process method which is one of multi-criteria decision-making methods has been used. Because this method considers the interaction of the criteria with each other and their relationships and dependencies. There are 24 sub-criteria under the 7 main criteria related to surgeons, operating room schedules, operating room resources, equipment and consumables, operating room staff, patients and other factors. The network structure of these criteria is created with the analytical network process method. Then, the significance levels of the criteria have been calculated. From the results obtained, the criteria for surgeons among the main criteria is in the foreground. The results show that resources in operating rooms should be used effectively. Therefore, it is necessary to pay attention to use resources effectively in the operating room scheduling processes.

Keywords: Operating room scheduling, multi-criteria decision making, analytic network process, operating room.

Ameliyathane Çizelgeleme Süreçlerinin Analitik Ağ Süreci Yöntemi ile Değerlendirilmesi

ÖZ

Ameliyathane çizelgeleme süreçleri birden çok performans kriteri birlikte değerlendirilmelidir. Bu nedenle ameliyathane çizelgeleme problemi karmaşık ve zor bir problemdir. Sonuç olarak, makul bir zamanda en iyi çözümü, hatta yüksek kaliteli çözümleri elde etmek çok zordur. Bu nedenle ameliyathanenin çizelgeleme ve planlama sürecinde etkili olan kriterlerin değerlendirilmesi ele alınmıştır. Bu çalışmada, çok ölçütlü karar verme yöntemlerinden biri olan analitik ağ süreci yöntemi kullanılmıştır. Bu yöntem, kriterlerin birbirleriyle etkileşimini ve bunların ilişkilerini ve bağımlılıklarını dikkate almaktadır. Cerrah, ameliyathane programları, ameliyathane kaynakları, ekipman ve sarf malzemeleri, ameliyathane personeli, hastalar ve diğer faktörlerle ilgili 7 ana kriter altında 24 alt kriter bulunmaktadır. Bu kriterlerin ağ yapısı, analitik ağ süreci yöntemi ile oluşturulmuştur. Daha sonra kriterlerin önem dereceleri hesaplanmıştır. Elde edilen sonuçlardan ana kriterler arasında cerrah kriteri ön plana çıkmıştır. Sonuçlar ameliyathanelerdeki kaynakların etkin kullanılması gerektiğini göstermektedir. Bu nedenle ameliyathane planlama süreçlerinde kaynakların etkin kullanılmasına özen gösterilmesi gerekmektedir.

Anahtar Kelimeler: Ameliyathane çizelgeleme, çok ölçütlü karar verme, analitik ağ süreci, ameliyathane.

1. INTRODUCTION

Operating room scheduling problem is confronted as a special branch in optimization problems. Therefore, planning and scheduling studies to achieve such goals as productivity and reproductivity in the operating room have been extensively addressed by researchers over the last four decades [1]. Researchers have been developed a wide range of approaches to the solution process by identifying the problem. By taking into account the different performance criteria, the problems have provided solutions with these new approaches. Due to the effective use of operating rooms depends on a balanced distribution, accurate estimation of the duration of each type of operation should be made [1].

The operating room scheduling problem is defined as the problem of surgical operations being assigned to operating rooms under specific limitations and objectives. In general, the concept of scheduling is the process of planning which time period and which resources to perform [2]. In these schedules, there are times of start and completion of the works to be performed. The objectives are determined in the schedule and progress is made for these purposes.

As the target to be realized increases, the complexity of the problem handled increases and the solution process becomes more difficult. The creation of true, feasible schedules can take time or even be difficult because of the level of difficulty. Therefore, determining the problem type is very important [3].

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There are many purposes to be accomplished in the problem of operating room scheduling and planning. These goals may be contradictory or parallel to each other. Since it is not possible to evaluate all objectives at the same time, flexibility is allowed, and solutions are made under assumptions [4]. This study focuses on the performance concept which is becoming more important in operation room management. Because the efficiency obtained from the performance of operating rooms directly affects the marginal value of hospital resources. Operating room performance is directly related to scheduling and planning activities in operating rooms. The more the goals taken into account in the schedules, the more effective the operating room processes. The aims to be performed in the operating room scheduling processes are composed of many sources. These resources can be collected in main groups as human, machine and system. Hence, in this study, the criteria that are effective in the operating room scheduling processes are taken into consideration. Criteria that are effective in the process are evaluated with the chief personnel responsible for the operating rooms in a state hospital and the relationship between them is determined. Analytic network process method is a method that allows reflecting the relationships between criteria with quantitative values. Therefore, the analytical network process method is used in this study and network structure is established according to the interactions and dependencies of the criteria. According to this network structure, the binary comparison matrices are created with the help of the staff in the hospital and the importance ratios are calculated according to each other.

Studies in the operating rooms have increased in the literature in recent years. When we looked at the literature, did not find the study of factors that affect the scheduling processes of the operating rooms. However, although this problem is similar, there are very few studies on the performance evaluation of operating rooms with separate evaluation criteria. The performance evaluation of operating rooms is a matter of organizational importance for hospital managers [1]. When the literature is reviewed, [5] aimed to measure the activity of the operating rooms with data envelopment analysis. By interpreting the resulting differences as inefficiency among facilities, they have proposed various resource changes to increase productivity. [6] stated that the measurement of the performance value of operating rooms depends on various factors. Under various resource constraints, they suggest the ordering of operations to improve the use of operation rooms. [7] noted that auditing the operational process for performance evaluation of the operating room is a useful job for managers. First, they developed a model and aimed to measure acceptable performance with financial interactions, customers, internal business processes and learning and growth perspective. When studies are examined, they aim to measure their performance in order to improve the use of operating rooms. By doing these performance measurements based on operations, they aimed to sort out the operations and balance the use of resources. Although the studies focus on the internal structure of the operating room scheduling processes, it is seen that the factors affecting the processes and the analytical evaluation of these factors are not addressed. Hamilton and Breslawski [8] described the operating room processes under human, machine and system resources with a comprehensive study. This study, which sheds light on the performance of the processes, can determine which factors are effective. In this way, while planning activities, it is possible to make useful plans by focusing on these factors. Considering these processes as a ladder step, it is seen that each step is interdependent and necessary. In this context, firstly, factors affecting the performance need to be evaluated in order to be able to make good scheduling and to reach the operating room scheduling objectives. One of the most important steps in increasing efficiency is the performance concept. This study considers the concept of performance in the operating room scheduling process. Thus, this study contributes to increasing the efficiency of the operating room scheduling processes in the literature. In addition to Hamilton and Breslawski [8] and other studies in the literature, an analytical perspective has been provided. At the same time Gur et al. [9] approached the performance of the operating room from a different perspective. Factors affecting the performance of the operating room are also included in the scheduling activities in the operating rooms. So, Gur et al. [9], the performance of the scheduling process is also considered to be another factor affecting the overall performance of the operating rooms. In this study, it is thought that the operation room scheduling processes should be considered as a separate problem. From this point of view, unlike the literature, the operation room scheduling processes are taken into consideration in this study. Relations between the effective criteria in these processes are modelled. The weights are also calculated by the analytical network process method. In this respect, the relations and feedbacks between the two criteria are examined and qualitative data are evaluated as quantitative data. According to these weights, the most effective criteria in the scheduling process have been determined. With the schedules prepared considering the weight of these criteria, it is considered that the yield to be obtained will increase.

Performance evaluation in operating rooms is a very important issue for hospitals. When this issue is examined separately from the perspective of the patient and the hospital, its importance increases considerably. If it is considered for patients, the operating room capacity should be managed well in order to perform operations in operating rooms, that is, to schedule. This is due to the use of operating rooms, that is, well planning. The waiting times of the patients will be shortened, and the formation of patient queues will be prevented. From a hospital perspective, there is a reduction in costs for operating rooms that are effectively and efficiently managed. Effective use of operating rooms is subject to

well-executed planning and scheduling. Efficient use of resources and reducing waiting times of patients bring many benefits. Increasing the satisfaction rate of patients and decreasing the costs arising from idle operating rooms bring patient satisfaction as well. Therefore, it is important to evaluate the performance of scheduling activities in operating rooms. Determining the factors that need to be considered to be able to plan effectively is very important for both the hospital and patients. In the scheduling problems discussed in the literature, modeling will be done by considering these factors. This will increase the efficiency of the schedule and provide added value to the literature. Its real-life reflection is the reduction of costs for the hospital, reduction of waiting times for patients, increasing the use of operating rooms, and reducing unnecessary waiting for surgeons. As a result, efficient operating room scheduling and efficient management of operating rooms with multiple resources are increased.

This study consists of five parts. The first part is the introduction section, and the outline of the study is given. The second part describes the scheduling and planning process of the operating room. In the third part, information about the solution method used in the study is given. A case study is given in the fourth part. In the last part, the results of the application are evaluated, and the literature contribution of the study is given.

2. MATERIAL and METHOD

2.1. The Process of Operating Rooms Scheduling and Planning

There are many factors such as human, machine and system that are encountered in scheduling processes and need to be considered during the scheduling process. Firstly, it is necessary to determine the works to be done and the capacity needs of the resources required for these works. These processes involve the desired time intervals, the importance and urgency levels, the resource-equipment requirements to be used, and, most importantly, the determination of the main objectives of the schedule to be established. The schedules formed by considering these factors must be applicable and true by the institutions.

The scheduling problem, which has an important place in the strategic, tactical and operational decisions of the managers [1], has been studied by various authors in the literature in various fields. There are many types of scheduling issues that are a special issue in operational research problems. Operating room scheduling is one of these types. The problem of operating room scheduling and planning is a difficult and complex issue that has gained popularity in the field of healthcare research. Basically, the operating room scheduling problem can be defined as the separation of the existing resources and operating rooms in hospitals in different surgical specialties.

Operating room scheduling, which is addressed at the operational level [1], focuses entirely on resource capacity planning and scheduling. The available resource should be used in the most appropriate way among hospital units. At the strategic level, strategic goals such as patient satisfaction, motivation and satisfaction of the staff, and dimensioning of the operating room resources are taken into account in order to achieve organizational goals. Sources such as PACU and ICU, which are related to the operating room, are also dimensioned. Planning at this level is usually around one year and patient volumes are determined. On the tactical level, operating room scheduling is the process of planning a few weeks of resources in hospitals. In this process, the actual patient request is taken as the basic input. The capacities and resources of the operating room are divided according to the expertise to perform the operation [10].

From this point, the researchers have developed a wide range of approaches for operating room scheduling and planning activities, which are solved under many assumptions due to their complex nature. Studies in the literature show that, when parts such as PACU and ICU, which are between the operating room sections, are included in the problem, the problem increases the difficulty level but on the other hand appears to have a positive effect on performance quality. As the number of elements involved increases, the problem becomes more difficult to solve with optimal methods. When these conditions are not overlooked, it is thought that the long-term effect will increase in the hospital.

In operating rooms, which are considered as a single unit, in the solution process, it is desirable to achieve goals such as the utilization rate of operating rooms, minimizing patient waiting, minimizing costs, and increasing staff-patient satisfaction. As the number of elements in the problem increases, the level of difficulty of the problem also increases in a direct proportion. In order to support the solution process in these situations, researchers try to obtain useful results by offering different suggestions. It is among these different suggestions to give weight to stochastic studies that can take into account the uncertain situations such as the use of different methods integrated, the duration of illness or the duration of the operation of the patient. The researchers gain different perspectives on probing with these different solution techniques. The quality of the obtained solutions which is at the desired level is very difficult due to the nature of the problem. However, [11] have made the use of operating rooms more efficient with the model they proposed in the solution process of the problem. Reflecting surgeons' preferences to their models, they have achieved a successful result despite human and material constraints and challenging goals. The results show that the solution model is an alternative to challenging goals.

2.2. Analytic Network Process

Individuals or businesses are faced with situations such as deciding between solutions in daily life. This decision-making situation can have multiple objectives that are desired to be realized. In these cases, multi-objective

decision making methods are at the forefront. Having developed a one-way and hierarchical solution to decision making problems by modelling, [12] also developed an analytic network process method that takes into account the relationships among decision criteria. Many decision problems cannot be modelled hierarchically due to the dependency of upper-level criteria with lower-level criteria [13].

Within the decision problem in the analytic network process method, there are the criteria affecting the decision, the relations among them, the dependencies and the feedbacks. All of these comes together to form the network model structure. The network structure is not a hierarchical structure that is fed downwards. The criteria contained within are clustered together and continue their dependency with the feedback loop. This type of model is called a feedback model [14]. The ANP method allows models that cannot be modelled hierarchically to be modelled with network structures that allow decision levels and complex relationships.

In the hierarchical structure, there are grades of the criteria that affect this aim towards the lower levels starting from the aim at the upper level. Alternatives are at the bottom. There is a relationship flowing from top to bottom and it is assumed that these characters are not influenced by each other. In network structure, criterion is allowed to interact with each other and there is feedback. The arrows shown in the network structure represent the relationship between the two groups. The direction of the arrows indicates the direction of interaction. Dependency among these groups is called external dependency, the dependency within the group is called internal dependency [15]. The ANP method covers all the criteria for decision making and focuses on the purpose of the criteria. At the same time, quantitative and qualitative criteria are incorporated into the model to increase the efficiency of resolution in decision problems. The solution process of the analytical network process method consists of 4 steps [16].

Step 1. Define the decision problem and establish network structure:

In this step, the decision maker must first identify the problem in which it is located. It should determine well the boundaries of the problem, and the factors that affect the problem. Then, by explicitly conveying the problem, the factors affecting the problem must establish a rational network structure. This structure should clearly show the external and internal dependencies of the factors in the clusters [17]

Step 2. Creation of binary comparison matrices and obtaining priority vectors:

The comparison matrices arising from the interactions between criteria and relationships reveal that decision-makers can evaluate factors according to each other. Thus, the importance weights of the criteria can be determined. Decision makers are questioning the importance of each criterion in these decision-making matrices. It is tried to determine what contribution is to probe and aims. When these comparisons are made, the 1-9 importance scale of [12] is used. [18].

Step 3. Creation of super matrix structures:

Supermatrix structures are formed by combining the binary comparison matrices that decision makers make to compare the criteria. Super matrix structures consist of 3 sections. In the unweighted supermatrix structure formed by combining the first comparisons made, all the evaluators are included. Then, by superimposing the corresponding weighted values of the clusters in this structure, a weighted supermatrix structure is formed. With this weighted supermatrix structure, it is ensured that the weights converge to each other by taking the force from (2k + 1) degrees. The limit super matrix structure is formed by weights equalized at one point. [19].

Step 4. Determine the best option among alternatives:

With the obtained limit super matrix, the importance weights of the factors and alternatives affecting the problem are determined. The highest value among these weights is the best alternative among the alternatives, and the criterion is the criterion that most influences the decision process. Thus, it is possible to make a comparison between the alternatives and the criterion within the limit super matrix structure.

In the literature, the ANP method has been applied in a wide range of topics. In the service sector, the ANP method in practice is preferred by decision makers since it can reflect the relationship between the criteria affecting the process. In the transportation sector, researchers have also taken account of budget balancing with integrated methods ([20], [21]). In the field of logistics, [22] in warehouse selection, [23] used the ANP method in inventory control.

The ANP method is used in a variety of methods that are integrated. Among multi-criteria decision-making methods, [24]; [25] with TOPSIS method, [26]; [27]; [28]; [29] with PROMETHEE method have implemented by integrating. Goal programming in multi-purpose optimization methods is used in the field of schedules by [30]; [31].

In this study, we focused on performance quality in the scheduling processes in the operating room which is one of the hospital units. Improvement of the overall process of the operating rooms and its efficiency depends on the effectiveness of the scheduling and planning activities are shown among the aims of this study. The effective execution of operating room scheduling and planning processes depends on many factors. The definition of these factors (especially Table 1) is seen when the studies in the literature are examined. However, no study has been found that analytically evaluates the interactions among these factors. From this point of view, it is aimed to determine to what extent these factors affect each other. Therefore, it is preferred to use multi-criteria decision-making methods which are effective in the evaluation of these multiple criteria. When the interaction and criteria structure between the criteria are taken into

consideration, the analytical network process method comes to the fore. Thus, by utilizing the advantages of this method, it is evaluated how much the criteria affect each other and the system of all criteria.

3. RESULTS

Health systems are under pressure to sustain cost growth to meet growing needs and demands of the growing population and to keep their budget under control. For this reason, it is very important for hospital organizations to optimally use available resources. Hospital managers tend to reduce patient costs while at the same time providing patient satisfaction. The operating rooms are the largest share of the hospital budget [1], both in terms of income and in expenditure items. The operating rooms contain complex and challenging planning and scheduling problems at all levels of control. Planning and scheduling procedures in hospitals have a wide variety of variables such as availability of surgeon, surgeon's preferences, working hours, availability of resources, uncertain patient arrivals. Having optimal schedules helps reduce hospitals' staff and patient expense, reduce waiting time for patients and reduce waiting lists, and improve the effective use of resources. The implementation steps of the work are given in Figure 1.

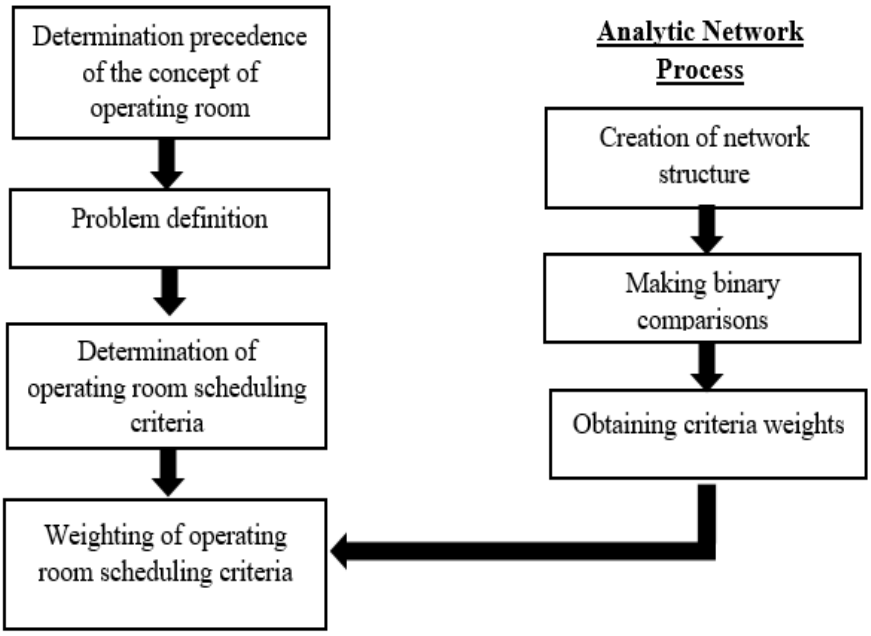

Figure 1. Implementation steps

Problem definition

This study involves analysing previous operating room scheduling procedures and evaluating the effectiveness of these schedules to improve them. In particular, the process of setting up surgical programs for operating rooms in a state hospital has been studied. The success of planning and schedules for the structure and culture of hospital organizations depends on various criteria. The values obtained as a result of the operating room schedule require a correct identification of the important points qualitatively and quantitatively. These criteria can sometimes interact with each other. In determining the relationships between the criteria and determining the importance ratios according to each other, the ANP method in the foreground of the multi-criteria decision-making methods.

Step 1. Define the decision problem and establish network structure:

In this step, the criteria that affect the process of the operating room have been are determined. In Hamilton and Breslawski [8] study, the criteria that are effective in the operating room scheduling process have been taken as reference. The criteria to be considered and evaluated on these criteria have been determined by experts in a state hospital. The interactions between the criteria have been are established with the staff responsible for the operating room and other staff who assisted in the creation of these schedules. The results obtained have been are considered to be reasonable by discussing. Table 1 has been given gives the factors affecting the schedules.

Criteria considered to be interacting with each other have been are determined and 24 sub-criteria are grouped under 7 main criteria. Network structure was established by determining interactions and dependencies between criteria. The network structure formed in Figure 2 has been is given

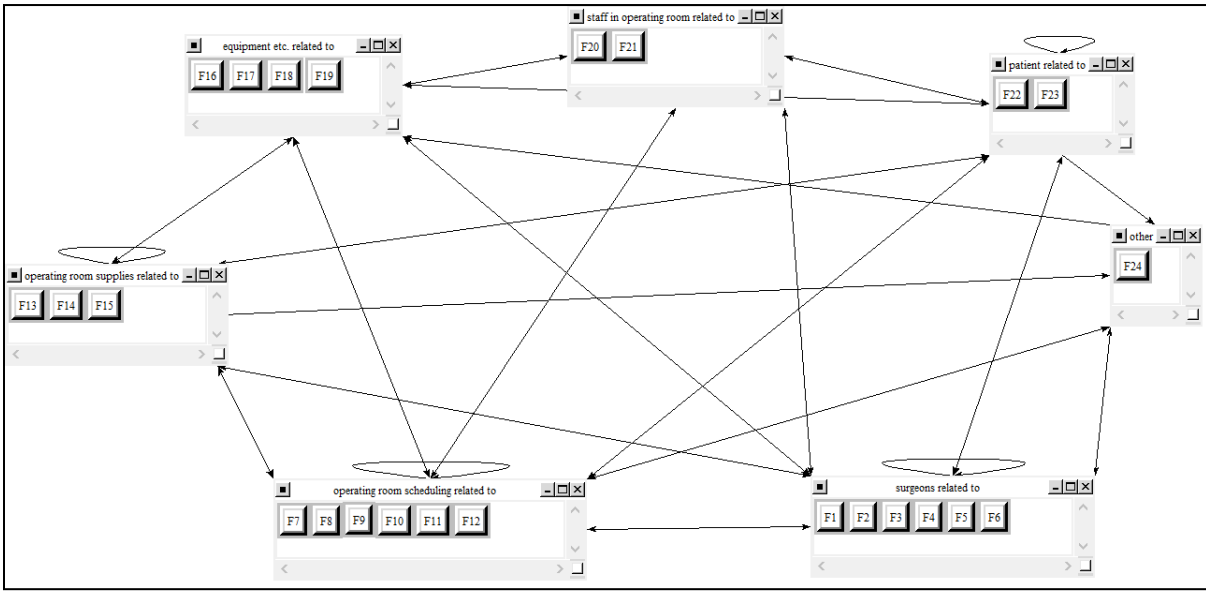

Figure 2. Network structure of criteria affecting operating room scheduling

Step 2: Calculation of the Eigenvector by Creating a Binary Comparison Matrix:

Criteria have a comparison structure with the criteria that they are in interaction. Binary comparisons of criteria interacting using Saaty's [12] 1-9 scale are made with experts. It is noted that in these binary comparisons the consistency ratio should be less than 0,1. In Table 1, the importance of these criteria has been is given according to each other

Table 1. Weight of criteria affecting operating room scheduling

Main Criteria	Sub-Criteria No	Sub-Criteria	Sub-Criteria Weight
Criteria for surgeons **(0,31)**	**F1**	Surgeons' assigned start times	0,085
	F2	Late arrivals of surgeons	0,078
	F3	Service/surgeon priorities	0,291
	F4	Surgeons' office hours	0,348
	F5	Cancellations by surgeon over time	0,165
	F6	Emergency additions by surgeon over time	0,033
Criteria for operating room schedules themselves **(0,10)**	**F7**	Number of elective surgeries scheduled	0,243
	F8	Estimated surgery durations	0,072
	F9	Possibility of cancellations in the schedule	0,268
	F10	Possibility of additions to the schedule	0,341
	F11	Estimated room clean up duration	0,030
	F12	Estimated room set up duration	0,046
Criteria for operating room resources **(0,12)**	**F13**	Number of beds in postanesthesia care unit	0,258
	F14	Number of operating rooms	0,441
	F15	Availability of beds in intensive care unit	0,301
Criteria for equipment, consumables **(0,11)**	**F16**	Late arrivals of equipment	0,102
	F17	Late arrivals of supplies	0,061
	F18	Equipment limitations	0,276
	F19	Supply limitations	0,561
Criteria for operating room staff **(0,02)**	**F20**	Late arrivals of nurses	0,408
	F21	Late arrivals of anaesthesia personnel	0,592
Criteria for patients **(0,11)**	**F22**	Incomplete schedules	0,717
	F23	Late arrivals of patients	0,283
Political **(0,25)**	**F24**	Political factors (e.g., only certain surgeons may use new equipment, one surgeon cannot follow another surgeon	1

Table 2 shows an exemplary structure for the binary comparison matrices formed according to the interaction between the criteria. Similar to this structure, other comparison matrices are formed. Table 3 shows the binary matrix between the criteria. These binary matrices have been are solved in the Super Decision package program. Consistency rates of all binary matrices have been are found to be lower than 0.1.

Table 2. Comparisons wrt " Late arrivals of anesthesia personnel " node in "criteria for surgeons" cluster

Surgeons' assigned start times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service/surgeon priorities
Surgeons' assigned start times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Surgeons' office hours
Surgeons' assigned start times	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cancellations by surgeon over time
Service/surgeon priorities	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Surgeons' office hours
Service/surgeon priorities	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cancellations by surgeon over time
Surgeons' office hours	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cancellations by surgeon over time

Table 3. Comparisons wrt " Emergency additions by surgeon over time " node in " Criteria for equipment, consumables" cluster

Late arrivals of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Late arrivals of supplies
Late arrivals of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Equipment limitations
Late arrivals of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supply limitations
Late arrivals of supplies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Equipment limitations
Late arrivals of supplies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supply limitations
Equipment limitations	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supply limitations

Looking at the results of Table 1, it is seen that operating room scheduling processes are affected by factors related to surgeons by 31% of the main criteria. By examining the sub-criteria contained within each main criterion in its own set, the most important sub criteria are the working time of the surgeons, the probability of the operation being added to the schedules, the availability of proper operation, the availability of materials that can be used during the operation (inventory status related to these materials), the late arrival of the anaesthesia personnel and the inability to complete the schedules.

4. DISCUSSION

When all these effective criteria are considered together, it is seen how important the factors are in the process of operating room schedules. Taking all these criteria into consideration makes the process quite complex. Excessive surgeons' working time causes both extra costs resulting from overtime and low satisfaction levels of surgeons. This, in turn, indirectly reduces the level of patient satisfaction by reducing the quality of ill-delivered services. The possibility of adding operations later on to the schedules can change the overall order of the schedules which are manually prepared long time and effort. This causes the patients' operations to be postponed or cancelled. Whether the schedules are prepared without paying attention to whether or not the operating room in the hospital is appropriate, or suddenly the operating room is unusable, is also may cause surgeons to wait idle and also to postpone or cancel patients. The presence of the materials to be used in the operation process is an important factor as it affects the operation process. Also, even if the surgeon and the patient are present at the time of operation, the anaesthesia staff may be delayed, late for the operation of the patients, and may change the order of the schedules, thus causing more delays. All these factors can also cause cancellations in schedules. Failure to complete a schedule is not just about that day's situation, it means that all wait lists are delayed. Therefore, all these factors mainly affect the aims of hospital managers. Since it is impossible to prepare perfect schedules by paying attention to all these factors, planning by paying attention to these weights will benefit the desired purposes at the highest level.

In the results, it is seen that the criteria related to the surgeons come to the fore with rate of 31%. This result shows that surgeons have an important share in the operating room scheduling processes. The fact that the surgeons are important components in the operating rooms proves the accuracy of the results. Even a small factor related to surgeons has a significant impact on the course of these processes. For example, the working time of surgeons at a rate of 34% directly indicates the importance of the efficiency of surgeons. Because the imbalance in working hours and the high workload on surgeons cause excessive fatigue and loss of attention during the day. The results of this condition are important enough to result in death of the patient. Another criterion which has an important ratio among the main criteria is the "other" criterion. This criterion, which has a rate of 25%, has a special effect in the operating room

scheduling processes. Because it has political reasons in terms of sub-criteria. In other words, it is the result of some operations which are directly effective in the scheduling and planning activities. These procedures include, for example, some surgeons have a desire to have excess rights. They tend to be able to use the resources of the hospital in the schedules by using the power of having too much right. This leads to the transformation from the normal state of the process to the plans and schedules that are created according to the individual's own wishes. The schedules and plans created in this way are transformed into inefficient structures that meet the individual's own specific needs, away from the main objectives of the hospital. However, the main objectives of the hospital are to keep the profit margin high and to keep patient satisfaction high. Taking into account the special requests of a single person causes all other purposes to be ignored. The schedules and plans created in this way are not possible to achieve the efficiency to achieve the aims of the hospital [1].

5. CONCLUSION

There are many outsourced criteria that affect the scheduling processes of operating rooms, which have a very complex and variable structure. The effectiveness of the scheduling processes in the operating room is seen as one of the main objectives that hospital managers want to realize. In the operating rooms, the schedules to ensure the effective and efficient use of resources are a priority. As the most important factor in the hospital, and at the same time as a unit which has a financial impact, the operating room is accepted [1]. This has led to a reflection of the level of competition in recent years in the healthcare sector and the focus of hospital managers on the effectiveness of operating room schedules and plans. Hospitals are aimed to improve the performance of their units in order to be able to evaluate themselves. In the operating rooms, efforts are being made to improve scheduling activities.

In this study, the problem of determining the criteria that are effective in the scheduling process of the operating room which is applied in a state hospital is discussed. The 7 main criteria and 24 sub-criteria are analysed by the ANP method in multi-criteria decision-making methods due to the interaction and interaction between themselves at the criteria with the help of head personnel in charge of operating rooms in the hospital. It is a very difficult and complicated process to consider these criteria which are effective in the scheduling processes of the operating rooms. In particular, the criteria for surgeons need to be considered. For this purpose, a new approach has been developed for determining the effective criteria in the scheduling process of the operating rooms with the ANP method. From the results obtained, the criteria for surgeons among the main criteria is in the foreground. The main criterion for operating room personnel is the lowest ranking in the weighting order. Since the working hours in real life are obvious, the operating room staff are usually at the beginning of their duty at full time. However, when you look at the criteria for surgeons, the process is particularly affected by from the working time of surgeons. Because the efficiency of the surgeons' performance is important, they are also effective in the scheduling process depending on the operations they perform. The efficiency obtained from surgeons who work overtime will be reduced and the operation time will be prolonged, which will cause the patients to be delayed or cancelled. At the same time, surgeons and patient satisfaction levels will fall.

From point of view, all the criteria affect each other according to their weight. It is very difficult or even impossible to take all these criteria into consideration when scheduling activities are being carried out. It is not possible to obtain results by extending the solution process. Since all the criteria cannot be taken into consideration, schedules are usually created under the assumptions. When hospital managers take these criteria into account according to their significance level, they observe that the efficiency increases than the previous schedule.

This study includes the evaluation of the criteria that are effective in the operating room scheduling processes. No studies have been found in the literature to evaluate the scheduling processes. Thus, this study contributes to how the effectiveness of the operating room schedules can be increased. At the same time, the relations between the criteria are evaluated by the ANP method which is effective in the decision-making process, and the transfer of the qualitative data to the quantitative data is ensured. In real life, hospital administrators will be able to receive the yield they want to obtain from the operating rooms, taking these weights into account. It is also a basic work for researchers in the proceeding studies. In future research, the number of these criteria can be increased, and different solution techniques can be used in the evaluation process. At the same time, these criteria can be integrated into the scheduling models using the calculated importance ratings. Thus, in the scheduling models, both multiple performance criteria are taken into consideration and enabling the achievement of the desired objectives to be achieved more.

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DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Şeyda GÜR: She analyzed the data, made the solution process and wrote an article.

Tamer EREN: Controlled the resolution process. Contributed to article writing and made final checks.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Gür, Ş., Eren, T. "Application of Operational Research Techniques in Operating Room Scheduling Problems: Literature Overview." ***Journal of Healthcare Engineering***, (2018).

[2] Pinedo, M., Planning and Scheduling in Manufacturing and Services. ***Springer***, New York, (2005).

[3] Çivril, H., Genetic algorithms for nurse scheduling problems, ***Master Thesis***. Süleyman Demirel University, Isparta, (2009).

[4] Rothstein, D. H., & Raval, M. V. "Operating Room Efficiency. In Seminars in Pediatric Surgery", ***WB Saunders***, 27, 2, 79-85, (2018).

[5] Basson MD, Butler T. "Evaluation of Operating Room Suite Efficiency in the Veterans Health Administration System by Using Data-Envelopment Analysis." ***The American journal of surgery***, 192(5):649-656, (2006).

[6] Jebali A, Alouane ABH, Ladet P. "Operating Rooms Scheduling." ***International Journal of Production Economics***, 99(1):52-62, (2006).

[7] Lin QL, Liu L, Liu HC, Wang DJ. "Integrating Hierarchical Balanced Scorecard with Fuzzy Linguistic for Evaluating Operating Room Performance in Hospitals." ***Expert Systems with Applications***, 40(6):1917-1924, (2013).

[8] Hamilton, D. M., Breslawski, S. "Operating Room Scheduling." ***AORN Journal***, 59(3), 665-668, (1994).

[9] Gür, Ş., Uslu, B., Eren, T., Akca, N., Yilmaz, A., & Sönmez, S. "Evaluation of Operating Room Performance in Hospitals by Using Analytic Network Process." ***Gazi Journal of Health Sciences***, 3(3), 10-25, (2018).

[10] Van Oostrum, J. M., Bredenhoff, E., & Hans, E. W. "Suitability and Managerial Implications of a Master Surgical Scheduling Approach." ***Annals of Operations Research***, 178(1), 91-104, (2010).

[11] Hanset, A., Meskens, N., & Duvivier, D. "Using Constraint Programming to Schedule an Operating Theatre." in Health Care Management (WHCM), IEEE Workshop On. (2010).

[12] Saaty, T. L., The Analytic Network Process, RWS Publications, ***Pittsburg***, PA, (1996).

[13] Karabacak, G., Munition selection with AHP and ANP, ***Master Thesis***. Ataturk University, Erzurum, (2012).

[14] Büyükyazıcı, M., Analytic network process, ***Master Thesis***. Hacettepe University, Ankara, (2000).

[15] Karamahmutoğlu, Y., Analytic network process and applied to Turkish insurance sector. ***Master Thesis***, Marmara University Banking and Insurance Institute, Istanbul, (2010).

[16] Özder, E. H., Integration of analytic network process and goal programming methods in supplier selection: A case study. ***Master Thesis***. Kırıkkale University, Kırıkkale, (2015).

[17] Saaty, T. L. Analytic hierarchy process. In Encyclopedia of operations research and management science (pp. 52-64). ***Springer***, Boston, MA, (2013).

[18] Saaty, T. L. The Analytic network process: decision making with dependence and feedback, ***RWS Publ***, (1996).

[19] Saaty, T. L. Theory and applications of the analytic network process: decision making with benefits, opportunities, costs, and risks. ***RWS publications***, (2005).

[20] Gür Ş., Hamurcu M., Eren T., "Using Analytic Network Process and Goal Programming Methods for Project Selection in the Public Institution" ***Les Cahiers du MECAS***, 13, 36-51, (2016).

[21] Hamurcu M., Gür Ş., Özder E.H., Eren T., "A Multicriteria Decision Making for Monorail Projects with Analytic Network Process and 0-1 Goal Programming", ***International Journal of Advances in Electronics and Computer Science***, 3 (7), 8-12, (2016).

[22] Gül, E., Eren, T., "Warehouse Selection with Analytic Hierarchy Process Method and Goal Programming in Logistic Distribution Network Problems", ***Harran University Journal of Engineering***, 2, 1, 1-13, (2017).

[23] Beğik, M., Hamurcu, M., Eren, T., "An Application of ABC Analysis and Analytic Network Process at the Stock Control in Heat Tools Company", ***Kırıkkale University Journal of Social Sciences***, 7 (1), 197-216, (2017).

[24] Görgülü İ., Korkmaz M., Eren T., "Optimal investment strategy selection with analytical network process and TOPSIS methods", ***Sigma Engineering and Science Journal***, 31 (2), 203-213, (2013).

[25] Özcan, E.C., Ünlüsoy, S., Eren, T., "Evaluation of the Renewable Energy Investments in Turkey Using ANP and TOPSIS Methods", ***Selcuk University Journal of Engineering, Science and Technology***, 5 (2), 204-219, (2017).

[26] Bedir N., Özder E.H., Eren T., "ANP-PROMETHEE Methods for Food Sector Third Party Logistics Company Selection ", 5th National Logistics and Supply Chain Congress, 512-519, Mersin, 26-28 Mayıs (2016).

[27] Özder E.H., Bedir N., Eren T., "Academic Staff Selection with ANP & PROMETHEE Method: A Case Study In Turkey" International Academic Conference on Engineering, Technology and Innovations (IACETI), Dubai, UAE, March 5th, (2016).

[28] Gür, Ş., Bedir, N., Eren, T., "Selection of Marketing Strategies with Analytical Network Process and PROMETHE Method for Medium Sized Business in Food Sector", ***Nevsehir Journal of Science and Technology***, 6:1, 79-92, (2017).

[29] Özcan, E.C., Özcan, N.A., Eren, T., "Selection of the Solar Power Plants with CSP Technologies by Combined ANP-PROMETHEE Approach", ***Başkent University, Journal of Commercial Sciences***, 1 (1), 18-44, (2017).

[30] Bağ N., Özdemir M., Eren T., "Solving A 0-1 Goal Programming and ANP Methods with Nurse Scheduling Problem" ***International Journal of Engineering Research and Development***, 4 (1), 2-6, (2012).

[31] Hamurcu M., Eren T., "Decision Making for Rail System Projects with AHP-GP and ANP-GP", ***Journal of Gazi Engineering Sciences***, 3(3): 1-13, (2017)