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Research Article

SUPPLIER SELECTION WITH AHP AND 0-1 GOAL PROGRAMMING: AN APPLICATION IN HEALTHCARE INDUSTRY

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ABSTRACT
In order for health institutions to continue their activities, the goods and services they need must be supplied at the right time, in the right amount, at the right quality, at an affordable price and from the right source. This is possible with an effective supply chain management and selection of the right supplier. Supplier selection studies in the health sector are almost nonexistent, therefore, it was wanted to contribute to the literature by studying in this sector. In this study, it was aimed to work with the right suppliers to ensure that a dental health center provides critical medical supplies. First of all, the products of vital importance were determined by ABC (Always, Better Control)-VED (Vital, Essential, Desirable) matrix analysis and a supplier list was created. The best suppliers were selected with the Zero-One Goal Programming method based on AHP priorities, one of the multi-criteria decision making methods, by determining the criteria suitable for the sector.It is thought that this model will contribute significantly to the literature and will save time in supplier selection studies in the health sector.

Keywords: *Supplier Selection, Healthcare Industry, Multiple Criteria Decision Making (MCDM), Goal Programming*

1. INTRODUCTION

In order for health institutions to continue their activities, the goods and services they need must be supplied at the right time, in the right amount, at the right quality, at an affordable price and from the right source. This is possible with an effective supply chain management (SCM). For this reason, more emphasis is placed on supply chain management in today's healthcare industry. SCM in hospitals provides elimination of all activities, movements and processes, minimizing errors, and increasing the efficiency of the process between the inputs and outputs.

The procurement activities of the health institution, where human health and even life is in question, should be carried out without interruption, because there is no compensation for the fault of logistics activities in health institutions. Any disruption that may be experienced can cost human life. Therefore, suppliers should be selected very carefully in healthcare institutions (Aptel & Pourjalali 2001: 68).

One of the most important components in SCM is supplier selection (Tookey and Thiruchelvam, 2011). Because choosing an appropriate supplier reduces purchasing costs, improves profits, reduces product delivery time, increases customer satisfaction and strengthens competitiveness (Frej et al., 2017).

Various supplier selection methods as observed in the literature have been classified in main categories and sub-categories. Table 1 summarizes the supplier selection methods (Taherdoost and Brard, 2019). Among the supplier selection studies, which have a very wide area in the literature, only the literature review of Analytic Hierarchy Process (AHP) and Goal Programming (GP) method are used together are presented below;

Dağdeviren and Eren (2001) applied AHP and zero one goal programming (ZOGP) method together in order to perform supplier selection in their studies.

Wang et al. (2004) proposed an integrated AHP and preemptive goal programming (PGP) model in their studies.

Perçin (2006) applied an integrated AHP and GP model for supplier selection. The model was to determine the optimal order quantity from the most appropriate supplier while considering the capacities of potential suppliers.

Mızrak et al. (2008) applied a goal programming (GP) approach with AHP priorities was utilized to solve the problem of materials' supplier selection for a company operating in textile industry.

Sivrikaya et al. (2015) presented an integrated evaluation approach for decision support enabling effective supplier selection and ordering processes in textile industry. The integrated evaluation method in their studies includes two phases that consist of fuzzy AHP and goal programming approaches.

Ünal et al. (2019) proposed an approach for integrated Fuzzy Analytical Hierarchy Process (FAHP) and GP method for supplier selection in a hotel business in Antalya.

As a result of the literature research, it was seen that there are very few studies in which ZOGP and AHP were used together in supplier selection. Integrated AHP and ZOGP method has been proposed because it is thought to contribute to the literature.

In this study, an application has been made for the selection of suppliers of high value and vital medical supplies to be purchased by the oral health center. ABC (Always Better Control) and VED (Vital, Essential, Desirable) analysis methods were combined with the matrix created to determine the vital and high value product group. There are limited studies on ABC and VED matrix analysis in the health sector. Some of the recent studies are mentioned below;

Nigah et al. (2010), Yeşilyurt and Bayhan (2015), Karagöz and Yıldız (2015), Fitriana et al. (2017), Guimarães et al. (2019) applied the ABC-VED matrix analysis method for inventory management in the health sector recently.

Table 1. Classification of Supplier Selection Methods (source Taherdoost and Brard, 2019)

Supplier Selection Methods	
Statistical/Probabilistic (Cluster Analysis)	Fuzzy Set Theory
Multi Attribute Decision Making (Categorical Method)	AHP ANP (Analytic Network Process) TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) MAUT (Multi-Attribute Utility Theory) Outranking Methods: ELECTRE (Elimination and Choice Expressing Reality) PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations)
Methods Based on Costs	ABC (Activity Based Costing) TCO (Total Cost of Ownership)
Mathematical Programming	Linear Programming MOLP (Multi-Objective Linear Programming) Goal Programming
Artificial Intelligence	CBR (Case-Based Reasoning) ANN (Artificial Neural Network)

A model has been developed by integrating the priorities of AHP, one of the MCDM methods, into a zero-one goal programming model for selecting the best supplier to provide this product group. The zero-one goal programming model is a type of GP method, in which the decision variable values can either result in one or zero. The advantage of ZOGP is that the model can help the decision makers to select an optimal allocation solution for limited resources.

In Chapter 2, the literature review for supplier selection in the healthcare sector is examined. In Chapter 3, the methodology of the study is given and the methods used are explained in detail. Chapter 4 includes the application section. Finally, Chapter 5 includes the results of the study and the findings obtained.

2. SUPPLY CHAIN MANAGEMENT IN HEALTCARE INDUSTRY

Today, healthcare industry grows rapidly. Therefore healthcare delivery systems has become a major priority in the field. (Fashoto et al., 2016). The healthcare sector supply chain is characterized by its complexity, which results on the one hand from the multitude of different supplies used by the institutions.

A major characteristic of the healthcare sector supply chain is the simultaneous presence of two chains: one external and the other internal (Rivard-Royer et al.,2002). (see Figure 1).

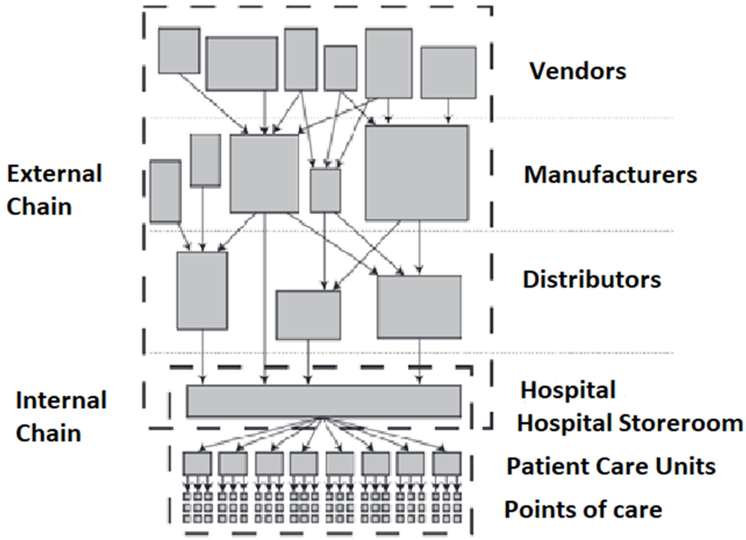

Figure 1. Supply Chain in Healtcare Sector (Source: Rivard-Royer, Landry and Beaulieu, 2002)

In the health sector supply chain structure, producers are divided into two as primary and secondary producers. Primary manufacture involves the creation of the active ingredient contained within the medication. Secondary Production converted the active ingredient into usable products. The final products are distributed to healthcare organizations by distributors, wholesalers and manufacturers and there is a backward flow from them. (Kritchanchai, 2014). Figure 2 summarizes the health sector supply chain structure.

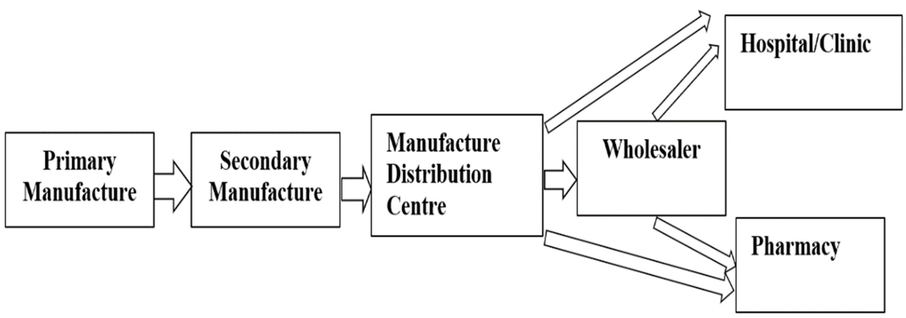

Figure 2. Healthcare Supply Chain Structure (Source: Mustaffa and Potter, 2009)

2.1. Literature Review Of Supplier Selection Studies And The Criteria Used In The Health Sector

Supplier selection problem is described as a complex multi-criteria decision problem that can contain many quantitative and qualitative variables together.

Therefore, the systematic evaluation of such a problem is important in terms of producing correct solutions. One of the first studies on supplier selection was conducted by Dickson (1966) in America. Dickson sent a questionnaire to 273 selected people from the purchasing agent and the executives of the National Association of Purchasing. Here, 23 criteria were used and the most important criteria were determined as product quality, on-time delivery and warranty policy (Dickson, 1966: 16-17).

It is seen that various criteria are used in the studies on the supplier selection problem in the literature. In this study, the criteria used in the health sector were examined. The literature review in this field is given in Table 2.

Kirytopoulos, Leopoulos, and Voulgaridou (2008) presented a comprehensive method for evaluating and selecting proposals in pharmaceutical industry clusters in their work. The best supplier was selected in line with the criteria determined by the analytical network process (ANP).

Enyinda, Dunu, and Bell-Hanyes (2010) made use of the analytical hierarchy process (AHP) model in their articles. They developed the Expert Selection Software by conducting a case study to solve the supplier selection process problem in a pharmaceutical company.

Vankatesh et al. (2015) addressed the problem of selecting suppliers for blood bag purchase, which is critical in the health sector. They made their supplier selection with TOPSIS method in line with the criteria determined by the literature review and expert opinions.

Fashoto, Akimuwesi, Owalabi, and Adelekan (2016) used analytical hierarchy process (AHP) and artificial neural network (ANN) in their studies. They developed a decision support model for evaluating and selecting the healthcare providers of tertiary institutions.

Bahadori et al. (2017) used a combination of ANN and fuzzy VIKOR in their study. They have developed a model for selecting the best supplier in the hospital. The results obtained from the model showed that the most effective factor in supplier selection is 'quality'.

Forghani et al. (2018) worked in a multi-supplier pharmaceutical company.In order to improve supplier selection, they first used the principal component analysis (PCA) method to reduce the number of supplier selection criteria. Then, they obtained the importance value of each supplier for each product using the method based on the concept of Z-numbers called Z-TOPSIS. Finally, they used these values as input in mixed integer linear programming (MILP). With the developed model, they determined the suppliers and the amount of products supplied from the relevant suppliers.

Manivel and Ranganathan (2019) analyzed the Supplier Selection process in line with the interviews with the pharmacy manager. They have applied the combination of Fuzzy Analytical Hierarchy Process (FAHP) and Fuzzy Ideal Solution methods (FTOPSIS) for the selection of suppliers.

Table 2. Supplier Selection Criteria in Healthcare Industry

Supplier Selection Criteria	
Authors	**Criteria**
Kirytopoulos, Leopoulos and Voulgaridou (2008)	Price, Quality, Service, Supplier’s Profile, Risk
Enyinda,Dunu ve Bell-Hanyes (2010)	Quality, Cost, Compliance with Legislation, Service, Supplier Reliability, Risk Management, Supplier’s Profile, Green Purchasing
Venkatesh and diğ. (2015)	Purchasing Cost, Production Quality, Financial Status
Fashoto, Akimuwesi, Owalabi and Adelekan (2016)	Cost, Service, Risk, Quality, Delivery
Bahadori and et al. (2017)	Price, Quality, Delivery Time, Payment Terms, The Suppliers Background, Packaging and Transport Quality
Forghani, Sadjadi, Farhang ve Morhadam (2018)	Cost, Quality, Service, Delivery, Supplier Profile
Manivel and Ranganathan (2019)	Cost, Delivery, Service, Flexibility, Supplier Reliability
Doğan and Akbal (2019)	Price, Technical Competence, Service Quality, Repair Service and Guarantee Policy
Yazdani et al. (2020)	Offer Price, Supplier's Stock Capacity, Batch Volume, Flexibility, Technology and Quality

Doğan and Akbal (2019) discussed the selection of a medical company for a university hospital in their study and used the AHP method, which is one of the multi criteria decision making methods, to determine the most suitable supplier for both the patient and the hospital.

Yazdani, Torkayesh, Chatterjee (2020) conducted their studies in order to realize the sustainable supplier selection in a hospital in Spain. They determined the importance weights of alternative suppliers using the DEMATEL and BWM (Best Worst Method) method. The best supplier; They determined it using the EDAS (Evaluation According to Average Solution Distance) method.

3. METODOLOGY

In this study, ABC-VED matrix analysis method was used to determine critical product groups. Then these products are grouped according to their application areas. Later, alternative suppliers were determined for these product groups. Later, in order to determine the priority values of the suppliers, the AHP method was preferred because the interactions of the criteria with each other are not taken into account in the decision-making process and because it can compare more than one quantitative and qualitative criteria at the same time. In solving the problem, 0-1 Goal Programming method was preferred because it realizes many goals at the same time and offers an effective solution method.

Figures or Tables should be sized the whole width of a column, as shown in Table 1 or Fig. 1 (Figs. 1 and/to n) in the present example, or the whole width over two columns. Do not place any text besides the figures or tables. Do not place them altogether at the end of manuscripts.

3.1. ABC Analysis

ABC analysis is defined to the inventory control model that separates the products in inventory according to the number of use and cost value in a year. The principle that forms the basis of the analysis was first put forward by H. Ford Dickie, one of the employees of General Electric. This method, which was developed in 1896 by an Italian economist named Vilfredo Pareto, is also known as the pareto rule (Demiral 2013: 48).

The following steps are followed in classifying the stocks according to the ABC principle:

1. All inventory items are listed.
2. The investment made in these elements; It is calculated as (Unit price / cost) x Annual Demand.
3. Annual investment values are put in order from large to small.
4. The investment made to each element is calculated as what% of the total investment is.
5. The cumulative sums of the ratios in (4) are found.
6. By examining the cumulative percentages,

The elements that make up 70-80% of the investment are defined as A group, 20-25% as B group, and the remainder as C group (Yenersoy, 2011).

3.2. VED Analysis

Errors and lack of materials in hospital facilities can cause patient losses or disabilities. Therefore, sometimes the lack of a low cost material in hospitals can be of vital importance. Although the cost of the medical equipment used for vascular access is very low, its value for the patient is much greater. Lack of such materials may cause disruption or failure of treatments. Therefore, inventory control methods of hospital enterprises take into account not only cost but also vital importance (Karagöz and Yıldız 2015: 319).

While ABC method classifies inventories according to their cost; VED classifies medical supplies, especially drugs and consumables, according to the vital needs of the patient. (Kaptanoğlu, 2013: 32).

VED analysis classifies the inventory items in the pharmaceutical and medical supplies inventory list of hospital enterprises as vital (V) essential (E) and desirable (D). İnventory with critical importance for survival of patients are defined as V, inventory materials with lower critical importance than V are defined as E and inventory materials with the lowest usage requirement are defined as D group (Vaz, et al. 2008: 120).

3.3. ABC-VED Matrix Analysis

The ABC-VED matrix is a method that considers both the critical values and the economic and importance levels of drugs and medical supplies. It also categorizes the control of inventories according to priority (Pund et al., 2016: 469-470).

The ABC-VED matrix is formulated by cross-tabulating ABC and VED analysis. The combination obtained is classified into three groups (Vaz, et al., 2008: 120).After determining the groups to be checked and evaluated in the ABC-VED matrix, the materials in the V, E, D groups are ABC classified.

First, in the first group, all vital (V) inventory materials and A group inventory materials are handled. This group includes AV, BV, CV, AE and AD subclasses. Second, among the remaining inventory materials, all subclasses of essential (E) and B group are gathered into a group. Accordingly, in this second group there will be BE, BD and CE subclasses. Finally, the third category consists of the CD group (Gupta et al., 2010: 201-205).

Table 3 shows the ABC-VED matrix analysis.

Table 3.ABC-VED Matris

Category	V	E	D
A	AV	AE	AD
B	BV	BE	BD
C	CV	CE	CD

3.4. AHP

AHP, which is one of the multi-criteria decision making methods in selecting the right supplier and was introduced by Thomas Saaty in the second half of the 1900s, is an effective tool to deal with complex decision making and helps the decision maker to set priorities and make the best decision. In addition, AHP is a useful technique to check the consistency of the decision maker's evaluations and thus reduce bias in the decision-making process (Saaty, 1980).

The steps of AHP are shown in Table 4.

Table 4. Steps of AHP

1.Step: Decision making problem is defined.
2.Step: The hierarchy of the problem is created.
3.Step: The Criteria Are Compared Between Each Other. $$\begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nm} \end{bmatrix} \quad (1)$$
4.Step: Assigning Weights and Priorities $$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$ $$W = \frac{\sum_{j=1}^{n} b_{ij}}{n} \quad (3)$$
5.Step: Calculation of Consistency Ratio $$CR = \frac{CI}{RI} \quad (4)$$ $$CI = \frac{\pi_{max} - n}{n-1} \quad (5)$$
6.Step: Evaluation of Consistency Rate

π_{max} – computed average from values of divided weighed sum vector elements by associated priority value.

n – the number of criteria.

RI-the value for the corresponding size of matrix proposed by Saaty (1980) can be found in Table 5.

Table 5. Randomness Index

Matrix size	Random Consistency index (RI)
1	0,0
2	0,0
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

In the AHP method, after the problem definition and target are determined, alternatives and criteria are determined. Saaty (2008) developed a scale to compare the determined criteria and determine the advantages. If one criterion is more important than another, the scale acts with the logic of giving importance to a value from 1 to 9 (Equation 1).

A paired comparison matrix is created between the criteria determined in line with this scale. After the comparison matrix is created, the eigenvector showing the importance of each item relative to the other items is created (Equation 2 and 3). The "Consistency Index (CI)", which is an indicator of consistency, is calculated and divided by the Randomness index (Equation 4). If CR> 0.1, the decision matrix is considered inconsistent, if CR≤0.1, the decision matrix is considered consistent (Equation 5).

3.5 0-1 Goal Programming

GP tries to come up with a compromise solution that takes into account the importance of multiple conflicting objectives.

Unwanted deviation variables are minimized by target programming. In goal programming, each goal requested from the decision maker is formulated to achieve a certain numerical goal, minimizing the total penalty arising from missing these goals, that is, the weighted sum of the deviations of each of the goal functions from their goals (Öztürk, 2009: 273). Its main purpose is to transform a multi-purpose problem into a single-purpose problem. The result of the model is generally called effective solution (Taha, 2007: 343).

Charnes and Cooper (1961) were the first researchers to introduce the goal programming (GP) method. Later, scientists such as Lee (1972), Flavell (1976) Ignizio (1985), Tamiz (1998), Vitoriano and Romero (2001), Chang (2002) developed the goal programming method (Karaatlı and Davras, 2014).

4. APPLICATION

In this study was carried out in an oral and dental health center operating in Ankara. It is aimed to provide the materials needed by the enterprise in order to provide a quality health service on time and on site. For this purpose, materials with critical importance that must be included in the inventory of medical products to be purchased were determined using the ABC-VED Matrix method. Later, the suppliers of tooth extraction tools grouped by the application area among these materials have been determined.

In order to determine the priority values of the suppliers, the AHP method was preferred because the interactions of the criteria with each other are not taken into account in the decision-making process and because it can compare more than one quantitative and qualitative criteria at the same time. The solution was implemented with the program Super Decision (2.10.0). In solving the problem, 0-1 Goal Programming method was preferred because it realizes many goals at the same time and provides an effective solution method. The 0-1 Goal Programming model was developed by transforming the determined goals into constraints and adding the priority values obtained from AHP as constraints. The model was solved with Lindo 6.1 program and the right suppliers were selected for critical product groups.

4.1. Finding Critical Product Groups with ABC-VED Matrix Analysis

It is planned to purchase 104 products of dental consumables in the oral and dental health center where the application is performed. ABC-VED analysis method was used to determine the critical materials that must be kept in the center among 104 items to be ordered.

ABC-VED Matrix analysis was created by combining 104 items of materials according to whether they are critical or not. The results of the analysis are shown in Table 6. According to these results, the products in category I, which must be kept in the oral and dental health center, correspond to 71.15% of the total materials and 91.26% of the total material value.

The materials in the category II correspond to 21.15% of the total materials and 8.34% of the total value. So, materials in category I are lesser importance than the materials in category II in terms of both amount and value.

The least important of the materials in the category III correspond to 7.7% of the total materials and 0.4% of the total value.

According to the result of ABC-VED Matrix analysis, 74 items of materials in Category I were identified as critical materials. For this reason, these materials should be provided with priority.

In this study, among 74 critical products, the products used in tooth extraction, created according to the application area, were taken into consideration.

In the next stage, the priorities of the suppliers in this group with AHP will be determined.

Table 6. ABC-VED Matrix

Group	Products	Products Ratio	Value (TL)	Value Ratio
I.Category (AV+AE+AD+BV+CV)	74	%71,15	31.722.422	%91,26
II.Category (BE+CE+BD)	22	%21,15	2.899.915	%8,34
III.Category (CD)	8	%7.7	138.529	%0,40
TOTAL	104	%100	34.760,87	%100

4.2. Determining the weights of criteria and ranking of suppliers with AHP

As a result of the ABC-VED Matrix analysis, criteria were determined by the experts to select the right suppliers to supply the tooth extraction tools in Category I.

Criteria;

Price; It is aimed to find the supplier with the most suitable offer.

Delivery; The supplier's ability to deliver the right amount of products at the desired time has been taken into account.

Quality; An evaluation was made by taking into account the improper product percentages of the suppliers.

Supplier Reliability; The past performance of the suppliers has been taken into account.

The Analytical Hierarchical structure created for tooth extraction tools is shown in Figure 3.

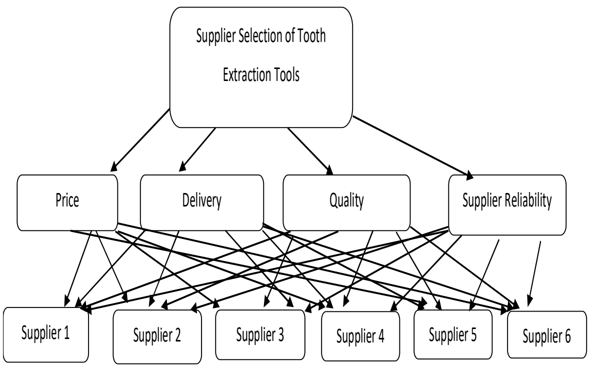

Figure 3. AHP Structure

4.2.1. Comparison of Criteria with AHP

Criteria were evaluated by experts using Saaty's 1-9 point preference scale, and the geometric mean of the results is shown in Table 7.

Table 7. Compration Matrix

Criteria	Price	Quality	Supplier Reliability	Delivery
Price	1	0.215	0.203	0.382
Quality	4.64	1	2.3	3.3
Supplier Reliability	4.93	0.438	1	2.28
Delivery	2.62	0.30	0.438	1

The comparison matrix of the criteria has been solved by Super Decision (2.10). The consistency ratio of the criteria was calculated as 0.03348. A consistency ratio of less than 0.1 indicates that the criteria were evaluated consistently.

The weights of the criteria are included in Table 8.

Table 8. Weights of Criteria

Criteria	Weights of Criteria
Price	0.072
Quality	0.484
Supplier Reliability	0.293
Delivery	0.150

According to the results obtained by the evaluations of experts, it has been observed that the quality criterion is the most important in the selection of the supplier for the product group that has critical importance in the health sector, and the price criterion is the least important.

4.2.2. Comparison of Suppliers by Criteria

Comparison of suppliers by each criterion is included in Table 9-12. As a result of the comparisons, weights of the suppliers were calculated according to the criteria.

4.2.3. Sorting Alternatives with AHP

As the last step in AHP, the priorities of suppliers are obtained by multiplying the criteria weights of the suppliers and the weight of each criterion. The sorting of suppliers by AHP are shown in Table 13. According to the AHP result, the first priority was Supplier 3, followed by suppliers with number 6,1,5,4,2, respectively.

Table 9. Comparison of Suppliers by Criteria of Price and Priority Values

Suppliers	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Priority Values	Consistency Rate
Supplier 1	1	0.333	0.20	0.16	0.143	0.11	0.0265	
Supplier 2	3	1	0.33	0.16	0.143	0.11	0.0410	
Supplier 3	5	3	1	0.33	0.25	0.20	0.0860	
Supplier 4	5.9	5.9	3	1	0.5	0.33	0.1735	**0.05650<0.1**
Supplier 5	7	7	4	2	1	0.33	0.2443	
Supplier 6	9	9	5	3	3	1	0.4283	

Table 10. Comparison of Suppliers by Criteria of Quality and Priority Values

Suppliers	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Priority Values	Consistency Rate
Supplier 1	1	0.5	0.11	0.33	0.143	0.2	0.032	
Supplier 2	2	1	0.143	0.33	0.2	0.25	0.047	
Supplier 3	9	7	1	7	2	3	0.421	
Supplier 4	3	3	0.143	1	0.25	0.33	0.080	**0.02970<0.1**
Supplier 5	7	5	0.5	4	1	2	0.255	
Supplier 6	5	4	0.3	3	0.5	1	0.165	

Table 11. Comparison of Suppliers by Criteria of Supplier Reliability and Priority Values

Suppliers	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Priority Values	Consistency Rate
Supplier 1	1	0.33	0.25	0.25	0.33	0.143	0.039	
Supplier 2	3	1	0.33	0.33	1.28	0.33	0.090	
Supplier 3	4	3	1	1.28	3	0.33	0.198	
Supplier 4	4	3	0.781	1	0.5	0.25	0.144	**0.07038<0.1**
Supplier 5	3	0.781	0.33	2	1	0.25	0.122	
Supplier 6	7	3	3	4	4	1	0.406	

Table 12. Comparison of Suppliers by Criteria of Delivery and Priority Values

Suppliers	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Priority Values	Consistency Rate
Supplier 1	1	9	0.33	9	7	3	0.310	
Supplier 2	0.11	1	0.143	3	0.33	0.25	0.042	
Supplier 3	3	7	1	9	5	3	0.413	
Supplier 4	0.11	0.33	0.11	1	0.25	0.16	0.025	**0.06604<0.1**
Supplier 5	0.143	3	0.2	4	1	0.5	0.077	
Supplier 6	0.33	4	0.33	6	2	1	0.132	

Table 13. The Sorting of Suppliers by AHP

Suppliers	Price	Quality	Supplier Reliability	Delivery	Priority Value	Sorting of Suppliers
Supplier 1	0.0265	0.310	0.032	0.039	0.168	3
Supplier 2	0.0410	0.0420	0.047	0.090	0.051	6
Supplier 3	0.0860	0.413	0.421	0.198	0.360	1
Supplier 4	0.1735	0.025	0.080	0.144	0.069	5
Supplier 5	0.2443	0.077	0.255	0.122	0.147	4
Supplier 6	0.4283	0.132	0.165	0.406	0.204	2

4.3. AHP Priorities Integrated 0-1 Goal Programming Model

In this section, the targets are determined by the oral and dental health center about the material cost and supply times. Then these constraints are formulated in model. Later, the priority values of the suppliers obtained from AHP were added as a constraint in the 0-1 Goal Programming model.

The targets determined in 0-1 Goal Programming are as follows;

Goal 1: The prices do not exceed the average approximate cost.

Goal 2: Not exceeding the appropriate delivery time for the product.

Goal 3: To protect the priority values obtained from AHP.

The proposed model for 0-1 Programming, which provides an effective solution method by meeting these three targets at the same time, is as follows;

Min Z = $(d1^+) + (d2^+) + (d3^-) + (d3^+)$ (6)

Constrains:

$\sum_{i=1}^{n} A_i x_i + d1^- - d1^+ = C$ (7)

$\sum_{i=1}^{n} t_i x_i + d2^- - d2^+ = T$ (8)

$\sum_{i=1}^{n} w_i x_i + d3^- - d3^+ = 1$ (9)

$\sum_{i=1}^{n} x_i = 1$ (10)

$x_i = 0$ or 1 $\forall_i$ (11)

$dj^-, dj^+ \geq 0$ $\forall_j$ (12)

Decision Variables:

x_i= if the order is to be given to the supplier i, takes the value "1", if not, "0".

Deviation Variables:

$d1^-$: negative deviation from approximate cost,
$d1^+$: positive deviation from approximate cost,
$d2^-$: negative deviation from delivery time,
$d2^+$: positive deviation from delivery time,
$d3^-$: negative deviation from priority values obtained from AHP
$d3^+$: pozitif deviation from priority values obtained from AHP.

Model related parameters are shown in the Table 14.

Z= Sum of deviation variables,
A_i=The amount of offered price by the supplier i,
C=Approximate cost amount determined by the enterprise for the tools used in tooth extraction,
t_i=Delivery time of supplier i,
T=Delivery time
w_i=Priority value of supplier i obtained from AHP

Objective Function:

It is aimed to minimize the sum of deviations from the determined targets.

Table 14. Parameters

Suppliers	**Prices (A_i)**	**Delivery Time (t_i)**	**Priority Values of AHP**
Supplier 1	53.134TL	7	0,16
Supplier 2	19.238 TL	5	0,05
Supplier 3	12.710 TL	4	0,36
Supplier 4	11.221 TL	4	0,071
Supplier 5	9.762 TL	5	0,152
Supplier 6	8.338 TL	3	0,204

Constrains:

Equation 7 is a approximate cost amount constrains.

Equation 8 is a delivery time constrains.

Equation 9 is a priority value of supplier obtained from AHP constrains.

Equation 10 is a restriction of selecting only one supplier constrains.

Equation 11 is a deviation variables take a value of 0 or 1 constrains.

The formulation of the 0-1 goal programming model with integrated AHP priorities with this information is as follows,

Min Z = $(d1^+) + (d2^+) + (d3^-) + (d3^+)$ (12)

Equation 12 is aimed to minimize the sum of deviations from the determined targets.

53.134x_1+19.238 x_2+12.710 x_3+11.22 x_4+9.762 x_5+ 8.338 x_6+ $d1^- - d1^+$ =26.625 (13)

Equation 13 is a approximate cost amount constrains.

7 x_1+5 x_2+4 x_3+4 x_4+5 x_5+3 x_6+$d2^- - d2^+$=10 (14)

Equation 14 is a delivery time constrains.

0,16 x_1+ 0,05 x_2+ 0,36 x_3+ 0,071 x_4+ 0,152 x_5+ 0,204 x_6+ $d3^- - d3^+$ =1 (15)

Equation 15 is a priority value of supplier obtained from AHP constrains.

$\sum_1^6 x_i$=1 (16)

Equation 16 is a restriction of selecting only one supplier constrains.

x_i=0 or 1 i=1,2,3,4,5,6 (17)

Equation 17 is a decision variable. İf the order is to be given to the supplier i, takes the value "1", if not, "0".

dj^- ≥0 , dj^+≥0 j=1,2,3 (18)

Equation 18 is a deviation variables take a value of 0 or 1 constrains.

4.4. Results of 0-1 Goal Programing

The model was solved in Lindo 6.1 program on a 64 bit operating system computer with Intel Core ™ i7-7500U @ 2.70 GHz-2.90 GHz processor. The results obtained from the program are shown in the Table 15.

Table 15. Results of The Model

Decision Variable	Value	Deviation Variable	Value
x_1	0	$d1^-$	13 915
x_2	0	$d1^+$	0
x_3	1	$d2^-$	6
x_4	0	$d2^+$	0
x_5	0	$d3^-$	0,64
x_6	0	$d3^+$	0

According to the results obtained from the program, it was found that the desired targets were achieved and an order should be provided from Supplier 3. The effects of deviation variables on constraints are as follows;

A gain of 13 915 TL was obtained from the cost amount.

A saving of 6 days from the delivery time.

It seems that in order to reach the AHP priorities goal, the enterprise must make a purchasing decision.

5. CONCLUSION

Medical materials used in diagnosis, treatment and examination procedures of patients in health institutions are of vital importance. Correct decisions should be made in the procurement of these materials needed in service provision. Since the number of suppliers of health institutions is high, making a decision becomes more difficult.

The aim of this study is to select the most appropriate supplier among the medical equipment suppliers of an oral dental health center operating in Ankara by using the AHP method, one of the multi-criteria decision making methods, and the 0-1 goal programming method in an integrated manner.

In this context, in order to decide on the most suitable supplier, the procurement department manager and employees of the hospital were interviewed and their experiences were used.

While determining the medical company suppliers, price, supplier reliability, quality and delivery criteria were taken as basis. The criterion quality criterion with the highest priority value at the end of the study; The criterion with the lowest priority was the price criterion. According to this result, it was revealed that the hospital made a quality-oriented decision while choosing its medical supplier. Considering the weight of the alternatives in terms of criteria, it was decided that supplier 3 should be selected as the most suitable supplier. Created using data obtained from AHP and other constraints

The zero one goal programming model created using the data obtained from AHP and other constraints was solved with Lindo (6.1). As a result of the solution, it was found that order from Supplier 3 should be consistent with AHP.

Supplier selection studies in the health sector are almost nonexistent, so this study emphasized the importance of working with the right suppliers to find the products that are critical in the health sector at the right quality at the right time. With this study, an enterprise operating in the health sector has determined its suppliers, which are determined according to critical product groups, using effective stock control methods, with an AHP priority integrated 0-1 goal programming model. It is thought that this model will contribute significantly to the literature and will save time in supplier selection studies in the health sector. In this respect, the study differs from other studies because it deals with a real life problem.

In the future studies, different criteria are used in the supplier selection and evaluations in the health sector and different multi criteria decision making methods by modeling with goal programming and the results can be compared.

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