REVIEW ARTICLE

Analytic hierarchy process as module for productivity evaluation and decision-making of the operation theater

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ABSTRACT

The analytic hierarchy process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales, these scales that measure intangibles in relative terms. The aim of the article was to develop a model for productivity measurement of the operation theater (OT), which could be applied as a model for quality improvement and decision-making. AHP is used in this article to evolve such a model. The steps consist of identifying the critical success factors for measuring the productivity of OT, identifying subfactors that infl auence the critical factors, comparing the pairwise, deriving their relative importance and ratings, and calculating the cumulative effect according to the attributes in OT. The cumulative productivitycan be calculated by the end and can be compared Ideal productivity to measure the productive of OT in percentage fraction. Hence, the productivity could be calculated. Hence, AHP is a very useful model to measure the productivity in OT.

Key words: Analytic hierarchy process, decision-making, operating theater, performance measures, productivity

INTRODUCTION

The analytic hierarchy process (AHP) is a general theory of measurement. They are derived by making pairwise comparisons using numerical judgments from an absolute scale of numbers. This is essential when both subjective and objective factors need to be considered in the same pool.[1] AHP provides a way to derive and synthesize relative scales systematically. The various factors are arranged in a hierarchy and measured according to the factor and subfactor represented within these structures. It is used to derive ratio scales from both discrete and continuous paired comparisons.[2]

These comparisons may be taken from actual measurements or from a fundamental scale which reflects the relative strength of preferences and feelings. The AHP has a special concern with departure from consistency, its measurement, and on dependence within and between the groups of elements of its structure. Some key and basic steps involved in this methodology are: [3,4]

- Define the problem
- Broaden the objectives of the problem or consider all actors, objectives, and its outcome
- Identify the criteria that influence the behavior
- Structure the problem in a hierarchy of different levels constituting goal, criteria, subcriteria, and alternatives.

The AHP has found its widest applications in multi-factors decision-making, planning, and resource allocation (MFDA), and in conflict resolution.[5] The AHP is a method which

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incorporates benefits and risks, explicitly by combining the importance of differences in probabilities of outcomes related to alternatives and the weighting of the importance of those outcomes.[6,7] MFDA techniques can be used to structure complex decisions and improve the transparency of the decision-making process.[8]

Hence, our aim was to develop a model for productivity measurement of the operation theater (OT), which could be applied as model for quality improvement and decision-making.

RESEARCH METHODOLOGY

The suggested module of analytic hierarchy process for measuring productivity of operation theater

Step 1

Broaden the objectives of the problem (calculation of the productivity of OT) and goal (effective and efficient OT). Identify the criteria that influence the productivity (input factors = "operating room and the teamwork" and output factors = "patient factors"). Structure the problem in a hierarchy of different levels constituting goal, criteria, subcriteria, and alternatives as shown Figure 1 and Table 1.

Compare each element in the corresponding level and calibrate them on the numerical scale of numbers that indicates how many times more important or dominant one element is over another element with observance thefactor with respect to which they are compared. A 9-point numerical scale was used for the comparison. The intensity and the definitions of the pair wise comparison are as follows:

1 = equal importance; 2 = weak or slight; 3 = moderate importance; 4 = moderate plus; 5 = strong importance; 6 = strong plus; 7 = very strong; 8 = very, very strong; 9 = extreme importance or 1.1–1.9 if the activities are very close, according to Saaty in 1980.[2]

Step 2

The pairwise comparisons of various factors generated at step 2 are organized into a square matrix. The diagonal elements of the matrix are 1. The factor in the I row is better than factor in the J column if the value of element (I, J) is

Table 1: The factors that influence the productivity

Operating room (input) factor		
	Surgical skills (input) factor	
		Time
		Quality of product (evaluation rating scale using dedicated check-lists)
		Care for equipment, instrument, etc.
		Patient care (operating theater and during the postoperative period)
The teamwork (input) factor		
	Anesthesia skills	
		Time
		Therapeutic interventions
		Monitoring
		Patient care
	Surgical skills (input) factor	
		Time
		Quality of product (evaluation rating scale using dedicated check-lists)
		Care for equipment, instrument, etc.
		Patient care (operating theater and during the postoperative period)
	Nursing skills performance measures	
		Patient care (admission-discharge protocols waiting time)
		Supply-chain management
		Time
		Care for equipment, instrument, etc.
	Nonsurgical skills (input) factor	
		Situation awareness
		Leadership
		Decision-making
		Communication and teamwork
		Attitude of staff
Patient (output) factors		
	Patient satisfaction (attitude of staff, service)	
	Safety (morbidity, mortality)	
	Patient care (admission-discharge protocols waiting time)	

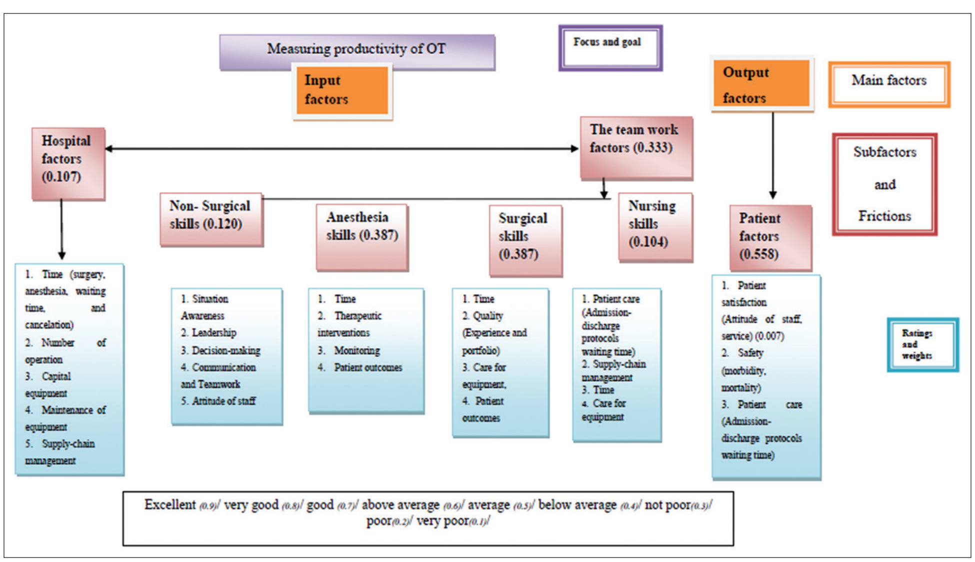

Figure 1: Hierarchy diagram of analytic hierarchy process of operation theater

more than 1; otherwise, the factor in the J column is better than that in the I row. The (J, I) element of the matrix is the reciprocal of the (I, J) element.

Step 3

The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalized eigenvector are termed weights with respect to the criteria or subcriteria and ratings with respect to the alternatives.

This is calculated as the fraction of the importance of each critical success factor with respect to the sum of the overall comparison between the factors. By the equation:
Cumulative weight (CW) = AI1 + BI2 + CI3/n, as;
AI1= (AJ1/∑ AJ1 + AJ2 + AJ3),
BI1= (BJ1/∑ BJ1 + BJ2 + BJ3),
CI1= (CJ1/∑ CJ1 + CJ2 + CJ3),
n = number of rows.

For example, in Table 2, the sum of all the values of importance (AJ) for the operating room factor is 5.333 (1 + 1/3 + 4) in J column, and the fraction of process alone will be 1 over 5.333 (0.188) and that of structure will be 1/3 over 5.333 (0.062) and 4 over 5.333 (0.745). The overall importance of the operating room factors was calculated as an average for each factor [in I row Table 2]. Thus, cumulative priorities for operating room factor (0.188 + 0.077 + 0.058 divided by 3), which equal 0.107, as shown Tables 2-7.

Step 4

For all the subfactors, nine attributes were identified, namely excellent/very good/good/above average/average/below average/not poor/poor/very poor. For each subfactor, the excellent attribute received a weight of 0.9, the above average weight of 0.6, and the very poor weight of 0.1, as shown in Figure 1.

Table 2: Pairwise comparison matrix for the main factors

Factors I row	J column			
	Operating room factor (A)	The teamwork factor (B)	Patient factors (C)	CW
Operating room	1 (0.188)	1/3 (0.077)	1/4 (0.058)	0.107
The teamwork	1/3 (0.062)	1 (0.232)	3 (0.705)	0.333
Patient factors	4 (0.745)	3 (0.697)	1 (0.232)	0.558

Numbers in parentheses denote the normalized matrix. CW: Cumulative weight

Step 5

The rating of each alternative is multiplied by the weights of the subfactor and aggregated to get local ratings with respect to each factor. The local ratings are then multiplied by the weights of the factor and aggregated to get cumulative productivity. The AHP produces weight values for each alternative based on the judged importance of one alternative over another with respect to a common factor.

RESULTS

The cumulative productivity could be calculated by the end and could be compared with Ideal productivity. Hence, the productivity could be calculated through the equation:

$$\text{Productivity} = \frac{\text{Cumulative productivity} \begin{pmatrix} \text{True weighted input factors /} \\ \text{True weighted output factors} \end{pmatrix}}{\text{Ideal productivity} \begin{pmatrix} \text{Ideal weighted input factors /} \\ \text{Ideal weighted output factors} \end{pmatrix}} \times 100$$

After the process of paired comparisons, decision-making could be started according to the weight of each factor and subfactor.

DISCUSSION

The productivity of operating rooms is one of the main problems facing by health economics. By considering exclusively an economic point of view, this investment is usually balanced by the benefits derived to the patient and the service provider. The OT also account for about 40% of the hospital's total expenses which include manpower costs (i.e., salaries of surgeons, anesthetists, nurses, etc.).[9]

Productivity provides valuable information on how an OT is performing, where it would like to be, and how it can achieve its goals.[10] It is generally defined as the

Table 3: Pairwise comparison matrix of the operating room subfactors with respect to the goal

Operating room subfactors	Time	Number of operation	Capital equipment	Maintenance of equipment	Supply-chain management	Cumulative weight
Time	1 (0.523)	1/3 (0.032)	1/4 (0.028)	1/5 (0.021)	1/6 (0.104)	0.141
Number of operation	3 (0.175)	1 (0.097)	1/2 (0.057)	1 (0.108)	1/6 (0.104)	0.108
Capital equipment	4 (0.210)	2 (0.194)	1 (0.114)	1 (0.108)	1/6 (0.104)	0.146
Maintenance of equipment	5 (0.263)	1 (0.097)	1 (0.114)	1 (0.108)	1/6 (0.104)	0.137
Supply-chain management	6 (0.315)	6 (0.582)	6 (0.685)	6 (0.652)	1 (0.625)	0.515

ratio of units of outputs to units of inputs.[11] Oh *et al*. on calculating the productivity ratio stated that "it is simple in the case of a single-input, single-output firm." For a single-input, single-output firm productivity (P) can be defined as: (P = Y/X) where Y is the number of units of the firm's single-output and X is the number of units of the firm's single-input.[12] However, for the more realistic case of a multiple-input, multiple-output firm, calculating the productivity ratio is significantly more difficult and less objective. Multiple factors should be measured if we are calculating the productivity of OT, as it depends on the performance of both OT itself and the teamwork.[13] Our present model attempts to achieve this link by having measures for all those parameters (hospital factor, patient factors, and the teamwork factors) using the weight of each factor and subfactor relatively to each other, either they are subjective or objective factors. Hence, AHP is one of the important tools to evaluate the productivity.

The traditional health-care decision-making tools are largely viewed as tools that inform health professionals' or health-care organizations' decisions instead of stimulating patient involvement. Involving patients in the decision-making process could make a potentially significant difference in health outcomes and reduce the cost of care. It is worth nothing that patients' involvement is not intended to transfer power to patients, but to endorse the decisions of clinicians and policymakers. As such, mechanisms to involve patients in decision-making processes need to be established.[11]

The process of paired comparisons has far broader uses for making decisions. Saaty stated that "we can deal with a decision from four different standpoints: The benefits (B) that the decision brings, the opportunities (O) it creates, the costs (C) that it incurs, and the risks (R) that it might have to face." He referred to these merits together as BOCR.[2]

The alternatives could be ranked for each of the four merits. The four rankings are then combined into a

Table 4: Pairwise comparison matrix of the main criteria with respect to the goal

Patient (output) subfactors	Patient satisfaction	Safety	Patient care	Cumulative weight
Patient satisfaction	1 (0.166)	1/4 (0.157)	1 (0.250)	0.191
Safety	4 (0.666)	1 (0.631)	3 (0.750)	0.682
Patient care	1 (0.166)	1/3 (0.210)	1 (0.250)	0.208

Table 5: Pairwise comparison matrix of the teamwork subfactors with respect to the goal

The teamwork subfactors	Surgical skills	Nonsurgical skills	Anesthesia skills	Nursing skill	Cumulative weight
Surgical skills	1 (0.387)	3 (0.375)	1 (0.387)	4 (0.400)	0.387
Nonsurgical skills	1/3 (0.129)	1 (0.125)	1/3 (0.129)	1 (0.100)	0.120
Anesthesia skills	1 (0.387)	3 (0.375)	1 (0.387)	4 (0.400)	0.387
Nursing skill	1/4 (0.097)	1 (0.125)	1/4 (0.097)	1 (0.100)	0.104

Table 6: Pairwise comparison matrix of nursing skills, surgical skills, and surgical skills subfactors with respect to the goal

Subfactor	Items				Cumulative weight
Nursing skills subfactors	**Time**	**Evaluation rating scale**	**Supply-chain management**	**Patient care**	
Time	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Supply-chain management	3 (0.333)	1 (0.384)	3 (0.333)	1 (0.400)	0.362
Care for equipment	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Patient care	4 (0.444)	1 (0.384)	4 (0.444)	1 (0.400)	0.412
Surgical skills subfactors	**Time**	**Evaluation rating scale**	**Care for equipment**	**Patient care**	
Time	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Evaluation rating scale	3 (0.333)	1 (0.384)	3 (0.333)	1 (0.400)	0.362
Care for equipment	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Patient care	4 (0.444)	1 (0.384)	4 (0.444)	1 (0.400)	0.412
Surgical skills subfactors	**Time**	**Therapeutic interventions**	**Monitoring**	**Patient care**	
Time	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Therapeutic interventions	3 (0.333)	1 (0.384)	3 (0.333)	1 (0.400)	0.362
Monitoring	1 (0.111)	1/3 (0.128)	1 (0.111)	1/4 (0.100)	0.112
Patient care	4 (0.444)	1 (0.384)	4 (0.444)	1 (0.400)	0.412

Table 7: Pairwise comparison matrix of nonsurgical skills subfactors with respect to the goal

Nonsurgical skills subfactors	Time	Evaluation rating scale	Care for equipment	Patient care	Cumulative weight
Situation awareness	1 (0.250)	1 (0.250)	1 (0.250)	1 (0.250)	0.250
Leadership	1 (0.250)	1 (0.250)	1 (0.250)	1 (0.250)	0.250
Communication and teamwork	1 (0.250)	1 (0.250)	1 (0.250)	1 (0.250)	0.250
Decision-making attitude of staff	1 (0.250)	1 (0.250)	1 (0.250)	1 (0.250)	0.250

single overall ranking by rating the best alternative in each of the BOCR on strategic factor or subfactor that an individual or a government uses to decide whether or not to implement one or the other of the numerous decisions that they face.

Ritrovato *et al*. compared the core model with integrating the multicriteria decision-making analysis using the AHP supplies a more timely as well as contextualized evidence, making it possible to obtain data that are more relevant and easier to interpret, and therefore more useful for decision makers to make investment choices with greater awareness.[13,14]

CONCLUSION AND RECOMMENDATION

The productivity in the OR do not depend only on the hospital, patient or the teamwork skill factors (they are either objective or subjective), so it is not easy to be measure because the complexity of what we measure and the interaction between them. The productivity needs a calculation method, and AHP has a sound mathematical basis and its application is user-friendly.

Hence, AHP is a valuable tool to design a model to elect the cumulative productivity and the productivity percentage and to make a decision in OT. It could be used to compare it with another or with the standard one. Moreover, it could enable us to identify the deficiencies in the specific areas.

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Conflicts of interest

There are no conflicts of interest.

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