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USAGE OF ANALYTIC HIERARCHY PROCESS IN MEDICAL EQUIPMENT PURCHASING DECISIONS: A UNIVERSITY HOSPITAL CASE

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ABSTRACT

For acquiring the advantages of high technologies managers of health sector institutions occasionally must make important investment decisions. The most rational and maximum benefit must be required from these investments. In managing the hospitals which are financed by the government chiefly, decisions related to purchasing of the medical equipments convert into complex decision problems which require consideration of a good many criteria (financial criteria, medical benefits, other benefits, requirements, etc.). Purchased equipments will be used not only for taking the best yield from the existing resources, but also for different aims of following and applying the improved technologies and scientific techniques, and increasing the service quality.

In this study, medical equipment purchasing decision stages applied in a university hospital have been examined, and priorities of the medical equipments which are planned to be purchased have been determined with the help of Analytic Hierarchy Process which is one of the multicriteria decision making techniques.

Key Words: Purchasing decisions, medical equipment purchasing, analytic hierarchy process (AHP)

ÖZ

Birçok alanda olduğu gibi sağlık alanında da gelişen teknolojiyi yakalayabilmek için yatırımların yapılması zorunludur. Söz konusu bu yatırımların, rasyonel ve maksimum faydayı sağlayacak şekilde yapılması gerekmektedir. Büyük ölçüde devlet tarafından finanse edilen sağlık hizmetlerinin yürütüldüğü hastanelerde, mevcut kaynakların etkin kullanımının yanı sıra gelişen teknolojik ve bilimsel teknikleri izlemek, hizmet kalitesini arttırmak gibi farklı amaçlar için kullanılacak tıbbi cihazların satın alınmasıyla ilgili kararlar, çok sayıda kriterin (finansal, tıbbi fayda-katkı, diğer faydalar, gereklilikler gibi) dikkate alınmasını gerektiren karmaşık bir karar problemine dönüşmektedir.

Bu çalışmada, bir üniversite hastanesinde tıbbi cihaz satın alma karar süreci, çok kriterli karar verme tekniklerinden AHP kullanılarak incelenmiş; satın almaya konu olan tıbbi cihazların çok sayıdaki nitel ve nicel kritere göre öncelikleri AHP ile belirlenmiştir.

Anahtar Kelimeler: Satın alma kararları, Tıbbi cihaz, Analitik Hiyerarşi süreci (AHP)

INTRODUCTION

Hard economical conditions in which health companies operate force the managers of these companies to use various scientific methods and new technological equipments for providing more productive usage of their resources. Especially the situations such as increasing costs, limited budget, lasting inflation require development of planning and supervisory activities.

Health investments have always been important problems to be solved for the governments of the developing countries, and they like it or not, especially increasing international competitive pressures and health care reforms have increased their importance. Public hospitals are the foundations which are directly effected from these circumstances. And the allocative inefficiency is a fundamental flaw in the public hospitals of the developing countries. The inefficiencies drain the limited public resources allotted for health care (Withanachchi, et al., 2006).

Public hospitals are also the organizations who work with limited resources. The more rationally they manage their supplies, the less negative results of deficiencies or corruptions exist. Usage of medical technologies mostly requires considerable amounts of resources so they have to be used in temperate levels and where they are needed. Consequently public hospitals have to choose appropriate investment proposals among the alternatives, arrange them in order according to their importance degrees, and cease from some of them.

In many Turkish hospitals, there is not any definite standard to consider in the determination of medical equipment needs and no feasibility report based on cost-benefit analyses is being prepared. It is clear that if equipment purchasement is realized without making an evaluation of requirements and getting cooperation of the hospital management, then the capacities and the qualities of the purchased ones could be so far away from meeting the hospitals real needs.

To make the best choice among the alternative usage fields for the resources and to allocate the resources optimally, public hospital managers need to make decisions by evaluating investment proposals not only financially but also in the frame of future benefits. Therefore they have to make related decisions by considering a great number of qualitative and/or quantitative criteria. In other words equipment purchasement decision making process is a multi criteria decision making process for a hospital management team.

Rapidly developing medical technologies sometimes require great amounts of funds to be applied. And the highness of these technological investments, certain limits of their budgets and revolving funds obstruct public hospitals to realize all the technological investments they need to make. For this reason it is very important to make market research, service type analyses and cost-benefit analyses.

Especially in public hospitals it is not enough to evaluate an investment (i.e. a medical equipment purchasement) proposal financially because of these hospitals' functional properties. Financial evaluations must be integrated with the analyses data of medical and functional benefits such as contributions to nursing, diagnosis and treatment, capacity and economic life, number and the scope of the services to be supported.

First of all, the benefit – the result of investment project – need to be defined qualitatively and quantitatively. Quantitative results reveal the volume of the services that the project will provide and how many people will have the chance to take benefits from them. And the qualitative results reveal the structure of these services, characteristics of their beneficiaries (diagnosis, diagnosis and treatment, diagnosis and assistance to treatment, treatment, etc.) and how much benefit they will take.

Naturally, to consider the qualitative and quantitative criteria in appropriate categories can help the researchers making analyses. And with this categorization evaluation process of hospital investments comes to a state of complex and multi-criteria decision making problem. And Analytic Hierarchy Process which has the ability to determine the priorities and importance degrees of criteria, can be applied for the solution of such a problem.

1. ANALYTIC HIERARCHY PROCESS

Analytic Hierarchy Process (AHP), a multi-criteria evaluation procedure incorporating inconsistency and mimicking the human decision-making process (Saaty, 1980) is employed in our study's model. Since Saaty first developed this process in 1970s, AHP has been widely applied to complex technological, economical, and socio-political problems.

AHP is used to solve complex decision-making problems in different areas (Aras, et al., 2004) such as planning (Kwak and Lee, 2002; Radash and Kwak, 1998), resources evaluation (Jaber and Mohsen, 2001), measuring performance (Frei and Harker, 1998), allocating resources (Alphonce, 1997), choosing the best policy after finding a set of alternatives (Poh and Ang, 1999), setting priorities (Schniederjans and Wilson, 1991).

AHP addresses how to determine the relative importance of a set of activities in a multi-criteria decision making problem. The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria. AHP structures the decision problem in levels which correspond to one's understanding of the situation: goals, criteria, sub-criteria, and alternatives. By breaking the problem into levels, the decision-maker can focus on smaller sets of decisions. The pertinent data is derived by using a set of pair-wise comparisons. These comparisons are used to obtain the importance weights of the decision criteria, and the relative performance measurements of the alternatives in terms of each individual decision criteria.

AHP has two basic tasks: formulating and solving problem as a hierarchy, and eliciting judgments in the form of pair-wise comparisons. The elicitation of priorities for a given set of alternatives under a given criterion involves the completion of a *nxn matrix*, where *n* is the number of alternatives under consideration. Since the comparisons are assumed to be reciprocal, one needs to answer only $n(n-1)/2$ of the comparisons. In pair-wise comparisons, Saaty's judgment scale (2001) which takes integer values between 1 and 9, is used. The valuation scales in the pair-wise comparisons are those, where 1 is equals importance, 3 equals moderate importance, 5 equals strong importance, 7 equals very strong or demonstrated importance, and finally 9 equals extreme importance. Even numbered values fall in between importance levels.

In the hierarchy, the matrix of the upper nodes corresponds to level zero (the comparison of criteria) while the others are corresponding level one. And the construction of the square reciprocal matrices is performed by asking the decision maker to compare element i with element j, the value a_{ij}, with respect to a particular criteria or objective.

The use of such pair-wise comparisons to collect data from the decision maker offers significant advantages. AHP allows the decision maker to focus on the comparison of just two objects, which makes the observation as free as possible from extraneous influences. Additionally, pair-wise comparisons generate meaningful information about the decision problem, improving consistency in the decision-making process, especially if the process involves group decision making (Badri, 2001).

AHP is applicable to individual and group decision settings. In a group decision making, evaluation is carried out by a group of experts, who will be responsible for establishing and assessing weights to criteria. In a group decision making, evaluation is carried out by a group of experts, who will be responsible for establishing and assessing weights to criteria. There are three basic approaches that a group can use to assess weights: (i) consensus; (ii) vote or compromise; (iii) geometric mean of the individual judgments. In the first approach (consensus), the group of decision makers is required to reach a consensus on each judgment. If the group is unable to reach a consensus, then a vote or compromise is used in the second approach to set the judgments values. If a consensus cannot be achieved and the group is unwilling to vote or compromise, then a geometric mean of the individuals' judgments can be calculated. Geometric mean is the most common approach used in AHP with group decision making (Melon et al., 2006; Lai et al., 2002).

2. APPLICATION OF AHP IN MEDICAL INVESTMENT DECISION PROCESS

Since AHP is a scoring method that was designed to visually structure a complex decision problem into a simple hierarchy and then develop priorities within each level of the hierarchy by carrying out simple pair-wise comparisons of the relative importances of decision criteria, attributes, and alternatives (Harker, 1989; Vargas, 1990) it has a great potential to be used in health investment decisions, too. And when the literature is scrutinized, usage of AHP in different decision making problems of the health sector seems to be increasing rapidly.

Min, Amitava and Oswald made one of the notable researches for health care decisions by considering qualitative measurements (Min, et al., 1997). They proposed an AHP that can help medical clinics formulate viable service improvement strategies in the increasingly competitive health care industry. Their AHP model was formed with two main criteria (technical quality and functional quality) and three sub-criteria (clinic management, medical equipment and facilities, and patient satisfaction). To develop a meaningful set of guidelines for competitive benchmarking, and determine comparative measures of health care quality of medical clinics, they constituted the process with the data from expert opinions, self reports of the clinics included and a 22-item questionnaire patient survey.

Singpurwalla, Forman and Zalkind (1999) formed a "shared decision-making model" that both patients and their doctors agree is a significant improvement over the traditional system in which a doctor served as the primary decision maker. Their paper reported the results of an experimental use of AHP as a tool to facilitate shared decision making for two specific health care populations. In the AHP model they formed for cosmetic eyelid surgery, they included five criteria and two alternatives while forming the other AHP model for estrogen replacement therapy with seven criteria and three alternatives. After using AHP, the majority of both patients and physicians agreed that this technique improved physician-patient communication, thus greatly assisting shared health care decisions.

In another study made for assisting the individual hospitals or health system in its microeconomic health technology assessment, the AHP was used to support and document the evolution of the multidisciplinary and interdisciplinary process of selecting neonatal ventilators for a new women's health hospital (Sloane, et al., 2003). And the results of the AHP model they formed by using a ratings approach and a large number of (46) bottom-level criteria with the help of Expert Choise software program demonstrated the AHP's ability to facilitate an understanding of the underlying criteria and priorities, and to successfully support the hospital's purchasing negotiation.

AHP model was also suggested for the whole hospital investment decisions recently. Study of Wu, Lin and Chen (2006) presented an AHP model with six criteria each of which had three sub-criteria for the determination of optimal hospital location selection. Besides a literature review and interviews with experts, they adopted the modified Delphi method, the AHP and the sensitivity analysis to develop an evaluation method for selecting the optimal location of a regional hospital in Taiwan. So they provided a significant reference for hospital administrators and academics in establishing a standardized means of selecting the optimal location for new medical care facilities.

3. A CASE STUDY: APPLICATION OF AHP IN THE SELECTION OF MEDICAL EQUIPMENTS

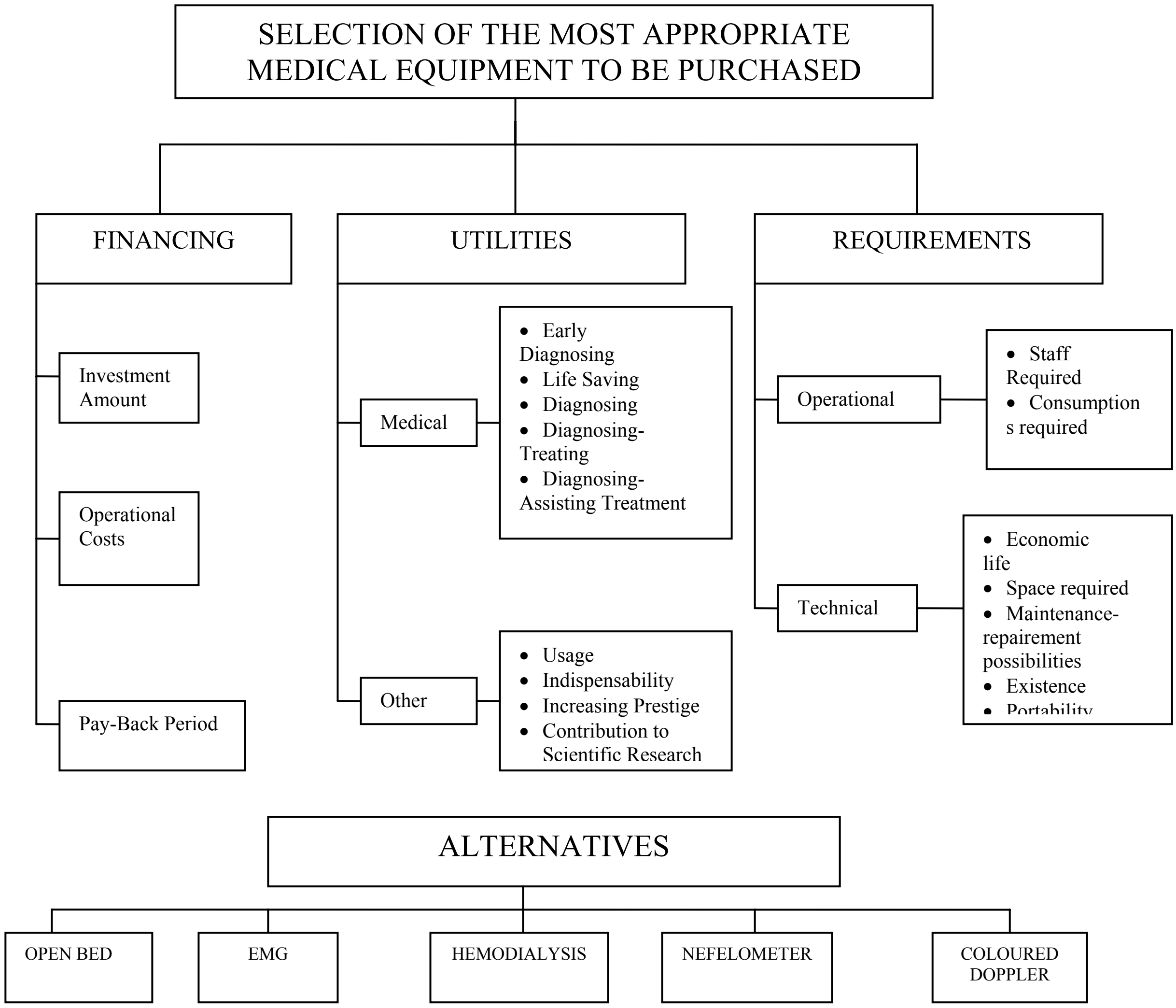
Selection process of a medical equipment to be purchased among five alternatives for pediatrics department of a public university hospital – Eskisehir Osmangazi Hospital – has been realized by using AHP in this research. The alternatives have been evaluated according to different criteria of which weights were determined with the help of AHP.

The hierarchical structure was formed by a purchasement committee with four members: hospital purchasement director, purchasement commission chairman, accountant and pediatrics department chairman. Members of the committee made group-decisions by reconciling. The priority values of the purchasement alternatives were determined by making bilateral comparisons in the frame of AHP hierarchy.

Firstly, the participants of the purchasement commitee were called to a meeting and their criterion suggestions for the model were taken. Then these suggestions were evaluated and designed as AHP criteria and *"Medical Equipment Selection Model" (MESM)* given in *Figure 1* was established with these contributions. MESM was structured in a hierarchy of five levels: The top level presenting the goal of the analysis (selection of the most appropriate medical equipment to be purchased); the second level including the main criteria (financing, utilities and requirements) which are usually too complex; the third level that is formed by the subcriteria (i.e. investment amount, medical utilities, operational requirements); the fourth level in which sub-subcriteria (i.e. early diagnosing, life saving, personnel requirements, portability) exist; and the last level defining the possible alternatives (open bed, electromiography, hemodialysis, nefelometer, coloured doppler). This establishment makes it possible to focus on each and every part of such a complex problem, and to derive priorities from simple comparisons for decision makers.

Financing which consists of the resources that can be used, payment conditions, date of maturity, prices is an important issue in purchasement of anything. The sub-criteria of financial criteria are return, operation costs and pay-back period. In selection of the medical equipments to be purchased, purchasement committee firstly considers the financial properties of these equipments such as return amount, pay-back period and operation costs. But these financial properties are also related with some other intangible properties of these equipments: medical and other benefits, utilities, demand, portability. So the committee considers the second criteria which has two sub-criteria, medical and other utilities.

Figure 1. Hierarchy of MESM



The portion of public hospitals has got to be very large in developing countries so that these hospitals' functional properties are rendering financial evaluations insufficient for purchasement decisions. Financial evaluation must be integrated with caring patient and services or the utilities that any investment would yield. First of all the project's utilities need to be defined in both qualitative and quantitative dimensions. On account of this requirement, utilities criterion was designed to have two sub-criteria – medical and other utilities – in the evaluation part of this study.

While taking early diagnosing, life saving, diagnosing, diagnosing-treating and diagnosing-assisting treatment as sub-sub-criteria of medical utilities sub-criteria, usage, indispensability, increasing prestige and contribution to scientific research were accepted as the sub-sub-criteria of other utilities sub-criteria.

The third main criterion of MESM is the requirements criterion including operational and technical requirements sub-criteria. There seems to be two sub-sub-criteria in the content of the operational requirements sub-criteria: staff required and consumptions required. Every medical equipment needs a 'user' depending on its usage frequency, structure and function. And this need makes staff factor's effect on productivity much more important. The user's lack of fundamental and practical knowledge about the equipment would influence productivity negatively. Consequently, the existence of the required staff is also an important criterion in purchasement of a medical equipment.

Another sub-criterion of the requirements criterion is related with technical requirements such as economic life, space required, maintenance-repairement possibilities, possession of the same equipment before and portability sub-sub-criteria. For all of the medical equipments to be used in hospitals long economic life is a desired feature. The amounts and qualities of the consumptions which would be required while using the equipment are also other criteria that must be considered.

In developing countries it is observed that maintenance and repairement services of medical equipments can be insufficient in many cases. And this criterion has a direct effect on the productivity of the equipments in question. The portability property of the equipment is considered for the possibility that other services can also use it in their activities. Whether the equipment has been possessed before or not and the size of the space required for assembling it are accepted as the other significant sub-sub-criteria to take place in MESM hierarchy.

Once the model is built, the decision makers who are participants in purchasement committee evaluate the elements by making pair-wise comparisons. In our study, decision makers made a consensus evaluation, rather than evaluating individually. A pair-wise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (as a single value that decision makers reach a reconciliation on) with respect to an element in the level above. Pair-wise comparisons are based on upper level control criteria. In establishing an AHP model, weights of main criteria must be determined first. For this reason, the decision makers make their pair-wise comparisons about main criteria and notify their judgments according to the overall goal.

The decision makers' data based on pair-wise comparison matrices were designed by Expert Choice in this study. Then relative weights for the alternatives were calculated with respect to the main criteria and their sub-criteria. In the result of these calculations 23 pair-wise comparison matrices were obtained from reconciled judgments of the purchasement committee for the whole model. Pair-wise comparison values of the study can be seen in *Table 1*.

Table 1. Pair-wise comparison values for the main criteria of Medical Equipment Selection (MES) problem

	Financing	***Utilities***	***Requirements***
Financing	1	1/3	3
Utilities	3	1	5
Requirements	1/3	1/5	1

In order to determine the relative importance value of the row variable compared to the column variable found in pair-wise comparison table prepared for the main criteria, a face to face questionnaire was applied to the purchasement committee in a meeting. The committee members answered questions such as "Which criterion is more important and how much important in selection of the most appropriate medical equipment to be purchased? Financial criterion or utilities criterion?" during this application.

In *Table 1*, a_{ij} *(where i=1 and j=3)* is 3 and denotes that financial properties are three times more important than the requirements of the medical equipments to be purchased for the pediatrics department. Or in other words, requirements criterion has just 1/3 of the importance degree of the financing criterion.

The other pair-wise comparison matrices of the sub-criteria and sub-sub-criteria were interpreted in the same way. It is possible to see the pair-wise comparison matrices of the sub-criteria of utilities main criterion in *Table 2*, and the pair-wise comparison matrices of sub-sub-criteria of the same main criterion's medical utilities sub-criteria. Also the following table (*Table 3*) displays the pair-wise comparison values for the sub-sub-criteria of medical utilities sub-criterion.

Table 2. Pair-wise comparison values for the sub-criteria of utilities main criterion in MES problem

	Medical Utilities	***Other Utilities***
Medical Utilities	1	1/9
Other Utilities	9	1

Table 3. Pair-wise comparison values for the sub-sub-criteria of medical utilities sub-criterion in MES problem

	Early Diagnosing	*Life Saving*	*Diagnosing*	*Diagnosing-Treating*	*Diagnosing-Assisting Treatment*
Early Diagnosing	1	1/9	5	3	3
Life Saving	9	1	9	9	9
Diagnosing	1/5	1/9	1	1/3	1/3
Diagnosing-Treating	1/3	1/9	3	1	1
Diagnosing-Assisting Treatment	1/3	1/9	3	1	1

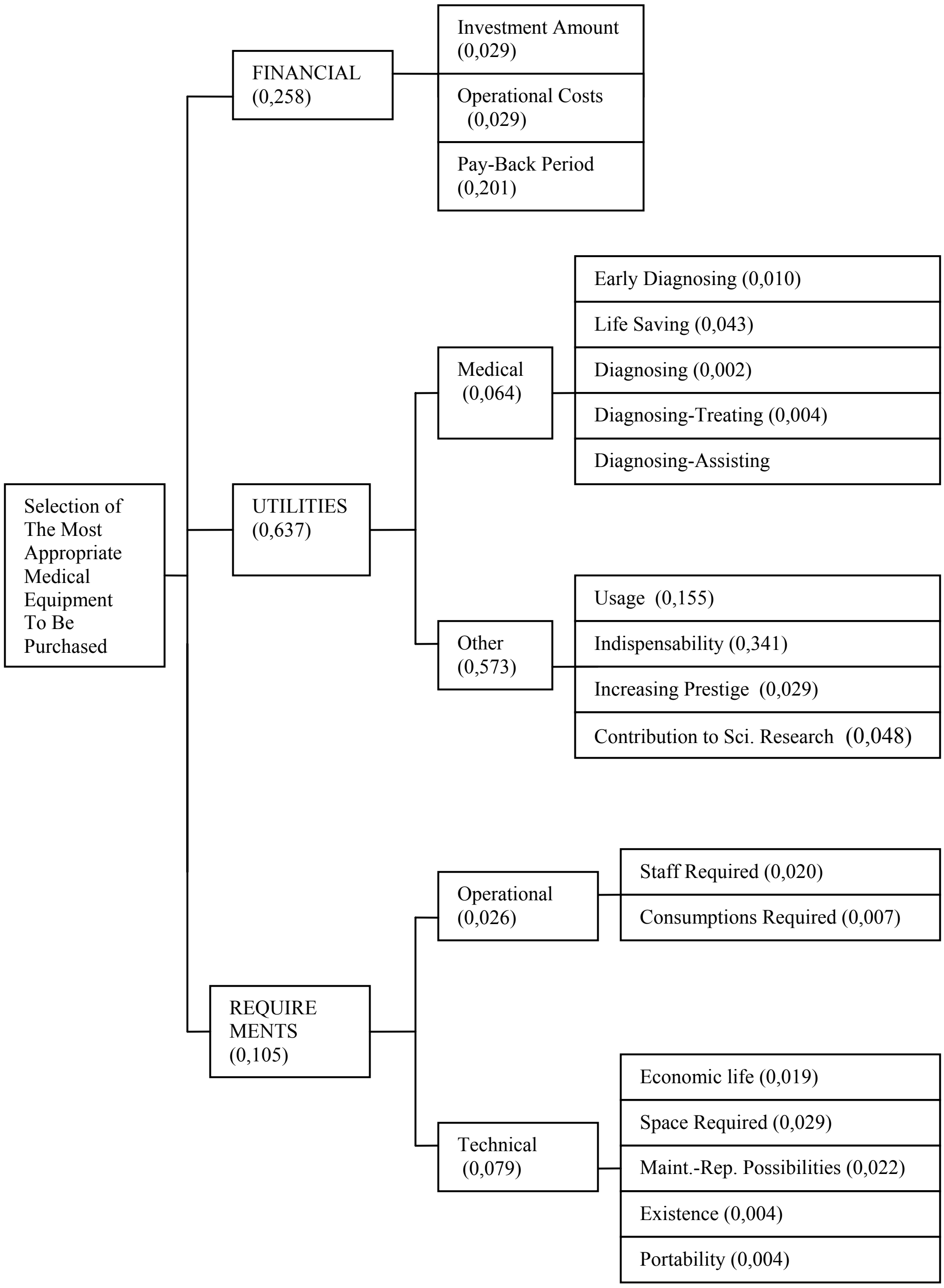
After the completion of the comparisons, the priorities were calculated and a measure of consistency of judgment was determined with the help of Expert Choice 2000. Generally the consistency ratio should be less than 0,10 (Saaty, 1995). By considering this supposition the priorities and consistency ratio were determined with respect to each of three criteria. And importance degrees (relative weights) calculated for the main criteria and their sub-criteria are given in *Figure 2*.

The committee notified that utilities criterion is the most important main criterion with 63,7 % and financial criterion is the second important main criterion with 25,8 %. Requirements criterion seems to be the most unimportant main criterion with 10,5 %. The most important sub-criterion of utilities main criterion is the others sub-criterion (57,3 %) under which the most important sub-sub-criterion is the indispensability (34,1 %).

After inputing the judgments of the decision makers to Expert Choice 2000, a consistency rate was determined for each matrix. And it has been seen that all of these consistency rates were smaller than 0,10. The consistency rate of MES problem's final matrix was found to be 0,06 which means that the decision makers have made consistent judgments.

The next step of the research was to synthesize the derived priorities based on the decision makers' judgments. Synthesis means adding up the global weights of the common nodes at the bottom level of the hierarchy so as to generate a composite priority for an alternative across all criteria. And the results of this process have the ability to indicate the overall priorities of the alternatives.

Figure 2: Relative weights of the main criteria in MES Problem



As it can be seen in Table 4; relatively the most important alternative medical equipment to be purhased for the pediatrics department of Eskisehir Osmangazi Hospital is coloured doppler with 30 %. Open bed and hemodialysis follows it with 27,2 % and 23,4 % respectively. Thus and so the decision makers of the pediatrics department prefer to purchase coloured doppler when they evaluate the alternatives with criteria included in this research. They secondly prefer open bed, thirdly hemodialysis, fourthly EMG and finally nefelometer.

Table 4. The results of AHP analysis for MES problem

Alternatives	*Relative Importance Value*	*Importance Order*
Open Bed	0,272	2
EMG	0,097	4
Hemodialysis	0,234	3
Nefelometer	0,096	5
Coloured Doppler	0,300	1

4. CONCLUSION

Like the other enterprises hospitals also may not have the potential to finance all the investment projects they need to realize at the same time. For it is not possible financially to apply all the beneficial investment projects in general, it would be rational to make an evaluation of the alternatives and rank them. Firstly the portion of the first preferred investment project is allocated, then the second one's potion follows it. If there is still financial source left, the third investment project will become a current issue.

The concept of cost comes on the scene because of the alternative usage of the inadequate sources. In respect of this, a source's cost can be defined as the benefit it would create in the case of its utilization in its best alternative usage. Thus it important to note that the cost of the health service programs includes not only the monetary expenditures made, but also the renounced benefits. The results of our research also put forth this fact for consideration: When the purchasement committee of university hospital's pediatrics department evaluate the alternative medical equipments to be purchased, the committee members have given the highest importance to utilities main criterion. Also the truth that pay-back period sub-criterion of the financial crtierion has the greatest importance strengthens this suggestion. The decision makers generally think that the funds which would be yielded by preferring the equipment with the shortest pay-back period can rapidly be transferred to other beneficial investments again.

It has been found that indispensability sub-sub-criterion took the greatest importance when the utilities main criterion was evaluated individually. The reason of it is thought to be the direct relationship between the health sector and human life.

The decision makers have assigned the greatest importance value to indispensability property of the equipment within the other utilities criterion (indispensability with 34,1 %).

So the possession of the same equipment before seems to have the least importance in the MESM hierarchy (existence 0,4 %).

The lowest importance degree (10,5 %) that purchasement committee assigned to requirements main criterion indicates health sector managers can easily decide purchasing a medical equipment without making feasibility if they believe that this equipment is beneficial and above all they have enough funds. So it can be said that most of the medical equipment purchasement decisions are made and applied with populist approach. Productivity of the a medical equipment is related with the existence of the qualified staff who can use it successfully, efficiency of its consumptions, convenience of the maintenance and repairement possibilities, and the length of it economic life. So especially in developing countries such as Turkey health sector managers do not seem to consider productivity too much important.

Lots of mistakes can be made in determination of medical equipment needs of the public hospitals and big sums can be squandered for purchasing unnecessary ones. Lack of objective standards for the medical equipments to be kept by the hospitals according to their specialty fields, physical capacities and geographical locations and the fact that most of the feasibility reports based on cost-benefit analyses are not prepared properly pave the way for these mistakes. Whereas hospital managers must keep their hospitals' conditions of technological infrastructure, staff number and qualification, and the equipments' technical properties, cost-benefit characteristics and maintenance-repairement circumstances in their minds while evaluating their needs and resources.

Public hospitals established in the the same settlements may have the same medical equipments individually for not applying well-planned rationalistic equipment purchasement policies. This results most of these equipments with the same qualifications to be operated with low capacity, and furthermore procurement of the needed other equipments to be postponed or impeded.

Our study presents a hierarchical decision structure which has an ability to evaluate many different criteria to be used in medical equipment purchasement decision processes of hospital managers. And it must be noted that combination of the priorities determined with AHP and target programming will help those concerned to reach different targets for designing different purchasement decision processes simultaneously.

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