Selecting Ultrasound Machine Using ELECTRE Method

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Abstract Disease diagnosis provides crucial information and serves as primary guide for treatment. Ultrasound machines are largely used by medical experts for this purpose. There are several models of ultrasound machines available in market with variety of features. Thus, selection of good ultrasound machine comes under the category of multi-criteria decision making. This paper focuses on use of Electre method to select best ultrasound machine fulfilling user's criteria. Six criteria were considered to select best model among five alternatives. The method can be applied to any number of characteristics and alternatives.

Keywords Multi-criteria decision making · Electre · Ultrasound · Outranking · Concordance · Discordance

1 Introduction

Ultrasound is a type of sound wave with a typical wavelength of more than 20,000 Hz. It lies in the range of frequency which human beings cannot hear. Medical ultrasound, an ultrasound technique, is used in clinical setting for image-based diagnostic procedures. Ultrasound machines are not only successfully helping medical doctors in examining medical conditions of a patient but also assisting in making treatment plan. Various organs of human body are scanned with the help of images produced by ultrasound machine. To high light the body structure, high-frequency sound waves are sent by ultrasound machine. A smart computing device is attached that receives the waves and convert them into an image. An ultrasound machine is characterized by variety of factors like application areas, transducer types, imaging modes, number of probes, image resolution, etc. Multiple criteria should be evaluated before selecting a best ultrasound machine. Multi-criteria decision-making problem offers variety of tools for solving decision-making problems involving consideration of

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multiple features. Multi-criteria decision-making approach of decision making is well equipped with variety of tools like AHP, Promethee, Topsis, Electre, etc.

Electre is one of the powerful tools that overcomes the problems associated with traditional decision-making aids [1]. Moreover, complex situations where decision making involves multiple criteria those include not only quantitative data but also qualitative data along with involvement of more than one decision maker are efficiently handled using Electre method. A model using Electre is proposed for handling collaboration between, buyers, suppliers and business partners [2]. Electre method is used in selecting best location for agriculture based industry [3]. To reduce environmental pollution by manufacturing industries, selection of suitable cutting fluid is made using Electre method [4]. Electre along with AHP is applied in evaluation of cyber security metrics [5]. Electre method is used in supply chain management in the selection of best supplier in flexible packing industry [6]. Desirable and consistent supplier for supplying fabric in clothing industry is made with help of Electre [7].

A model using Electre is proposed for handling collaboration between, buyers, suppliers and business partners [8]. To reduce environmental pollution by manufacturing industries, selection of suitable cutting fluid is made using Electre method [9]. Sustainability assessment of manufacturing industries having more safety requirements and large customer base is successfully carried out using Electre and Promethee method [10]. For in interrupted mobile communication, Electre method is applied by reducing the handoff failures [11]. For designing a new approach that includes stake holders and new technologies for implementation of Water Framework Directive, Electre and AHP methods were used [12]. Prioritization of requirement of customers banking, finance and investment sector [13], Electre method is applied in design and assessment of public transport system for big cities [14].

Recent trends show large use of multi-criteria decision-making methods in healthcare applications. This technique can assist decision makers (usually medical doctors) in health sector by empowering them in selecting best option among available set of alternatives. A report from Emerging Good Practices Task Force described the key steps and provided an overview of the principal methods involved in multi-criteria decision making [15]. In the research conducted by Dursun [16], the authors used both ordered weighted averaging (OWA) operator and fuzzy Topsis for efficient health waste management. Dehe [17] used evidential reasoning (ER) as well as analytical hierarchy process (AHP) to aid decision process for selecting best location for healthcare infrastructure. Multi-criteria decision making is also used by Carmen [18] in asset management in healthcare organizations by assisting in selecting best set of maintenance policies. Charles [19] applied multi-criteria decision making to design a best healthcare plan that meets requirements of both insurer and payer. Amini [20] successfully used AHP and Topsis to rank health care with regards to the execution of the family health program. Multi-criteria decision making is used in health technology assessment (HTA) to obtain best value for money [21] and management of health care is improved by evaluation of quality of services [22].

In this present paper, the use of Electre method is described with a help of a case study in selecting best ultrasound machine and meeting the specified requirements.

A brief introduction of Electre method is followed by its implementation in a case study.

2 ELECTRE (Elimination and Choice Translating Algorithm)

B. Roy proposed Electre Elimination Et Choix Traduisant la Realité (Elimination Et Choice Translating Reality) method in 1960s. A multi-criteria decision-making problem (MCDM) is described by:

(i) $A_i, I = 1,\ldots, m$, which denotes the alternatives.
(ii) $g_j, j = 1,\ldots, n$, which denotes the criteria.
(iii) $w_j, j = 1,\ldots,n$ also $\sum_{j=1}^{n} w_j$, which denotes the criteria.

The objective is to find the best alternative among available alternatives, where the performance matrix ($m \times n$) possess value for every alternative corresponding to every criterion. Also, the weights of the criteria are given in a weight matrix.

Let the defined criteria be like $g_{ij} = 1, 2\ldots, n$ where A corresponds to the set of alternatives. Any two alternatives a and b in set of alternatives A have either of following relations:

- $a\ P\ b$ Here, the preference is given to a than b $g(a) > g(b)$
- $a\ I\ b$ Here a remains not-so-different to b $g(a) > g(b)$
- $a\ R\ b$ (it remains not feasible to compare a and b)
  where $a,b \in A$,
  $g(a)$: value of alternative a for criteria g
  $g(b)$: value of alternative b for criteria g

Outranking relation is computed to describe the importance of one criterion over other. There are two sorts of comparisons required for the computation of outranking relation as given herewith, i.e., concordance and discordance.

- The decision maker is equipped by concordance test to check whether the alternative a can at least be good alike b.
- The intention of discordance test falls under the criteria in which the performance of a is worse compared to b. When there is a failure in this result, the high opposition can be said as vetoing the concordance test.
- The outranking relation of a S b can be finalized as true only when both concordance and discordance tests are passed.

2.1 Electre Method Steps

Step 1: Decision matrix formation

Here, the rows in decision matrix ($m \times n$) correspond to m alternatives whereas the criteria is denoted by n columns.

Step 2: Assignment of weights to criteria

Each of the criteria is assigned with weights of importance. Criteria with highest weight are most important to decision maker.

Step 3: Computation of concordance and discordance sets

Decision matrix data is compared for all the pairs of alternatives in terms of every criterion. Further, both concordance and discordance sets are analyzed. For every alternative pair a and b ($a, b = 1, 2,\ldots m$), the set of criteria is portioned into two following subsets:

- Concordance set, C: It consists of all the criteria due to which the alternative a is given preference against the other alternative i.e., b

$$C(a, b) = \left\{ j : g_j(a) \geq g_j(b) \right\} \tag{1}$$

where g_j (a) corresponds to alternative a's weight in terms of jth criteria.

Thus, C (a, b) denotes a set of criteria in which the alternative a is either better or equal to that of the alternative b.

- Discordance set, D: It is compliment of concordance set C (a, b). D contains all criteria for which alternative a is worse than alternative b.

$$D(a, b) = \left\{ j : g_j(a) < g_j(b) \right\} \tag{2}$$

where $g_j(a)$ is weight of alternative a with respect to jth criteria.

Step 4: Concordance matrix computation

When criteria value weights, for elements present in concordance set, are measured, it results in concordance matrix.

$$C(a, b) = \sum_{j \in C(a,b)} w_j \tag{3}$$

where W_j is weight of the criteria g_j for which alternative a is better than or equal to alternative b.

Step 5: Discordance matrix computation

In general, the discordance matrix is calculated by dividing the values of discordance set members with the total value of whole set.

$$D(a, b) = \frac{\max_{j \in D(a,b)} \left| g_j(a) - g_j(b) \right|}{\max_j \left| g_j(a) - g_j(b) \right|} \tag{4}$$

Step 6: Computation of outranking relationship

In this step, the average values of both concordance and discordance are considered. In case of concordance matrix, any C (a, b) value which is higher than or

equal to C average is considered to be 1, whereas in case of discordance matrix, any value less than or equal to D average is specified to be 0.

Step 7: Formation of net concordance and discordance matrix

In this step, the calculation of net concordance and discordance values is performed in order to rank among the set of available alternatives.

$$C_a = \sum_{k=1,k\neq a}^{m} C(a,k) - \sum_{k=1,k\neq a}^{m} C(k,a) \tag{5}$$

$$D_a = \sum_{k=1,k\neq a}^{m} D(a,k) - \sum_{k=1,k\neq a}^{m} D(k,a) \tag{6}$$

3 Application of ELECTRE Method in Selecting Best Ultrasound Machine

Five midrange price category models are considered from five leading brands, suitable for conducting ultrasound exams for patients across all ages and body types and offer fast and reliable diagnosis. Affinity 30 (Philips), Logiq P7 (GE), HS 50 (Samsung), DC 70 (mindray), S -1000 (Siemens) are the alternatives under consideration. Selection of ultrasound machine depends upon many factors like brand reputation, automatic OB measure, touch screen size, number of transducer ports, image quality and contrast imaging as set of evaluating criteria. We referred various websites [23, 24] and product manuals to get comparative data for the above mentioned models. The performance matrix for set of alternatives and criteria is shown in Table 1.

Assignment of weights to criteria is an important step in getting best result using Electre method. A questionnaire was prepared and sent to 15 healthcare providers (doctors and technicians performing ultrasounds). However, only eight of them responded. The weighted average of their criteria weights was computed. The criteria

Table 1 Performance matrix

Model name	Brand reputation 1	Automatic OB measure 2	Touch screen size 3	No of transducer ports 4	Image quality 5	Contrast imaging 6
Affinity 30	High	No	12	4	High	No
Logiq P7	High	Yes	10.4	3	Mid	Yes
HS 50	Mid	Yes	10.1	4	Mid	Yes
DC70	Low	Yes	10.4	4	Mid	Yes
S-1000	High	Yes	7	3	High	Yes

with highest weight are considered as more important. The associated weight matrix is shown in Table 2.

Pair-wise comparisons were performed for all elements in set of alternatives A and concordance sets are determined (Table 3).

Next, we compute concordance index for each alternative pair by adding weights for the criteria included in the corresponding concordance set. The concordance indexes are shown in Table 4.

Discordance computations will not be performed as the data in our preference matrix does not allow it. Next, outranking relationships will be computed by defining dominance relationship between pair of alternatives. Higher values of concordance

Table 2 Criteria weights

Criteria	Weights
Brand reputation	0.25
Automatic OB measure	0.20
Touch screen size	0.15
No. of transducer ports	0.10
Image quality	0.20
Contrast imaging	0.10

Table 3 Concordance set

C (A, L)	1, 3, 4, 5
C (A, H)	1, 3, 4, 5
C (A, D)	1, 3, 4, 5
C (A, S)	1, 3, 4, 5
C (L, A)	1, 2, , 6
C (L, H)	1, 2, 3, 5, 6
C (L, D)	1, 2, 3, 5, 6
C (L, S)	1, 2, 3, 4, 6
C (H, A)	2, 4, 6
C (H, L)	2, 4, 5, 6
C (H, D)	1, 2, 4, 5, 6
C (H, S)	2, 3, 4, 6
C (D, A)	2, 4, 6
C (D, L)	2, 3, 4, 5, 6
C (D, H)	2, 3, 4, 5, 6
C (D, S)	2, 3, 4, 6
C (S, A)	1, 2, 5, 6
C (S, L)	1, 2, 4, 5, 6
C (S.H)	1, 2, 5, 6
C (S, D)	1, 2, 5, 6

Table 4 Concordance indexes

	Affinity 30	Logiq P7	HS 50	DC 70	S-1000
Affinity 30	–	0.70	0.70	0.70	0.70
Logiq P7	0.55	–	0.9	0.9	0.80
HS 50	0.40	0.6	–	0.85	0.55
DC70	0.40	0.75	0.75	–	0.55
S–1000	0.75	0.85	0.75	0.75	–

index C (a, b) show that alternative a is dominant over alternative b. The method defines that a outranks b when C (a, b) > Average (C).

Average $C = 0.695$.

The outranking relationship between various alternatives is defined in Table 5.

Ranking among various alternatives will be evaluated with the help of net concordance and discordance matrix. Now, ranking will be determined by computing advantages. The net concordance is computed by following equation number 6. The net concordance is shown in Table 6.

After sorting net concordance in increasing order, it is determined that alternative Affinity 30 is most desirable followed by S-1000, Logiq P7, DC 70, HS 50 (Fig. 1).

Table 5 Outranking relationships

	Affinity 30	Logiq P7	HS 50	DC 70	S-1000
Affinity 30	–	1	1	1	1
Logiq P7		–	1	1	1
HS 50			–	1	
DC70		1	1	–	
S-1000	1	1	1	1	–

Table 6 Net concordance

	C (a, b)	C (b, a)	Net C
Affinity 30	4	1	3
Logiq P7	3	3	0
HS 50	1	4	−3
DC70	2	4	−2
S-1000	4	2	2

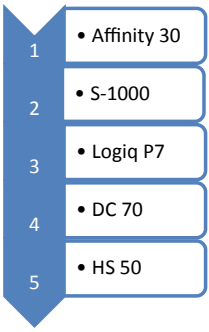

Fig. 1 Ranking of alternatives

4 Result Analysis and Discussions

Medical decisions related to both diagnostic and possible treatment very important as they have direct impact over life of individual. Many times these decisions become more complex if there are contradicting objectives. Thus, the well-structured approach, that can take care of nity gritties of complex decision-making problem, has a potential to improve the quality of decision making, up to a large extent. The Electre method proves to be a strong tool for decision-making problems involving both quantitative and qualitative attributes. The method starts with computation of concordance and discordance sets followed by computation of net concordance and out ranking relation. In the present paper, we have not considered discordance because the type of data we have does not support discordance. Finally, net concordance was computed, and final ranking of alternatives is obtained. Affinity30 is selected as best alternative and HS 50 as worst alternative. It is also observed that change in assignment of weights by decision maker can alter the ranking.

The problem of selecting best ultrasound machine is also modeled and evaluated with the help of AHP. Same set of criteria and alternatives was taken. Electre method asks experts to provide weights for various criteria while AHP method has a detailed procedure to calculate criteria weights by making pair-wise comparisons of criteria. The AHP method has a mechanism for checking consistency of decision makers but Electre method has no such provisions. It has been noticed in the study, for same set of consistent decision makers, Electre method and AHP method provided the same ranking.

5 Conclusions

Decision making in healthcare sector is complex in nature as a best decision should find a fine balance between various parameters from various stake holders. Judgments are not replaced by multi-criteria decision-making tools. It is actually involved in the identification, collection and structuring of the information for people who

make judgments and to support the deliberative process. Multi-criteria decision making provides transparent and consistent decisions. The present paper explained the working of Electre method in detail. Each of the steps that lead to ranking of relations is explained with the help of a case study.

Like any other method, the Electre method too has limitations. The main drawback is that if the criteria and criteria weights are not selected carefully, Electre method will yield non optimal results. Hence, with the selection of correct criteria and criteria weights the Electre method results in strong decision making aide for healthcare experts. The paper suggested easy to use and reliable tool for selecting best ultrasound machines that suits ones requirements.

This paper carries methodological importance as it explains in detail how set of available alternatives can be analyzed to suggest a ranking method for alternatives that can be ordered in the range of best to worst. Electre method was validated in a selection of ultrasound machine that includes only six parameters. It is evident from the literature that this is a scalable method though the current research work missed to validate it. The future research is intended to validate the method involving large-scale requirements.

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