Suggested Multi Criteria Decision Support System for Ranking Universities

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Abstract - **The evaluation of education with ranking lists of universities has become, over the past few years, increasingly popular. Rankings of higher education institutions are attractive to consumers, students, benefactors, alumni and governments: they promise to reduce uncertainty for those who have to make choices in an environment where full information is not available and quality cannot be equated to price. In this paper, we suggested a design for decision support system (DSS) to be implemented and used in the Association of Arab Universities. The paper suggested a design of the system using multi criteria optimization approach with multiple attributes and multiple objectives concerning the higher education quality assurance issues in the higher education institutions in the Arabic countries. Instead of methodology used to rank universities is a simple weighted sum, which has several limitations. First, the weights are predetermined with very little, if any, justification of their value. Therefore, it is assumed that the criteria have the same importance (i.e. weight) for everybody. This is clearly not true as each person is different and has different preferences. Moreover, commercial league tables use a simple aggregation, which is compensatory and does not differentiate between universities having strengths in different areas.**

Keywords: **Multi Criteria Decision Support Systems, Data Envelopment Analysis, Higher Education Quality Assurance, Ranking Universities.**

I. INTRODUCTION

During the past decades, operations research (OR) has come a long way as a field that supports scientific management. Within the OR field, various interconnected areas have been developed on the basis of different decision-making paradigms and problem contexts. OR, is mainly involved with model building and algorithmic optimization procedures that facilitate the analysis of complex real-world problems. This complexity can be due to the dimensionality of a given problem (e.g., the number of available options and actions), the uncertainty that prevails in most real-world situations, the nature of the available data which are often imprecise, as well as the multiple stakeholders that are often involved [1].

An important implication of the above issues involves the multidimensional character of real-world decision-making problems, which requires the consideration of multiple conflicting points of view, even in situations where a single decision maker is involved. Nowadays, economic, social, and environmental criteria are nowadays involved in practically all decision situations, in order to describe the diverse outcomes of the existing options. Within this context, the decision process should naturally explore the conflicting nature of the criteria, the corresponding tradeoffs, the goals set by the decision makers, and of course the way that these can be introduced in an appropriate decision model that takes into account the subjectivity of the decision process and the preferences of the decision makers [2].

Ranking universities is not a simple task, because there are as many as viewpoints that must be considered. For the time being, with the wide use of quality assurance regulations, and the methodologies used for assessment of higher education institutes in Arabic countries, help the researchers for finding suitable methods for giving weights to the attributes used in assessment process.

Several commercial universities ranking schemes are annually published. Alongside, criticisms of these rankings have also increased [3; 4; 5]. These leagues tables are based on a weighted sum of performances, which has some methodological problems. As each criterion is measured in a different unit, they need to be transformed to commensurate units in order to be summed together. The problem is that numerous ways of standardizing exist (commercial rankings generally uses z-transformation) and they often lead to a different final ranking. An example can be found in [6], where the authors emphases that “prior normalization of data is not a neutral operation, and the final result of aggregation may well depend on the normalization method used”; the same normalization problem is also observed in the Analytic Hierarchy Process (AHP), where different normalizations may lead to a rank reversal [7]. Moreover, AHP is difficult to use with a large volume of data, due to the high number of pair wise comparisons required [8].

Data Envelopment Analysis (DEA) is an often used ranking technique [9; 10; 11], which does not require any normalization. The global score of each Decision Making Unit (DMU) is defined as the ratio of the sum of its weighted output levels to the sum of its weighted input levels. The analogy with multi-criteria methods is striking if we replace the name “DMU” with “alternatives”, “outputs” with “criteria to be maximized” and “inputs” with “criteria to be minimized”. The particularity of this method is that weights are not allocated by users or experts; moreover it does not employ a common set of weights for all alternatives. Instead, for each alternative a different set of weights is calculated with a linear optimization procedure.

The aim of the optimization is to select weights in order to highlight their particular strength. Some constraints are added in order to ensure that when these weights are applied to all other candidates, none of the scores exceed 100%, the perfect efficiency. DEA has been widely used to rank universities or schools [12] and in many other sectors as compiled in [13].

II. RESEARCH METHODOLOGY

In this paper we propose to use Data Envelopment Analysis (DEA) as a tool for Multiple Criteria Decision Making (MCDM), for the task of generating ranking list for the Universities in Arabic countries (members in Association of Arab Universities - AAU). The prototype model that has been built is according to the assessment guide produced by AAU [14]. We focused on a part of this guide concerning the faculty staff member assessment. The other parts of the guide (which is very large) can be implemented in the same way of this suggested prototype system.

III. The DEA Model

DEA deals with the evaluation of the performance of Decision Making Units (DMU) performing a transformation process of several inputs, several outputs. Relying on a technique based on Linear Programming (LP) and without having to introduce any subjective or economic parameters, DEA provides a ‘measure of efficiency’ of each DMU allowing, in particular, to separate efficient from non-efficient DMU and to indicate for each non-efficient DMU its ‘efficient peers’.

The success of DEA in the area of performance evaluation together with the formal analogies existing between DEA and Multiple Criteria Decision Making (MCDM) (which become clear replacing DMU with alternatives, outputs with criteria to be maximized, inputs with criteria to be minimized, etc.) have lead some authors to propose to use DEA as a tool for MCDM.

A number of recent papers have begun the analysis of the links between DEA and MCDM. We shall concentrate here, using simple example, on the potential usefulness of DEA for MCDM [15].

The equivalence between the notion of ‘efficiency’ in DEA and that of ‘convex efficiency’ in MCDM is not a new fact. It is however worth recalling here since it is crucial for our purposes. Furthermore we shall use a simple model which, in our opinion, makes the result more transparent.

Let $X = \{a_1, a_2, ..., a_l\}$ be a finite set of alternatives that have been evaluated on a set of n real-valued criteria. Contrary to previous works in the area but in line with most works in the area of MCDM, we shall suppose throughout the paper that preference increases with all criteria. Although it is not difficult to generalize the analysis in order to include criteria to be ‘minimized’, this hypothesis will allow us to keep things simple considering DEA models having only ‘outputs’ and therefore to neglect the ‘return to scale’ problem. In order to avoid unnecessary complications, we shall also suppose that the evaluations of the alternatives on the criteria are strictly positive. We denote by $y_{jk} > 0$ the evaluation of alternative a_k on criterion j.

Alternative a_i is said to *dominate* alternative a_k if $y_{ji} \geq y_{jk}$ for $j = 1,2,...,n$, at least on of these inequalities being strict. An alternative $a \in X$ is said to be *efficient* in X if no alternative in X dominates it. It is clear, under very mild conditions on preferences, that efficient alternatives should receive special consideration in MCDM.

A ‘folk theorem’ in MCDM goes as follows: if it is possible to find a set of strictly positive weights $w_1, w_2, ..., w_n$ such that the weighted sum of the criteria for alternative a_i is larger or equal than the weighted sum for any other alternative in X, then a_i is efficient (in X). It should be noted that the weights used in this ‘folk theorem’ may be normalized in any convenient way, for example letting $\sum_{j=1}^{n} w_j = \alpha > 0$ or $\sum_{j=1}^{n} w_j y_{jk} = \beta > 0$ for some alternative a_k.

A ‘folk remark’ is the following: not all efficient alternatives in X can be characterized through the use of weighted sums if the image of X in the space of criteria is not convex as shown in figure 1.

In the area of MCDM, alternatives that maximize (in X) a weighted sum of all criteria for some strictly positive weights are called convex efficient (CE) in X; alternatives that are not CE are said to be convex dominated (CD). LP offers a powerful tool for testing if an alternative is CE; many different formulations can be used for this purpose. Let us consider the following LP designed to test if :

$a_* \in X = \{a_1, a_2, ..., a_l\}$ is CE :

(P) min D

Subject to

$$\sum_{j=1}^{n} (y_{j*} - y_{jk}) w_j + D \geq 0, \quad k = 1,2,...,l$$

$$\sum_{j=1}^{n} w_j y_{j*} = 1$$

$$w_j \geq \varepsilon, \quad j = 1,2,...,n$$

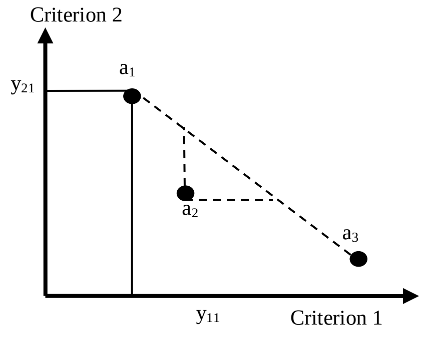

Figure (1): In $X = \{a_1, a_2, a_3\}$ All Alternatives are Efficient. Alternative a_2 can not Maximize a Weighted Sum of the Two Criteria

Where ε is an arbitrarily small positive number and y_{j*} denotes the evaluation of alternative a_* on criterion j. It should be observed that since $a_* \in X$ and a_* is compared to all alternatives in X, including itself, negative values of D are infeasible. It is easily seen that a_* is CE (in X) if and only if the optimal value of the objective function of (P) is 0. In fact, if a_* is CE, we have, be definition, $\sum_{j=1}^{n} y_{j*} w'_y \geq \sum_{j=1}^{n} y_{ik} w'_j$, $k = 1,2,\ldots,l$ for some strictly positive weights $w'_1, w'_2, \ldots, w'_n$. Now taking $w_j = w'_j / \sum_{j=1}^{n} w'_j y_{j*}$ and D=0 gives a feasible solution of (P) with a suitably chosen of ε. This is also an optimal solution since negative values of D are infeasible. Conversely if we have an optimal solution $w^*_1, w^*_2, \ldots, w^*_n$, D^* of (P) with $D^* = 0$, then $\sum_{j=1}^{n} y_{j*} w^*_j \geq \sum_{j=1}^{n} y_{jk} w^*_j$, , so that a_* is CE since $w^*_j \geq \varepsilon > 0$.

In view of Figure (1), it is clear that when a_* is CE, the optimal solution of (P) will not, in general, be unique: more than one set of 'optimal weights' w_j^* will be compatible with D^*=0. Taking the dual of (P) leads to:

$$\text{(D)} \qquad \max \; M + \varepsilon \sum_{j=1}^{n} s_j$$

Subject to:

$$y_{j*} M + \sum_{k=1}^{l} (y_{j*} - y_{jk}) \lambda_k + s_j = 0,$$

$$\sum_{k=1}^{l} \lambda_k = 1$$

$$\lambda_k \geq 0, s_j \geq 0, \quad M \text{ unrestricted}$$

Which is easily seen to be equivalent to the output oriented (primal) version of DEA, when there are no inputs (or equivalently when all alternatives have common values on all inputs). Loosely speaking and ignoring slacks, E=1+ M can be considered as a 'measure of inefficiency'. It is a kind of 'radial distance' from a_* to the CE frontier, that is the coefficient (>=1) by which the evaluations of a_* on all criteria should be multiplied in order to make it CE.

IV. Proposed System

We built a prototype system, for generating ranking list among universities. We considered the part of the AAU guide concerning the academic staff in the university. In the real application we shall include all the articles (and may be more) used in the assessment of the universities. The process of building the system has gone through many stages, starting from designing the database structure for saving the data collected, and ending with the application of the DEA method for finding the rank list. We shall explain these stages as follows:

A. *Designing the Database*

We followed the relational model for designing the database using Microsoft SQL-Server 2008™. As we mentioned before, we used the AAU guide as a reference for the needed data and attributes in the assessment process [14]. For this prototype model, we selected the information related to the academic staff working in the university. The suggested design for this part is shown in figure (2).

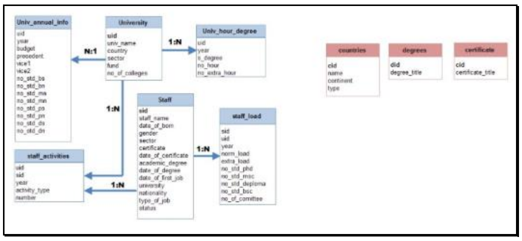

Figure (2): Suggested Design of the Universities Information Database

The database designed for this prototype system, is derived directly from the requirements needed by AAU, which is mentioned in the guide (14). If someone read the guide and then compare the information with those appear in the database, he/she may has some confusion. This is due to the nature of information required in the guide, the guide looks for information (data processed), and with this design of the database, we can get all these information (and more than this), by building the views across the tables inside the database.

B. *Data Samples*

Because of the absence of real data, we built a set of data for ten virtual universities. We estimated some values and attributes to fill the tables in the database. The data entered for these attributes in the database tables, are reflect the possible real data that can be observed during the assessment process. Also, the data selected with ranges that it can demonstrate the functionality of the suggested model, figure (3) shows a sample of the data entry forms used in the prototype system for gathering the staff information and his/her activities and duties. Figure (4) shows the form for entering the data concerning the universities.

We focus in this prototype design, and the simulated implementation on the most important data required in the decision support model. However, for the real implementation, there may be much more information required by the experts in AAU, such that we shall have the ability for building more accurate DDS for ranking the universities.

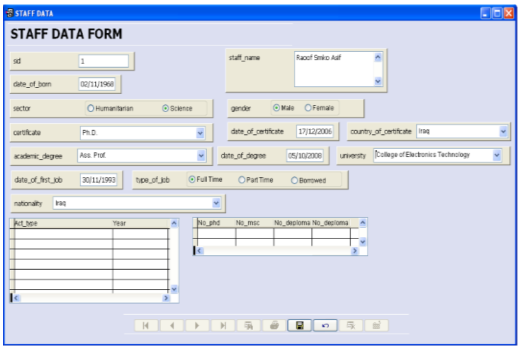

Figure (3): Data Entry Form for Staff Information

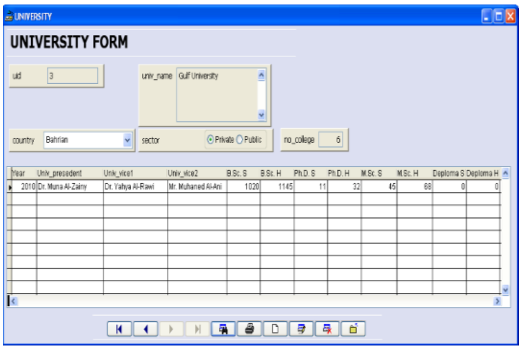

Figure (4): Universities Information Form

V. EXPERIMENT RESULTS

In this section, we discuss the implementation of the DEA method with the data entered in the database system. First we derived the decision matrix fro the data in the database as shown in table (1).

Table (1): The Decision Matrix with 10 Universities and 10 Criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
U1	0.028	23	1.2	2.3	1.1	3.2	52.4	78.5	3.6	92
U2	0.02	21	1.0	2.1	1.25	2.9	56.6	77.0	2.6	91.4
U3	0.045	22	0.8	1.4	1.05	1.8	48.9	74.6	2.78	93.5
U4	0.038	28	0.5	0.9	0.5	1.7	46.6	69.6	3.05	100
U5	0.030	30	1.5	1.1	0	1.2	42.1	63.6	2.02	82.4
U6	0.016	24	1.8	1.2	0.75	2.3	50.7	66.5	2.6	88.9
U7	0.0178	25	2	2.1	0.88	3.4	51.4	67.4	2.5	97
U8	0.034	12	1.3	1.7	1.2	3.2	53.7	72.4	3.1	98.4
U9	0.032	14	0.9	1.4	0.55	2.8	55.6	73.2	4.2	92.4
U10	0.022	16	0.7	1.3	0.68	2.9	54.2	70.6	3.5	85.6

Column (1) in this table are the set of the universities included in the ranking process; X={U1,U2,U3,U4,U5,U6,U7,U8,U9,U10}. For each of these universities, the systems calculate these criteria according to the DEA model. The total weights for each university must be equal to 1, and distributed among the criteria according to DEA method.

The first row of table (1) represents the criteria taken for the ranking process, which they are as follows:

C1: number of students / no of staff (staff ratio).
C2: number of hours per staff (weekly)
C3: Average number of attended conferences per staff.
C4: Average number of publications per staff
C5: Average number of Ph.D. students per staff.
C6: Average number of M.Sc. students per staff
C7: Average ages of staff
C8: Academic degrees indicator.
C9: Average number of committees per staff
C10: Percentage of permanent staff.

Te second step is the application of DEA method for finding the appropriate weights for these criteria. For this example data the set of weights obtained (after some approximation) are equal to:

W={0.15, 0.1, 0.15, 0.1, 0.05, 0.1, 0.1, 0.1, 0.05, 0.1}

By multiplying these weights with the decision matrix of table (1), we got the final matrix for weighted values of the decision criteria as shown in table (2).

Table (2): The weighted values of the criteria for the 10 universities

	CV1	CV2	CV3	CV4	CV5	CV6	CV7	CV8	CV9	CV10	SUM
U1	0.0043	3.45	0.18	0.345	0.165	0.48	7.86	11.78	0.54	13.8	38.599
U2	0.002	2.1	0.105	0.21	0.125	0.29	5.66	7.703	0.26	9.14	25.595
U3	0.0068	3.3	0.128	0.21	0.158	0.27	7.335	11.19	0.417	14	37.039
U4	0.0038	2.8	0.056	0.09	0.05	0.165	4.66	6.96	0.305	10	25.09
U5	0.0015	1.5	0.075	0.055	0	0.06	2.105	3.18	0.1013	4.12	11.198
U6	0.0016	2.4	0.18	0.12	0.075	0.23	5.07	6.65	0.26	8.89	23.877
U7	0.0018	2.5	0.2	0.21	0.088	0.34	5.14	6.74	0.25	9.7	25.17
U8	0.0034	1.2	0.13	0.17	0.12	0.32	5.37	7.245	0.31	9.84	24.708
U9	0.0016	0.7	0.045	0.07	0.028	0.14	2.78	3.66	0.21	4.62	12.254
U10	0.0022	1.6	0.075	0.13	0.068	0.29	5.42	7.06	0.35	8.56	23.555

VI. Conclusions and Ideas for Future Works

The system proposed in this paper follows the DEA method for solving multi criteria ranking problem. We suggest this method for ranking the Arabian Universities due to the assessment guide of AAU. We selected the part of this guide which concerning the academic staff only, we built a database for holding the required information, and we built a prototype system for finding the ranks of the universities, with virtual data entered to the database.

In future, when there will be a decision for implementing this model in real world, we may put some ideas for this future work as follows:

- Build the complete database that satisfies all the requirements of AAU.
- Build the online interactive software package that allows the higher education institutes around the Arabic countries to exchange there information, and updating the database with there own data.

- Determine all the criteria in each category of information that have effects on the ranking process.
- Build a system that can reflect the decision in multi view points.

These steps will help the AAU to follow the globalization environments in the world, with more powerful tools and realistic information about the higher institutes in the Arabic countries.

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