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# A Framework for Improving Patient Satisfaction by Reducing the Length of Stay in The Operation Suite Using the Combined DEMATEL-ANP Model

Seyedeh Raahil Mousavi[1], Mohammad Mehdi Sepehri [2,*] Seyed Esmaeil Najafi[1]

[1] Department of Industrial Engineering, Islamic Azad University Science and Research Branch, Tehran, Iran
[2] Faculty of Industrial and Systems Engineering, Tarbiat Modares University, Tehran 1411713116, Iran

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**ABSTRACT**

Operating room (OR) planning has gradually become an important element of Hospital administration in recent years. The OR performance plays a significant role in enhancing the quality of the care provided to the patients, and reducing patients' length of stay (LOS), which is the function of the OR performance, decreases the costs. Following a survey of the existing research and conducted interviews with clinical and non-clinical OR staff, there are several factors influencing patients' length of stay (LOS) in OR, and consequently the costs of OR. In this work, first, we implemented the DEMATEL to define the relationship between OR factors, next, employed ANP to identify the most influential factors on the LOS in the OR. The results show the most influential factors are operative time, operative setup, patient waiting time, anesthesia, and patient preparation. Running two rooms concurrently and minimizing turnover time (TOT) reduce patients' LOS by 10% and 5.6%, respectively, and improve the patients' and clinical personnel's satisfaction. Reducing the LOS not only leads to reduced OR costs but also helps increase the number of operations and thereby hospitals' revenue.

## 1. Introduction

The ever-growing healthcare costs have turned hospitals into highly important and costly organizations. In the case of Iran, hospitals take up a major share of resources allocated to the health sector, as well as 42% of the government's total current expenditures in the health sector [1]. In order to make meaningful progress in a hospital, the managers should develop fresh, creative ways of providing efficient and quality care. The operating suite, if managed effectively, can be one of the most reliable sources of profit in large hospitals [2]. Often labeled as the 'heart' or 'engine' of a hospital, the operating suite hosts 70% of all admissions. In recent years, Operating Room Planning (ORP) has gradually become a key component of hospital administration. As a result, efficient

* *Corresponding author.*
*E-mail address: mehdi.sepehri50@gmail.com*

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Operating Room (OR) performance is considered essential to the overall service quality and reputation of the medical institution. The operating suite is also integral to the financial state of hospitals, being responsible for an estimated 40% of hospitals' total costs. Effective management of the operating suite could help reduce costs, improve the medical personnel's morale, and maximize patient satisfaction [3].

Average Length of Stay (ALOS) is a key criterion for assessing the efficiency of hospitals [4,5]. Therefore, from a hospital management point of view, eliminating the unnecessary elements and minimizing the Length of Stay (LOS) leads to improved efficiency [6]; an outcome that underlines the significance of the subject of this research.

Numerous studies have been conducted on patients' LOS in hospitals (e.g., [7-9]). In particular, some researchers have attempted to predict this criterion in operating suites (e.g., [10-12]). The present study mainly focuses on identifying and analyzing the factors that affect the operating suite LOS.

ANP method based on DEMATEL is one of the most widely used methods in the field; decision making is multi-criteria. Many multi-criteria decision making methods do not consider the relationships between criteria. Therefore, criteria are assumed to have a hierarchical and linear structure. In the real world, the relationships between the criteria of decision problems can have a network structure; in this case, the problem cannot be analyzed by linear methods such as AHP, TOPSIS, VIKOR, etc.

### *1.1 Operating Room*

Various definitions have been proposed for the OR, some of which are presented in this subsection. The OR is a well-equipped room in which surgical procedures are performed [13]. It is an area in medical centers that is used for non-urgent surgeries [14]. It is a room in hospitals that contains a main operating table or similar surface and hosts one patient at a time, who undergoes surgery under the supervision of a physician or dentist. Surgeries are performed in order to diagnose, prevent, or cure a condition, and in some cases to relieve the patient's pain. The patient is placed on the operating table in order to facilitate the surgical procedure. An OR must have adjustable and sufficiently powerful sources of light in addition to sterilized instruments and devices for the surgical team (IBID). The terms operating theatre (or theater), operating suite, and operating and surgery room have often been used in place of OR in the literature, while the term 'hospital room' may also indirectly refer to the OR. (see Figure 1.)

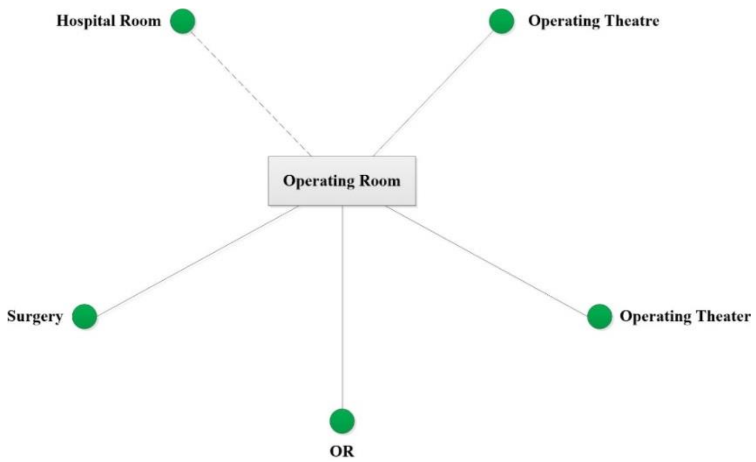


**Fig. 1.** Terms used “operating room” [14]

### *1.2 Length of Stay*

The LOS has been defined by the United Kingdom National Health Service (NHS) as the length of time a patient remains in the hospital to receive medical care. More precisely, LOS is calculated as the number of nights spent in the hospital from the day of admission until the day of discharge. Patients who are admitted and discharged on the same day are considered to have a LOS of less than a day.

i. Length of stay in the operating room.

The LOS in the OR is calculated as the time the patient enters the OR until their discharge from the recovery area.

### *1.3 DEMATEL Method*

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was developed between 1972 and 1976 by the Geneva Research Centre of the Battelle Memorial Institute. It assesses the causal relationships among the factors that shape decision problems and helps discover the most important factors by transforming the problems into readily intelligible structural models [15]. The technique was conceived with the purpose of improving the complex structure of problems through scientific research methods and contributing to the process of identifying science-based solutions with hierarchical structures [16]. It consists of causal graphs that categorize the problem's components into two groups of 'cause' and 'effect' to illustrate the relationships between the system's elements. A causal graph is constructed by graphing a number of ordered pairs, with the horizontal axis showing affectability and the vertical axis showing effectiveness. Thus, if a factor is positioned above the horizontal axis of a causal graph, it is categorized as a cause, and if below it, as an effect. Causal graphs help distinguish the difference(s) between cause-effect criteria and may lead to more accurate decisions [15].

The DEMATEL method consists of the following five steps:

ii. Step 1: The mean matrix is calculated. The respondents are asked to rate the direct effect the elements have on one another based on their judgment using an integer between 0 and 40.
iii. Step 2: The principal direct-effect matrix is formulated.
iv. Step 3: The normalized direct-effect matrix is computed.
v. Step 4: The final matrix of interrelationships is obtained which includes both direct and indirect effects.
vi. Step 5: The results, effects, and interrelationships are analyzed.
vii. The process above is carried out using Eqs. (1)-(5).

$$Z = \begin{bmatrix} z_{11} \cdots z_{1j} \cdots z_{1j} \\ \vdots \quad \vdots \quad \vdots \\ z_{i1} \cdots z_{ij} \cdots z_{in} \\ \vdots \quad \vdots \quad \vdots \\ z_{n1} \cdots z_{nj} \cdots z_{nn} \end{bmatrix} \tag{1}$$

$$X = \frac{Z}{\max\left(\underset{1 \le i \le n}{max} \sum_{j=1}^{n} z_{ij}.\ \underset{1 \le j \le n}{max} \sum_{i=1}^{n} z_{ij}\right)} \tag{2}$$

$$T = \lim_{k\to\infty}(X + X^2 + \cdots + X^k) = \lim_{k\to\infty} X(I + X + X^2 + \cdots + X^{k-1} = \lim_{k\to\infty} X \left[\frac{I - X^k}{I - X}\right] = X(I - X)^{-1} \tag{3}$$

$$D = (d_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{4}$$

$$D = (r_i)_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \tag{5}$$

Eqs. (1)-(3) help obtain the values of D and R in Eqs. (4) and (5). The purpose of computing the values of D and R is to determine a) the effect of each factor on the other factors, b) the number of effective factors, and c) the weight of each factor. The value of D + R represents the factor's degree of centrality, which indicates the number of factors interacting with the factor. On the other hand, the value of D - R represents each factor's strength of effect, indicating how prioritized the factor is over another factor. If D – R > 0, then the factor is considered a cause that influences the other factors. Conversely, if D – R < 0, then the factor is considered an effect that is influenced by the other factors. The larger the value of D – R is for a factor, the stronger its influence is on the other factors and the higher its priority [17].

The DEMATEL method has many useful properties and provides an efficient process for identifying the hierarchy and interrelationships between a system's components. It is a decision-making approach based on pairwise comparison which makes effective use of expert opinions to extract and categorize the influential components of a system. Then, based on graph theory, presents a hierarchical structure of all the system's elements which describes the mutual effectiveness and affectability of the elements and clearly specifies the strength of their inter-effect through quantitative values [18]. The graphs generated by this method illustrate the interrelationships between the system's elements such that the numbers on the axes state the strength of the effect each element has on another element. Therefore, the DEMATEL method's main advantage is creating a visual and tangible structural model of the elements' interrelationships [19,20]. The core idea behind the approach was that effective use of scientific research methods is indeed able to simplify the structure of complex problems and help identify applicable hierarchical solutions to deal with such problems [21,22].

Another advantage of the DEMATEL method lies in its ability to receive feedback on relationships and incorporate it into its proposed solutions. The elements of a system can be dependent on each other. The significance and weight of each element are not necessarily determined by upstream or downstream factors, but by all the constituents of the system or model [18].

### *1.4 ANP Method*

The ANP method was developed by Saaty in 1996 to specifically solve network problems. It rejected the key assumption of the Analytical Hierarchy Process (AHP) method that all relationships are hierarchical. When computing the relative weight of criteria using the ANP, the level of correlation between the criteria is demonstrated through reciprocal values. Contrastingly, in DEMATEL, the criteria do not have inverse values (1/value) in relation to one another, a fact that renders this method closer to real-world conditions, which renders the latter closer to real-world conditions. To overcome this shortcoming in the ANP, we use the total-influence matrix T, proposed in the DEMATEL method, to compute the relative weight of the criteria.

The ANP is a multicriteria decision-making technique that presented an improvement over the AHP by replacing the concept of hierarchy with a network. In fact, the ANP is a mathematical theory that simultaneously applies the correlation and feedback between different levels in various fields in a systematic fashion. Therefore, it can be considered the most complete multicriteria decision-making method available. The ANP provides deeper decision-making models and performs its analyses without considering any assumptions with regard to the independence of higher-level elements from lower-level or same-level ones. This characteristic has convinced many researchers to approve its effectiveness and make it their decision-making method of choice [19,23,24].

The rest of this paper is structured as follows. Section 2 discusses the Literature Review, Section 3 discusses the research methodology, Section 4 presents the results, Section 5 presents the discussion and the last section presents a brief conclusion, followed by the list of works cited throughout the study.

## 2. Literature Review

Numerous studies have been conducted on patients' LOS. Most of these studies have focused on LOS in the hospital and few have worked on LOS in the OR. In this section, we specifically review the factors that have been shown to affect patients' LOS in the OR.

Gruskay *et al.,* [11] compiled and evaluated pre-operation factors including the demographics of the patient, prior surgeries, determined levels, score given by the American Society of Anesthesiologists (ASA), other medical conditions (e.g., diabetes, high blood pressure, malignancy, pulmonary or cardiovascular disease); intra-operation factors including general complications, placement of drains, an estimated loss of blood, transfusion of blood, fluids injected, time in the OR, and time of surgery; and post-operation factors including complications, removal of drain, transfusion of blood, and destination of discharge. In order to determine the LOS predictors, the researchers used stepwise multi-variable regression. Notably, 'post-operation complications' were eliminated from the list of independent variables due to their close association with LOS.

In a retrospective research using an orthopedic database, Ricci *et al.,* [25] identified 635 patients aged 65 and higher who had been hospitalized for hip fracture between January 1999 and July 2006. Demographic data, ASA score, date of admission, date of discharge, date of surgery, and details on pre-operation cardiovascular tests were retrieved from the relevant hospital records. The researchers used the collected data to identify the day patients should be admitted during the week as well as to calculate the LOS and DTS (delay to surgery) in the hospital. Moreover, linear regression analysis was applied to identify independent DTS-related factors and those that increase the LOS. Chuang *et al.,* [12] concluded that the random forest method generates the most accurate and sustainable model for predicting the LOS. Furthermore, body temperature, blood sugar, and creatinine were identified as the factors that contribute to prolonged LOS the most among patients requiring urgent operations; while blood transfusion, blood temperature, and number of admissions to the ICU were the most influential factors on prolonged LOS following non-urgent operations.

Sajadi *et al.,* [26] are proposing mathematical methods for nurse scheduling that fulfill the hospital limitations and nurse preferences while minimizing the patients' waiting queue time. In order to reach the aforementioned objective, the emergency department of a governmental hospital is simulated by arena and a simulated annealing algorithm is applied to find the appropriate schedule. Results show that the waiting time of the achieved schedule from the proposed algorithm is 18% less than the existing schedule.

Achanta *et al.,* [10] employed multi-variable linear regression models to predict the LOS. In this research, the LOS was used as the continuous variable, while demographic variables and pre-operation (lab variables and comorbidities), intra-operation (surgery duration, wound category), and post-operation factors (complications) were taken as the problem's dependent variables.

Hadinezhad *et al.,* [27] conducted cross-sectional research on a sample of 152 psychiatric patients admitted to the psychiatric hospital of Mazandaran University of Medical Sciences. The patients' LOS was recorded at the end. The data collected by the researchers were analyzed using the statistical software *SPSS*. It was observed that Men's LOS was significantly longer than women. As for the effect of diagnosis, the longest LOS was recorded by patients diagnosed with psychosis. Notably, the LOS increased by 0.21 days per each instance of admission.

Hosseini-Shokouh *et al.,* [28] produced a review paper to summarize the studies conducted on the subject of LOS. The results are detailed in Table 1. Kim and Kwon [29] investigated factors that significantly influence the LOS in the recovery area. Number of surgeries, cardiovascular disease, surgery site, body temperature, airway obstruction, and volume of hemorrhage.

Khosravizadeh *et al.,* [9] proposed a structural model consisting of four dimensions and 29 influential factors on the LOS in hospitals. The independent variables identified by the researchers, in order of significance, included: the patient's condition, underlying factors, performance of clinical personnel, and the hospital's service provision quality. In order to determine the relationship between each factor and LOS, these factors were evaluated through second-order confirmatory factor analysis. The equation modeling method was executed in the modeling software AMOS in order to rank the dimensions and factors based on their influence, to ascertain the causal relationships between the variables, and generate the final model.

Göncü and Çetin [30] studied Supplier Selection Criteria in Healthcare Enterprises. The main purpose of the study is to develop a holistic MCDM model as a decision support system for supplier selection in the health sector. The Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Analytical Network Process (ANP) methods were used together to analyze the model.

Sharifian *et al.,* [31] conducted an applied study that evaluates the risk factors related to the implementation of clinical information technology projects in the hospital. Fuzzy logic was used in this study. They also applied an ANP-DEMATEL combined model with a fuzzy procedure to provide the analytic model of the study. According to the study findings, lack of top-executive support, and an unstable organizational environment were the two most important risk factors, while the main organizational factors and technology were also highly important.

Mamaghani *et al.,* [32] studied The maturity of business intelligence. In order to identify the effective factors, the Delphi method was used and experts' opinions were, and in order to determine the effectiveness and effectiveness of the indicators and finally to prioritize them, the DANP method. According to the results of the DANP process, flexible and expandable technical infrastructure criteria, data and system quality, and the correct definition of business intelligence problems and processes were prioritized as the three criteria with the highest ranking in the maturity of business intelligence.

Rostamzadeh *et al.,* [33] study DEMATEL technique integrated with the ANP is used for the determination and prioritization of cause–effect relationships among factors affecting construction falls. The interactions and important degree of each factor are specified, using the DEMATEL–ANP approach.

Ghaderi *et al.,* [34] proposed A descriptive-analytical approach was adopted to solve the problem of identifying the best locations for aerial ambulances, combining three distinct methods. The first step was to identify criteria affecting the location of air ambulances. Then, the location was determined using a fuzzy ANP model coupled with a fuzzy DEMATEL technique and a geographic information system.

The objective of this paper is to improve patient satisfaction by reducing the patient's LOS in the OR. To this end, DEMATEL and ANP methods are used sequentially, first DEMATEL is employed to determine the relationships between OR factors, next, its results are used by ANP to define improvement scenarios.

**Table 1**
Review of patient length of stay literature [32]

| | Author | Study titles | Case Study | Examined variables |
|---|---|---|---|---|
| 1 | Bashkin *et al.,* [35] | Organizational factors affecting length of stay in the emergency department: initial observational study | 15 patients in the emergency department of a city hospital in Israel | Registration times, nursing, doctor's appointments, decision making (discharge versus admission) use of specialized counseling and ancillary services, and time of discharge of hospitalized patients |
| 2 | Dodek *et al.,* [36] | Assessing the influence of Intensive Care Unit Organizational Factors on Outcomes in Canada: Is there residual confounding? | All ICU patients from 1994 to 1999 in British Columbia | Age and gender as moderators and management style data, daily rounds, presence of a head nurse, trained specialty physician, pharmacist, and nurse-to-patient ratio |
| 3 | Yaghoubi *et al.,* [37] | Investigating the factors affecting the length of stay of patients in Al-Zahra Medical Center based on hierarchical analysis | Hospital staff includes management, department, and educational supervisor and is responsible for all departments of the hospital | Patient-related factors, operating room facilities, patient visits, factors related to coordination of other departments, equipment and facilities, medical staff, quality of nursing |
| 4 | Ido *et al.,* [38] | Door to Intravenous Tissue Plasminogen Activator Time and Hospital Length of Stay in Acute Georgia, Ischemic Stroke Patients, 2007-2013 | 3154 patients with ischemic stroke treated with venous thrombolysis from 2007 to 2013 in Georgia | The effect of treatment time during the hospital stay, discharge status, embolism status on discharge, and bleeding complications |
| 5 | Kossovsky *et al.,* [39] | Relationship between hospital of care length of stay and quality in patients with congestive heart failure | Hospitals of the University of Geneva, Switzerland. 371 random samples from 1084 patients discharged with the main diagnosis of CHF between January 1997and December 1998 | Admission (score), assessment and treatment during the stay (treatment score), readiness for discharge |
| 6 | McMullan *et al.,* [40] | Resource utilization, length of hospital stay, and pattern of investigation ensure acute medical hospital admission | 830 emergency admissions to a Belfast Teaching Hospital in the United Kingdom | Duration of stay, diagnosis at discharge, paraclinical requests other than laboratory, admission days, age of patient |
| 7 | Borghans *et al.,* [41] | Benchmarking and reducing the length of stay in Durch hospitals | 69 hospitals out of 96 Dutch hospitals from 1994 to 2006 | Type of diagnosis, surgical method, age and sex of the patient, and length of stay |
| 8 | Nasiripour *at al.,* [42] | The effect of the full-time presence of a specialist on the length of stay of patients in the gynecology and obstetrics ward of Yazd Social Security Hospital | Three months in 2007 before the intervention and 3 months in 2008 after the intervention | Duration of patients' stay, duration of gynecologist in the ward |
| 9 | Gohari *et al.,* [43] | Application of multilevel model in determining the factors affecting the length of | 570 patients in six months of 2009 in social security hospitals throughout the country | Gender, age, type of insurance, and length of stay of patients |

| | | | | |
|---|---|---|---|---|
| | | stay of appendectomy patients | | Number of active beds and province and city |
| 10 | Nikookar *et al.,* [44] | Evaluation of the duration of unnecessary hospitalization and its costs in the elderly with stroke in the acute care ward of Shahid Dr. Fayyaz Bakhsh Hospital in Tehran | A total of 51 elderly patients aged 60 and over in 1392 | Age, length of stay, stroke-related patients, hospital costs |
| 11 | Arab *et al.,* [45] | Analysis of factors affecting the length of stay of patients in public hospitals in Lorestan province | 662 randomly admitted patients in 2006 | Duration of stay, age, sex, place of residence, marital status, type of insurance, flame, type of referral, patient status at discharge |
| 12 | Karim *et al.,* [46] | Investigating the factors related to the length of hospital stay: A systematic review | Systematic review | Demographic, clinical, hospital, and managerial |

## 3. Method

The present study was conducted on the operating suite of a specialty hospital in the city of Tehran, Iran. The influential factors on LOS in operating suite were collected via literature review summarized in Table 2, direct observation in operating suite, and questionnaires during the interviews with the sixty OR staff (including surgeons, clinical personnel, and operating suite technicians). The collected information/factors were classified under three categories pre-, intra-, and post-operation factors.

**Table 2**
Factors affecting LOS in operating suite according to prior studies

| Factor | Research papers |
|---|---|
| Pre-op factors | [10, 11, 47] |
| Patient's demographic characteristics | [10, 11, 25, 47, 48] |
| History of prior surgeries | [11] |
| Score of the American Society of Anesthesiologists | [11, 25, 47, 48] |
| History of clinical diseases (blood sugar, blood pressure, diabetes, etc.) | [10-12, 48] |
| Laboratory variables | [10] |
| Classification of body mass index | [48] |
| Intra-op factors | [10, 11] |
| Complications | [11] |
| Blood loss | [11] |
| Blood transfusion | [11] |
| Prescribed fluids | [11] |
| Surgery time | [10,11, 47, 48] |
| Wound classification | [10, 48] |
| Post-op factors | [10, 11, 47] |
| Blood transfusion | [11, 12] |
| Complications | [10, 11] |
| Body temperature | [12] |
| Creatinine | [12] |
| Number of ICU admissions | [12] |

In Figure 2, the top row indicates the operating suite activities, the middle row contains the factors listed in Table 2, and the bottom row includes the factors identified in the present research affecting the patients' operating suite LOS. The goal of the cross-process map, explained in Figure 2, is to illustrate the overlapping of the two sets of factors and the activities. The map also distinguishes factors that have been identified by prior studies from those proposed by the clinical personnel of the operating suite.

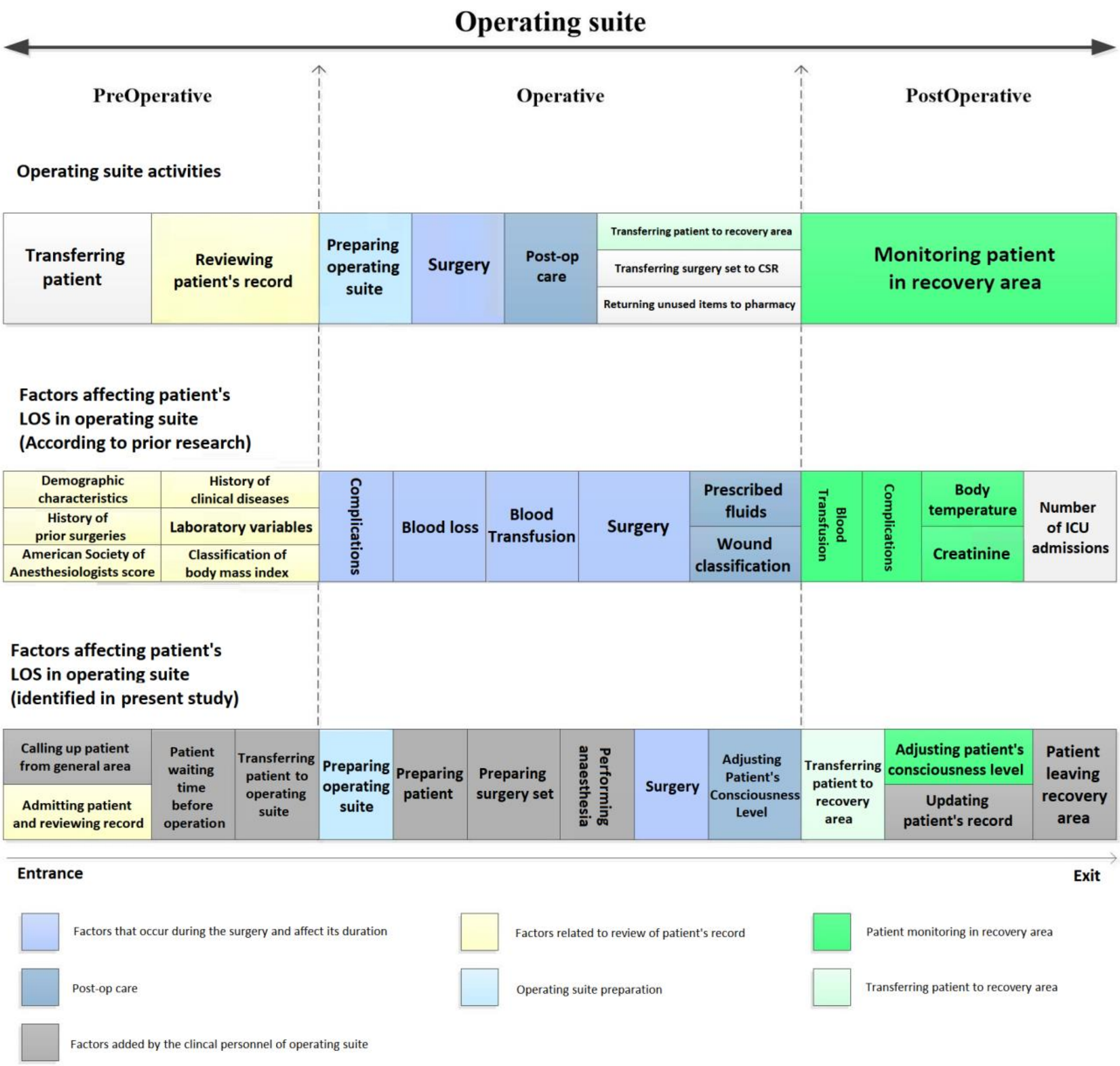


**Fig. 2.** Cross-Process map

Figure 3 shows the framework was used in this work, and explain how DEMATEL and ANP model works.

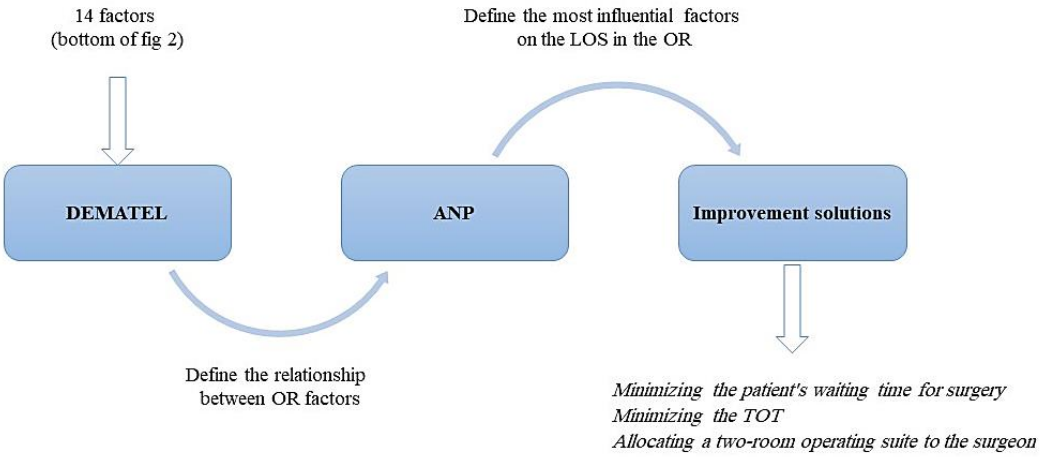


**Fig. 3.** DEMATEL-ANP framework

The decision-making trial and evaluation laboratory (DEMATEL) method was employed to obtain the relationships between the factors. The relationships are demonstrated in the form of networks and graphs (R + D, R – D). We call R + D the 'superiority vector' which indicates the total effectiveness and affectability of each factor, and R – D the 'relationship vector' which indicates each factor's effect on the system's other factors. We used the analytic network process (ANP) to compute each factor's weight (aka significance level) which was then analyzed using the multi-criteria decision-making software Super Decisions. Next, three scenarios were defined as part of the process of minimizing the patient's operating suite LOS: 1) reducing the patient's pre-op waiting time; 2) reducing the turnover time (TOT); and 3) allocating two separate ORs to the surgeon.

The Dematel and ANP tools have been widely used in various research studies for many years. However, the combination of Dematel and ANP methods in the current research topic, which focuses on reducing patient length of stay in the operating room, has not been addressed before.

In the context of the study, after identifying the factors, the most important step is to find the relationship between influential and affected factors. We know that influential factors should be prioritized in improvement plans, in simpler terms, allocating financial resources to the most important factors for improvement, which are the influential factors. After evaluations, the most suitable method for use in this area is the combined Dematel and ANP method.

It can be asserted that the Dematel and ANP methods are not innovative on their own, but the use of a combined method in our research topic is both innovative and effective in providing answers to our questions.

## 4. Results

The operating suite LOS for patients undergoing hernia operation was calculated. 60 operations performed over a 5-month period were investigated. The patients' average LOS was found to be 160 minutes. The factors affecting the operating suite LOS were identified and classified into three categories pre-, intra-, and post-op factors. Now let us examine the interrelationships between all factors within one network. The interrelationships between the factors, regardless of their category, were obtained using the DEMATEL technique as follows.

Literature review, summarized at Table 2, mentioned 17 factors influencing the LOS in OR. However, in this study, surgeons and clinical personnel suggested to focus on 14 factors observed in the OR, and depicted at bottom row of Figure 2, which some of them are reported at Table 2. The 14 factors, classified into three categories of pre-, intra-, and post-operation factors, are illustrated in Figure 5. The DEMATEL technique was then used to demonstrate the interrelationships between the factors. The matrix of interrelations, generated by the DEMATEL technique, indicates both the causal relationships between the factors, and their effectiveness and affectability. We first construct the direct relationship matrix (M). After this matrix is normalized, the total interrelationship matrix (T) is obtained:

$$T = N \times (1 - N) - 1$$

In order to develop the relationships network map, we should first obtain the threshold value. The threshold values of the networks were considered equal to the average of matrix T's elements, with the exception of the network of intra-operation factors, where 0.15 was strictly added to the threshold value. Each element of matrix T is compared with the threshold value. If an element is equal to or larger than the threshold value, it is replaced by 1; otherwise, by 0, until the matrix is complete. The results generated by the DEMATEL technique are presented in Figures 3-6. The vertical axis (R–D) represents affectability and the horizontal axis (R + D) represents effectiveness. If R – D > 0, the variable is effective, and if R – D < 0, it is effective.

*4.1 Relationships Between Categories*

The relationships between the categories are network-based and their effectiveness and affectability are presented below.

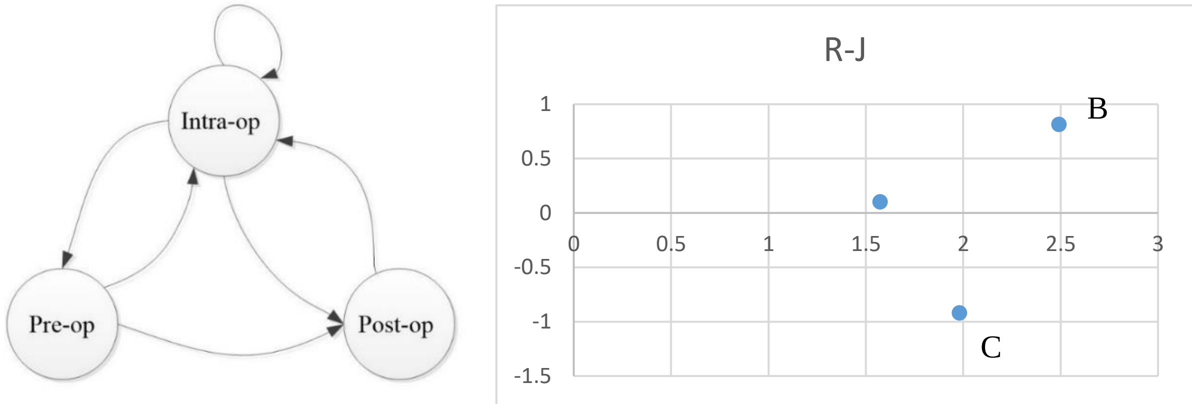


**Fig. 4.** Examining the relationships between approaches

The intra-operation category has the largest R + D value; thus, its factors have the most interaction with the other factors. As the vertical axis (R – D) represents affectability and the horizontal axis (R + D) represents effectiveness, it can be concluded that point B (intra-op category) has the greatest effect on patients' LOS. On the other hand, point C (post-op category) contains the most effective factors.

*4.2 Relationships Between Factors*

This subsection presents our evaluations of the relationships between the pre-, intra-, and post-operation factors, performed using the DEMATEL technique. The relationships are network-based, and their effectiveness and affectability are demonstrated by scatter graphs.

### *4.1.1 Relationships between pre-op factors*

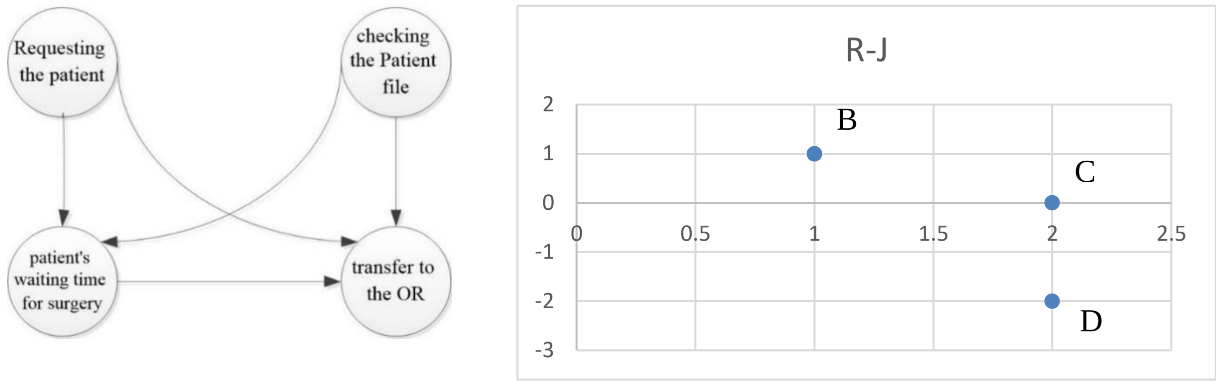


**Fig. 5.** Investigation of preoperative factors

Point D (transfer to the OR) and point C (patient's waiting time for surgery) are the most effective and most effective factors, respectively, among the pre-op factors. This is in accordance with the real-world case study, where the duration of time the patients spend waiting for the operation considerably affects the time of their transfer to the OR.

### *4.2.2 Relationships between intra-op factors*

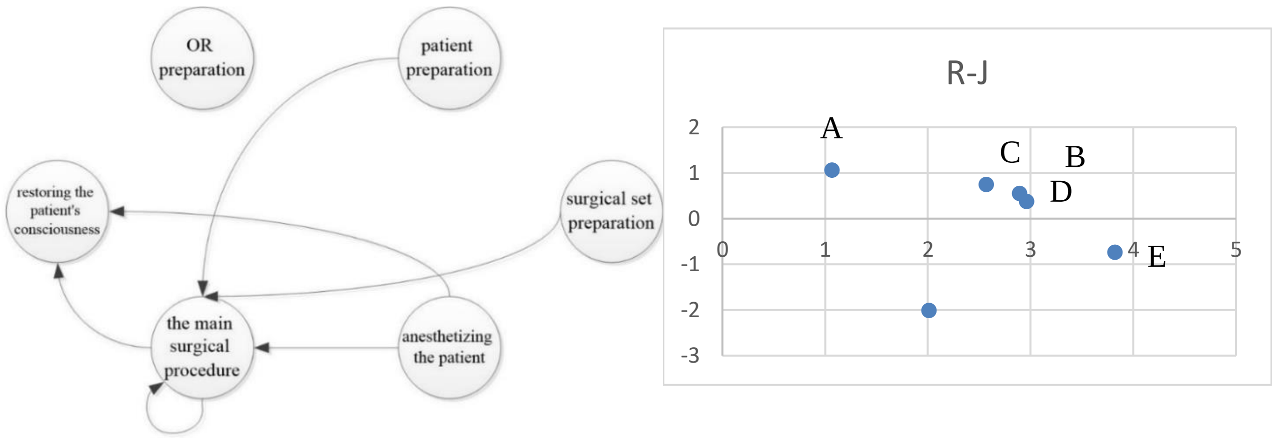


**Fig. 6.** Investigation of intra-operative factors

The largest value of R + D belongs to point E, which means that the main surgical procedure has the most interaction with the other factors. According to the graph above, OR preparation and surgical set preparation affect the patient's LOS the most. On the other hand, the time of modifying the patient's consciousness level is the most effective factor. This is in accordance with the real-world case study, since the longer it takes to prepare everything, anesthetize the patient, and perform the surgery, the further the patient's consciousness modification process is delayed.

### *4.2.3. Relationships between post-op factors*

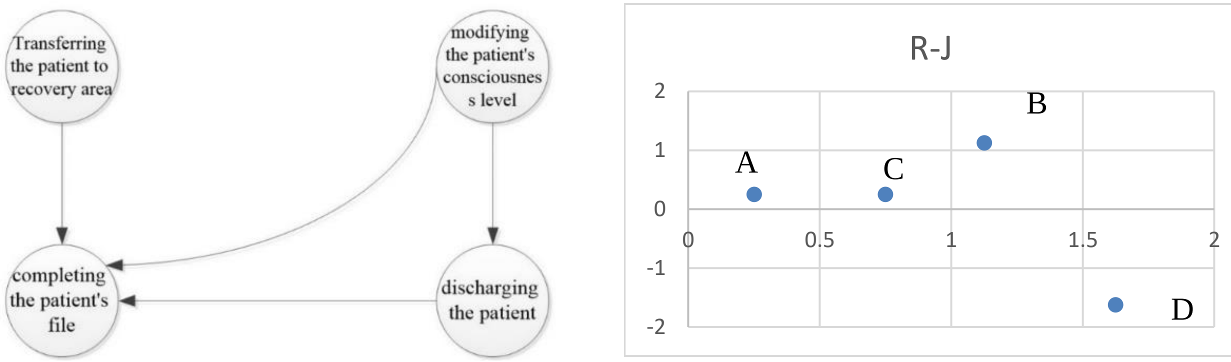


**Fig. 7.** Investigation of post-operative factors

It can be seen in Figure 7 that Point D (patient discharge) and point B (modifying patient's consciousness) represent the most effective and effective factors, respectively, among post-op factors.

### *4.2.4 Relationships between all factors*

Now let us examine the interrelationships between all factors within one network. The interrelationships between the factors, regardless of the three categories, were obtained using the DEMATEL technique as follows:

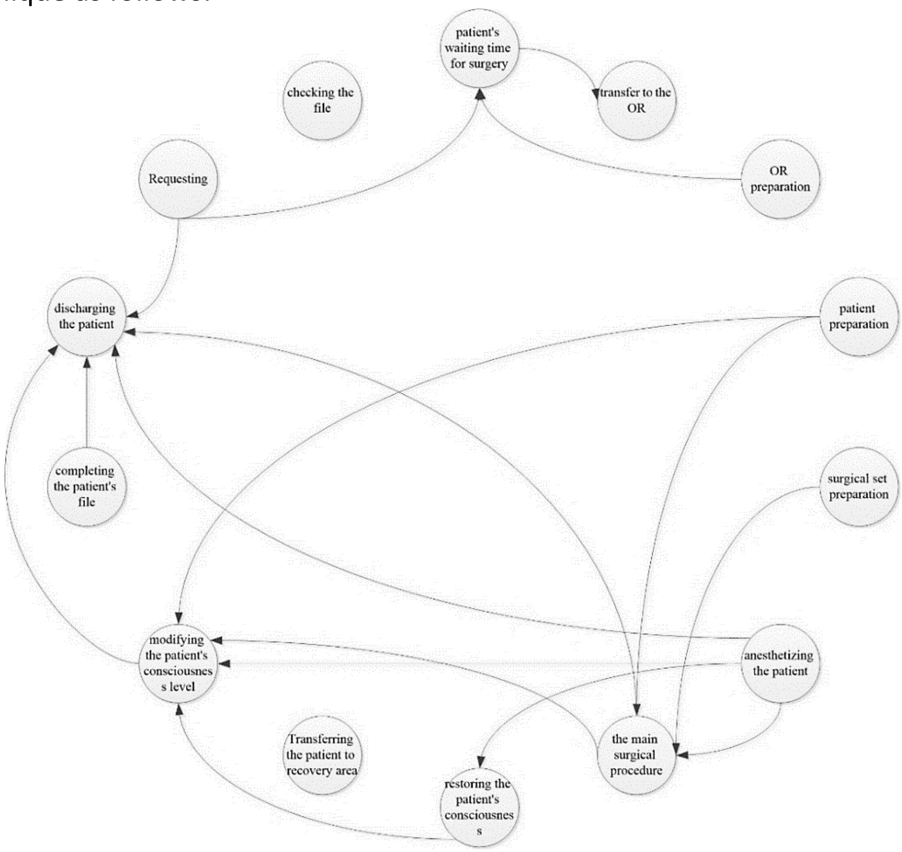

**Fig. 8.** Interrelationships between factors as obtained by DEMATEL

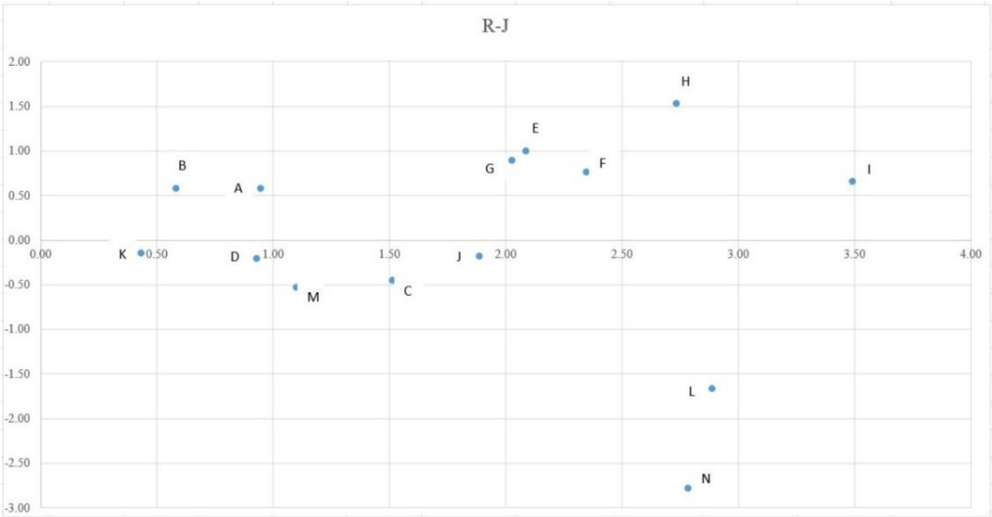


**Fig. 9.** Affectability and effectiveness of each factor as obtained by DEMATEL

| | | | | | |
|---|---|---|---|---|---|
| **A** | Calling up patients from the ward | **F** | Preparing patient | **K** | Transferring a patient to the recovery area |
| **B** | Patient handover and record review | **G** | Preparing surgical set and supplies | **L** | Adjusting patient's consciousness level (recovery area) |
| **C** | Patient pre-op waiting time | **H** | Anesthetizing patient | **M** | Updating patient's record |
| **D** | Transferring a patient to the operating suite | **I** | Performing surgery | **N** | Discharging patient from the recovery area and operating suite |
| **E** | Preparing operating suite | **J** | Adjusting patient's consciousness level (OR) | | |

After analyzing the interrelationships, anesthetizing the patient, operating suite preparation, and surgical set preparation were found to be the factors that affect the patients' LOS the most, while the patient's discharge time is the most effective factor of all.

### *4.3 Relationships Between Categories*

In this subsection, we determine the significance level (aka weight) of the factors. To this end, we enter the objective, categories, and factors in the decision-making software *Super Decisions*. Now we illustrate the interrelationships between the factors, which were previously generated using the DEMATEL technique (see Figure 8).

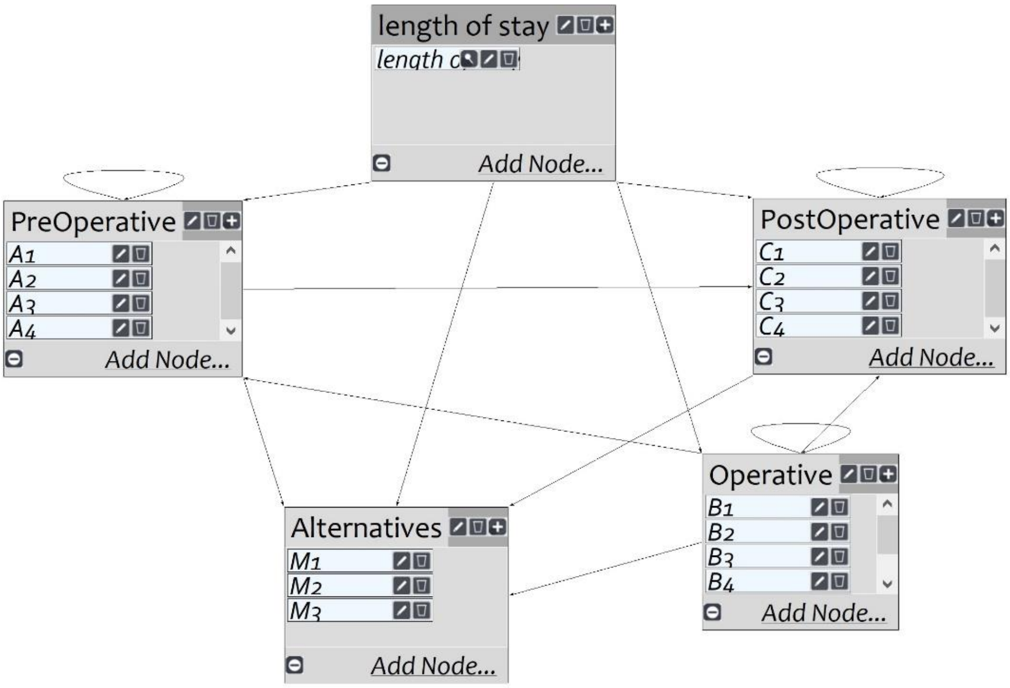


**Fig. 10.** ANP structure

By executing the ANP algorithm in full (see Figure 10), the weight of each factor is obtained. Table 3 presents all the factors and their weights without considering the categories. Among the pre-op factors, the patient's waiting time for surgery has the highest weight. As can be seen, if the patient is called for surgery in a timely fashion, the waiting time for surgery is reduced. Conversely, if the patient is called too early, the time they spend in the OR increases. In some cases, the opposite occurs: the patient is called at an optimal time, but nurses transfer the patient to the OR with some delay. This may result in one of the following two outcomes: First, the surgery team may be left waiting for the patient's arrival in the OR; in which case the hospital should compensate the extra cost of the clinical personnel's time. Second, the delay may be so long that another patient is brought to the OR instead. In this case, the late patient would have to wait for the other operation to complete, a significant delay that leads to patient dissatisfaction.

According to Figure 8 and Figure 9 and using the ANP technique, the significance i.e. weight of each factor was determined. The weights are listed in Table 3 as follows.

**Table 3**
Weights of factors

| Factor | Weight |
|---|---|
| Surgical procedure | 0.288958 |
| Surgical set prep | 0.178898 |
| Pre-op waiting time | 0.128078 |
| Patient anesthesia | 0.103647 |
| Patient prep. | 0.083859 |
| Patient call-up from the ward | 0.048283 |
| Consciousness adjustment (OR) | 0.04324 |
| Consciousness adjustment (Recovery) | 0.037712 |
| Operating suite prep | 0.023696 |
| Patient record update | 0.023465 |
| Patient call-up from the ward | 0.019138 |

| Factor | Weight |
|---|---|
| Patient transfer to the operating suite | 0.009486 |
| Patient transfer to the recovery area | 0.008149 |
| Patient discharge from the operating suite | 0.003392 |

The most significant factors when it comes to affecting the patients' operating suite LOS are the main surgical procedure (0.289), surgical set preparation (0.179), patient's waiting time for surgery (0.128), patient anesthesia (0.104), and patient preparation (0.084). Moreover, transferring the patient to the operating suite is the least significant factor of all, because there is often no delay before this activity and all transfers take a fixed amount of time.

*4.4 Improvement Solutions*

One of the strengths of this research is the use of the Dematel method. This method, due to its computational nature, divides factors into two categories: influential factors and influenced factors. When defining improvement projects, this method shows us that it is better to implement improvement scenarios in the area of influential factors. Sometimes influenced factors are the result of the activities of influential factors. That is, by improving influential factors, influenced factors also improve. This is the most important reason for using the Dematel method. The ANP method, alongside Dematel, guides us on which influential factors require more attention and which factors should have priority in spending for improvement projects. For this reason, the use of a combination of these two methods can help in a more precise analysis and selection of the best solutions for improving the issues under study, especially in the context of industrial engineering.

Given the analyses described thus far and the weights listed in Table 2, the following three processes were selected to help improve i.e. minimize the patient's LOS in the operating suite:

Minimizing the patient's waiting time for surgery: Requires that the patient be called up from the ward and transferred to the OR by the ward nurse in time.

i. Minimizing the TOT: The time interval between when the surgical dressing is applied to a patient and when the surgical incision is performed on the next patient [49]. TOT also involves adjusting the departing patient's consciousness, collecting and disposing of the instruments and supplies, preparing the OR and surgical set for the next operation, in addition to preparing and anesthetizing the next patient.

ii. Allocating a two-room operating suite to the surgeon: In this solution, two adjacent ORs are simultaneously put at the attending surgeon's disposal, such that the subsequent patient is not left waiting outside the OR, but transferred to the second room to undergo the final preparation (and, in some cases, even anesthesia) for their surgery. The surgeon comes to the second OR to initiate the next surgery as soon as the previous one is completed.

The three processes above were evaluated by the ANP technique and their weights were obtained as 0.16, 0.31, and 0.52, respectively. Hence, the two-room operating solution was identified as the optimal process, followed by TOT minimization and waiting time minimization.

We performed the three solutions in the operating suite and the following were the results (see Table 4).

Minimizing the patient's waiting time for surgery

Minimizing the TOT

Allocating a two-room operating suite to the surgeon

**Table 4**
Effect of each solution on the activities of the operating suite (only high-priority activities)

| Improvement solutions | Pre-op waiting time | Surgical set preparation | Patient preparation | Anesthesia | Surgical procedure | LOS |
|---|---|---|---|---|---|---|
| Minimizing pre-op waiting time | -5 | 0 | 0 | 0 | 0 | -5 |
| Minimizing TOT | -3 | -2 | -3 | -1 | 0 | -9 |
| Allocating two-room operating suite* | -10 | -6 | 0 | 0 | 0 | -16 |

* Improvement solution identified as executable in the operating suite.

As can be observed, the first solution reduces the patients' average operating suite LOS by 3.1%, the second solution by 5.6%, and the third solution by 10%.

## 5. Discussion

Patients' LOS in the operating suite has a direct relationship with costs in hospitals and, the longer the stay, the lower the profitability of the operating suite. If the LOS is reduced, it becomes possible to perform more operations and generate more revenue. Since operating suites are responsible for a major portion of any hospital's income, this results in significantly more profit for the hospital, as well. In the hospital studied in the present research, patients do not pay for surgeries. This makes it even more necessary to minimize the LOS because the hospital seeks to reduce its costs. At the moment, the costs of the hospital's operating suite exceed its revenue.

In the existing conditions, applying DEMATL and ANP revealed that the most influential factors on patients' operating suite LOS in order of significance are the main surgical procedure, surgical set preparation, patient pre-op waiting time, anesthesia, and patient preparation, respectively. In the other studies, Göncü and Çetin[ 30] developed a model by using the DEMATEL and ANP to select supplier in the health care, and Sharifian *et al.,* [31] employed ANP-DEMTEL combined approach to evaluate the risks of implementing the projects of clinical information technology in hospitals.

**Table 5**
The comparison of the studies conducted on the factors affecting the OR

| Case study | | Factors | The most influential factors |
|---|---|---|---|
| Gruskay *et al.,* [11] | Operating Room | Preoperative factors (patient demographics, previous surgery, levels instrumented, American Society of Anesthesiologists Score of the American Society of Anesthesiologists, and major medical comorbidities, including diabetes, hypertension, malignancy, pulmonary disease, or heart disease), intraoperative factors (complications, drain placement, estimated blood loss, blood transfusion, fluids administered, operating room time, and surgery time), postoperative factors (drain removal, blood transfusion, complications, and discharge destination) | Pre-op factors: Patient's demographic characteristics<br>History of prior surgeries<br>History of clinical diseases (blood sugar, blood pressure, diabetes, etc.)<br>Score of the American Society of Anesthesiologists<br>Intra-op factors: Complications<br>Blood loss<br>Blood transfusion<br>Prescribed fluids<br>Surgery time<br>Post-op factors:<br>Blood transfusion Complications |

| Case study | | Factors | The most influential factors |
|---|---|---|---|
| Chuang *et al.,* [12] | Emergency surgery | Demographics (Sex, age, education, primary caregiver)<br>Medical history (Diabetes, hypertension, cardiovascular disease, anemia, liver cirrhosis, cardiovascular<br>medicine)<br>Vital signs (Blood pressure, BMI, bowel record, GCS, Barthel Index, respiratory symptom, pulse,<br>body temperature, chest X-ray result, ECG results, comorbidity)<br>Laboratory data,<br>Operation physician data (Age, seniority)<br>Operation and nursing data (Intensive care unit entry times (before operation), operation site, operation position, mole of anesthesia, preoperative risk assessment score, multiple surgeries, ASA, blood transfusion) | History of clinical diseases (blood sugar, blood pressure, diabetes, etc.)<br>Blood transfusion<br>Body temperature Creatinine<br>Number of ICU admissions |
| Ricci *et al.,* [25] | Operating room | Demographic data<br>American Society of Anesthesiologists (ASA) score<br>hospital admission<br>discharge dates<br>the date of surgery | Patient's demographic characteristics<br>Score of the American Society of Anesthesiologists |
| Kohlnhofer *et al.,* [47] | Operating Room | Preoperative characteristics: American Society of Anesthesiologists (ASA) class 1 to 5, body mass index R30, diabetes mellitus, smoking, dyspnea, preoperative functional status, chronic obstructive pulmonary disease, ascites within 30 days before surgery, congestive heart failure within 30 days before surgery, hypertension, acute renal failure, hemodialysis, disseminated cancer, open wound, steroid/ immunosuppressive medication use, weight loss .10% within 6 months before surgery, bleeding disorder, transfusion of red blood cells within 72 hours before surgery, and sepsis within 48 hours before surgery.<br>Intraoperative characteristics: preoperative diagnosis, procedures occurring at the time of index surgery, length of procedure, and operative approach (laparoscopic or open).<br>Postoperative characteristics: length of stay, R2 complications, reoperation, and postoperative complications as defined by NSQIP criteria. | Pre-op factors<br>Patient's demographic characteristics<br>Score of the American Society of Anesthesiologists<br>Surgery time<br>Post-op factors |
| Helman *et al.,* [48] | Operating Room | Patient's demographic characteristics<br>Score of the American Society of Anesthesiologists<br>History of clinical diseases (blood sugar, blood pressure, diabetes, etc.)<br>Classification of body mass index<br>Surgery time<br>Wound classification | Surgery time<br>functional status,<br>perioperative steroid use,<br>active smoking |

As seen in Table 5, the identification of factors using the AAA method has resulted in significantly better outcomes.

In assessing patients' stay in the operating suite, it was found that the main surgical procedure takes up the largest share of the LOS. If all the right supplies and equipment are received from the operating suite's pharmacy in a timely manner, the overall length of the surgery can be reduced. In some cases, during the surgery, the surgeon may require an item that has not been brought to the operating room and which the assistant should get from the pharmacy. In other cases, the patient may need extra blood packets which also must be secured immediately. Such time-consuming incidents increase the surgeon's idle time in the operating room and, as a result, increase the overall duration of the surgery. Since the operating room remains occupied for a longer time than originally planned, the number of daily operations decreases and this imposes additional costs on the hospital.

Reducing patients' pre-op waiting times also affects the overall LOS. If patients are called up from the ward in a timely fashion, they will spend less time waiting behind the OR's closed doors. However, because patients are called up too early with surgery still in progress, the LOS increases. In some cases, the opposite occurs: the patient is called up at the right time, but the nurse brings the patient to the operating suite with some delay. The outcome of the two scenarios, however, is the same. Firstly, the surgical team remains idle until the patient's arrival; forcing the hospital to pay the clinical personnel more than it should. Secondly, the nurse's delay in transferring the patient may be so protracted that another patient is called up instead. In such cases, the patient who has missed their turn due to the nurse's delay would have to wait until the ongoing operation is over. This negatively affects the patient's satisfaction with the hospital.

In this study, due to increasing the number of clinical or service personnel causing more delays we only implicated the three DM scenarios defined by applying DEMATEL and ANP explained Table 4. For instance, it is highly uncommon to assign more service personnel, assistant surgeons, or recovery nurses for hernia operations. For other operations, the situation may be different and the conditions may be there to add extra assistants or even surgeons if required.

Implementing the two-room solution will reduce patients' average operating suite LOS by 10%. It also increases the clinical personnel's performance level and overall patient satisfaction. It should be noted, however, that allocating two ORs to the surgeon is only possible when two general operating suites are empty at the same time. We now describe the circumstances under which the two-room solution is adaptable. In the hospital studied for the purposes of this research, one of the operating suite shifts starts at 7:30 AM and ends at 4:00 PM. The surgeries often start either at 7:30 AM or 1:00 PM. In row A of Table 4, surgeon 2's operation starts at 1:00 PM, therefore surgeon 1 can have two rooms at their disposal between 7:30 AM and 1:00 PM. In row B, surgeon 2's operation ends at 1:00 PM and the operating suite can be made available to surgeon 1. Table 6 shows the impact of allocating two ORs to the surgeons.

**Table 6**

Number of operations performed before and after adopting the two-room solution

| | | |
|---|---|---|
| A | Number of surgeons 1's operations before allocating two ORs | 6 |
| | Number of Surgeon 1's operations after allocating two ORs | 9 |
| B | Number of surgeon 2's operations before allocating two ORs | 6 |
| | Number of surgeon 2's operations after allocating two ORs | 8 |

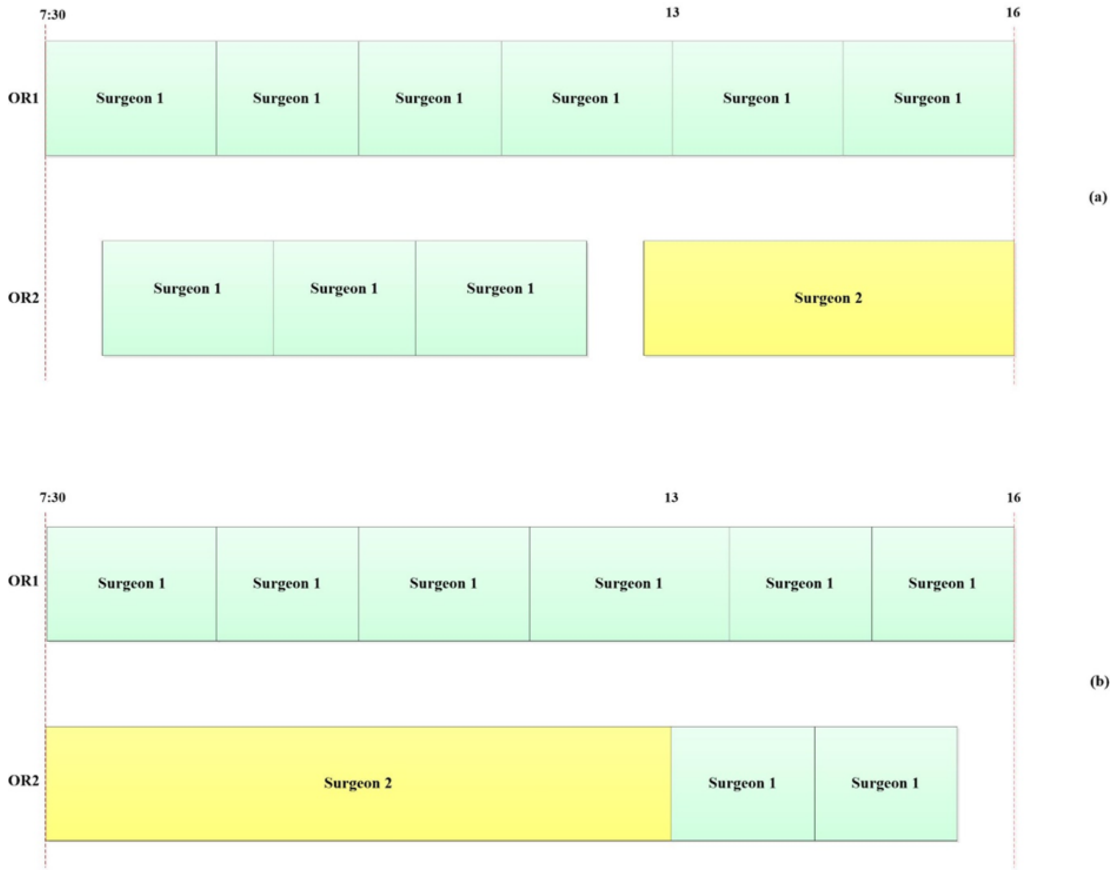


**Fig. 11.** Conditions where each surgeon can have two ORs

According to Figure 11 In mode A, surgeon 1 originally performs 6 operations. However, once the two-room solution is adopted, surgeon 1 becomes able to perform 9 surgeries. In mode B, the number of surgeon 2's operations rises from 6 to 8.

Given that in each shift, only one clinical team is allocated to each operating suite, if the surgical team remains unnecessarily idle or busy, extra costs are imposed on the hospital.

## 6. Conclusion

Today, one of the most important factors for the economic sustainability of hospitals is patient satisfaction with the hospital's performance. Hospitals are obligated to reduce dissatisfaction factors. After identifying these factors, using Dematel to determine the relationships between the factors and using ANP to determine their importance, two factors, "preoperative patient waiting time" and "surgical preparation," were identified as important factors. According to Figure 9, it is understood that "surgical preparation" is an influential factor and "preoperative waiting time" is an influential factor. Our analysis shows that by improving the "surgical preparation" factor, the "preoperative waiting time" factor decreases.

Among the proposed solutions, the most important is to utilize two operating rooms simultaneously. In this solution, influential factors are strengthened and also lead to the improvement of influenced factors. Studies show that using two operating rooms reduces the patient's stay in the operating room by 10%. This is one of the most important factors for patient and patient companion satisfaction, as an increase in the patient's stay in the operating room also increases the level of stress and anxiety. With a reduced length of stay, patient and companion satisfaction also increases. This is the most important result that can be achieved by reducing the patient's length of stay.

### *6.1 The limitations of their research*

The constraints in this research can be divided into two categories: author constraints and hospital constraints. Due to the lack of consistent and recorded data, we had to be present at over 80 abdominal surgeries over the course of two years, as our work was based on timing to calculate the patient's length of stay in the operating room. After presenting improvement solutions, there was a need for implementation in the operating room and examining the results. Due to hospital constraints, it was not possible to be present in the operating room for some procedures.

### *6.2 Future directions*

The nature of the research is such that after examining the current situation and presenting solutions, improvement scenarios need to be implemented in order to compare the results with the pre-implementation status. It is a challenging task both in terms of the author's time commitment and the implementation process. Therefore, simulating all the processes of the operating room is a more suitable method. One of the best tools for simulation is the use of agent-based simulation. Through simulation, improvement scenarios can be easily implemented and results evaluated. As a result, hospital managers can be justified that the chosen scenario is an appropriate one for improving the operating room.

The second suggestion for future research is to use the Q-methodology for consulted through the opinions of operating suite experts. Also, we suggest Using the proposed model for other surgical operations and analyzing the results.

## Author Contributions

Conceptualization, S.R.M, M.M.S.; methodology, S.R.M, S.E.N; software, S.R.M; validation, S.R.M, M.M.S. and S.E.N.; formal analysis, S.R.M, M.M.S.; investigation, S.R.M.; resources, S.R.M.; data curation, S.R.M.; writing—original draft preparation, S.R.M.; writing—review and editing, M.M.S, S.E.N.; visualization, S.R.M.; supervision, M.M.S, S.E.N.; project administration, S.R.M.; funding acquisition, S.R.M. All authors have read and agreed to the published version of the manuscript.

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## Data Availability Statement

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that They have no conflict of interest.

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