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Performance Evaluation of Airport Construction Energy-saving based on DEA

Network Design and Performance Analysis

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Abstract

Fuzzy Data Envelopment Analysis (DEA) evaluation model in Airport Construction Energy-saving have improved incomplete weight deficiency of information processing. Firstly, indices values were converted to trapezoid fuzzy numbers, then with incomplete information on indices weights as constraints, a fuzzy DEA model with outputs only and preference was established, and then by applying the α-cut approach, the model was transformed to a family of crisp DEA models and was solved. Experiments demonstrated the feasibility and applicability of the method.

Selection and/or peer-review under responsibility of the Intelligent Information Technology Application Research Association.

Keywords: Airport Construction Energy-saving; Fuzzy Theory; Incomplete information; Data Envelopment Analysis

1.Introduction

With the architecture market farther development, the research of energy- saving has become an important topic[1]. Architecture market reformation are transforming the structures and operating environments of construction energy-saving. Performance evaluation plays a crucial role in structural reforms in facilitating an understanding of the behavior of energy-saving[2].

Benchmarking models for Airport Construction Energy-saving have been introduced in UK and US[3][4], and have become common throughout Latin America and Europe[5], and have become common throughout the Latin America[6][7]. However, for developing countries, few studies have so far been reported. No detailed performance analysis has so far been reported, despite the fact that the sector has undergone reforms, and has further accelerated the process of change[8].

Some researches have applied Data Envelopment Analysis (DEA) to develop Airport Construction Energy-saving measures, but none of these DEA studies have incorporated energy-saving material. In this paper, we apply Data Envelopment Analysis- Analytic Hierarchy Process (DEA-AHP) methodology to analyze the Airport Construction Energy-saving measure, Fuzzy Data Envelopment Analysis (DEA) evaluation model in Airport Construction Energy-saving have improved incomplete weight deficiency of information processing. Firstly, indices values were converted to trapezoid fuzzy numbers, then with incomplete information on indices weights as constraints, a fuzzy DEA model with outputs only and preference was established, and then by applying the α-cut approach, the model was transformed to a family of crisp DEA models and was solved. Experiments demonstrated the feasibility and applicability of the method.

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2.DEA –AHP model

2.1.DEA

Data Envelopment Analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units. There are also parametric approaches which are used for the estimation of production frontiers (see Lovell & Schmidt 1988 for an early survey). One can also combine the relative strengths from each of these approaches in a hybrid method. Data Envelopment Analysis (DEA) is a Linear Programming methodology to measure the efficiency of multiple

Comparing the relative efficiency of Decision Making Unit (DMU) through mathematical programming, DEA is the method that assesses efficiency of decision-making unit based on the concept of relative efficiency. Based on input and output data of comprehensive analysis, DEA can draw the efficiency of each DMU comprehensive quantitative indexes. Accordingly, the DMU classification ranking will determine effective (that is, relative efficiency of the highest) DMU, and point out other non-effective DMU on the causes and extent[9][10]。Now the representative DEA model, have C^2GS^2 model, FG model and ST model.

C^2GS^2 model is as follows:

$$\max\left(\mu^T Y_0 + \mu_0\right) = V_P$$

$$s.t.\begin{cases}\omega^T X - \mu^T Y_j - \mu_0 \geq 0 \\ \omega^T X_0 = 1 \\ \omega \geq 0, \mu \geq 0\end{cases} \tag{1}$$

FG model:

$$\left(P_{FG}^I\right)\begin{cases}\max\left(\mu^T Y_0 - \mu_0\right) \\ w^T X_j - \mu^T Y_j + \mu_0 \geq 0, j = 1,\ldots,n, \\ w^T X_0 = 1, \\ w \geq 0, \mu \geq 0, \mu_0 \geq 0\end{cases} \tag{2}$$

$$\left(D_{FG}^I\right)\begin{cases}\min \theta \\ \sum_{j=1}^{n} X_j \lambda_j \leq \theta X_0, \\ \sum_{j=1}^{n} Y_j \lambda_j \geq Y_0, \\ \sum_{j=1}^{n} \lambda_j \leq 1 \\ \lambda_j \geq 0, j = 1,\ldots,n, \theta \in E^1.\end{cases} \tag{3}$$

The relative answers may be:

$$T_{FG} = \left\{(X, Y) \middle| \sum_{j=1}^{n} X_j \lambda_j \leq X, \sum_{j=1}^{n} Y_j \lambda_j \geq Y, \right.$$
$$\left. \sum_{j=1}^{n} \lambda_j \leq 1, \lambda_j \geq 0, j = 1,\ldots,n \right\}$$

$\left(D_{FG}^I\right)$ has the other form:

$$\begin{cases}\min \theta, \\ \left(\theta X_0, Y_0\right) \in T_{FG}.\end{cases} \tag{4}$$

FG model is chosen in this paper. FG model is one of DEA basic models, which is an ideal method that evaluates relatively effective technology for multiple inputs and multiple outputs decision-making units. It may involve the production set which is more than one set of convex set to meet convex, invalid and the smallest assumptions of justice system.

2.2.AHP

Analytic Hierarchy Process(AHP) The AHP enables the decision makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple conflicting criteria. The AHP method makes use of pair-wise comparisons matrix, hierarchical structures, and ratio scaling to apply weights to attributes. Problems are decomposed into the hierarchy of a goal, attributes, and alternatives by the AHP method[11] shown in Figure. 1.

Table I shows the scale for comparisons. The numbers 1, 3, 5, 7 and 9 are used as scaling ratios, corresponding to the strength of preference for one element over another. For example, number 9 represents extreme importance over another element. Generally, the 9-point scale is used because the qualitative distinctions are meaningful in practice and have an element of precision when the items are compared with one another. The ability to make qualitative distinctions is well represented by the 5 possible attributes of equal, moderate, strong, very strong, and extreme.

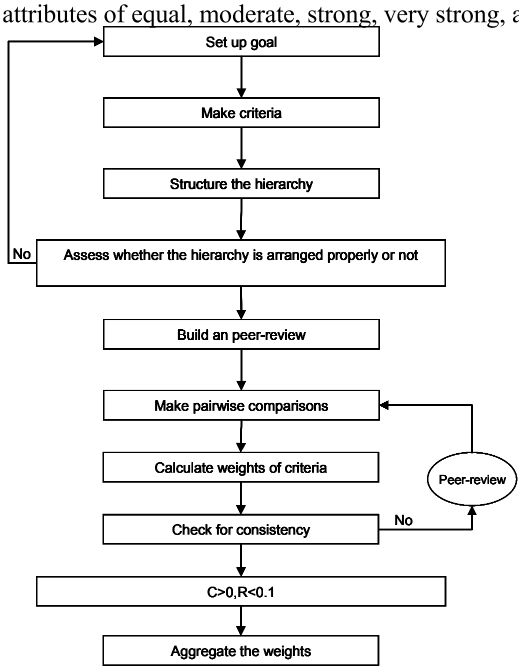

Figure1. The AHP method

TABLE I. SCALE FOR PAIRWISE COMPARISIONS

Important scale	Definition	Explanation
1	Equal important	Two elements contribute equally
3	Moderate important	One element is slightly favored over another
5	Strong important	One element is strongly favored over another
7	Very strong important	An element is very strongly favored over another
9	Extreme important	One element is the most favored over another

When we apply the AHP method to take the weights of criteria and alternatives, the decision maker should be consistent in the preference ratings. The equation below describes the process of taking the overall weights of alternatives.

$$\begin{pmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \begin{pmatrix} w \\ w_2 \\ \vdots \\ w_3 \end{pmatrix} = \begin{bmatrix} nw_1 \\ nw_2 \\ \vdots \\ nw_n \end{bmatrix} \Rightarrow AX = nX \tag{5}$$

Where a_{ij} represents the importance of alternative i over alternative j and a_{ik} represents the importance of alternative i over alternative k, a_{ij} a_{jk} must be equal to a_{ik} that is an estimate of the ratio $\frac{w_i}{w_k}$ for the judgments.

2.3. Comprehensive model

Each airport energy-saving measures as a decision unit, after pretreatment of fuzzy index (the higher the value, the more good, namely all indexes as output index as the basis, incomplete weight information of linear expression as constraint, establish only output index and contain preference information of the fuzzy DEA model, as follows:

(FG) :

$$\max \sum_{i=1}^{b} w_i r_{ik} = \tilde{E}_k .$$
$$\sum_{i=1}^{b} w_i r_{ij} \le 1, j = 1,2,...,a; \tag{6}$$
$$\mathbf{Cw} \le \mathbf{b};$$
$$w_i \ge 0.$$

Among above, the $\tilde{E}_k$ is model of optimal value, called the evaluation index proportion schemes k, $\mathbf{w} = (w_1, w_2, ..., w_m)^T$ is said each index weight a group of variable, C is $n_1 \times m$ dimension of the coefficient matrix (n_1 is weight the constraint condition of number), $\mathbf{b} = (b_1, b_2, ..., b_n)^T$ is the constant vector.

Model (FG), for a given incomplete weight information, just click on the parameters of the C and B values are properly set, can build constraint $\mathbf{Cw} \le \mathbf{b}$ this model of index eliminate the influence of dimensional and orders of magnitude, the corresponding weights with practical meaning, eliminate the traditional fuzzy DEA model the weight coefficient is not practical meaning of defects.

2.4. Model Algorithm

Model (FG) is a not directly solving fuzzy mathematical programming. To facilitate the solution model (FG) in various fuzzy number, use their own α ((0≤ α ≤1) sets of interval the model (FG) has been written for:

(FG1):

$$\max \sum_{i=1}^{m} w_i \left[(r_{ik})_\alpha^L, (r_{ik})_\alpha^U \right] = (\tilde{E}_k)_\alpha .$$
$$\sum_{i=1}^{m} w_i \left[(r_{ik})_\alpha^L, (r_{ik})_\alpha^U \right] \le 1, \ j = 1,2,...,n; \tag{7}$$
$$\mathbf{Cw} \le \mathbf{b};$$
$$w_i \ge 0.$$

Among above:

$$\left(r_{ij}\right)_\alpha^L = \min\left\{ r_{ij} | r_{ij} \in \operatorname{supp}\left(r_{ij}\right) 且 \mu_{r_{ij}}\left(r_{ij}\right) \ge \alpha \right\}$$
$$\left(r_{ij}\right)_\alpha^U = \max\left\{ r_{ij} | r_{ij} \in \operatorname{supp}\left(r_{ij}\right) 且 \mu_{r_{ij}}\left(r_{ij}\right) \ge \alpha \right\}$$

For any given α value, in its evaluation index $\left[(r_{ik})_\theta^L, (r_{ik})_\theta^U \right]$ sets interval α scope changes, its value but can small. Therefore, all evaluation indexes of any kind of portfolio corresponds to an evaluation results. In order to determine the model (FG) in the confidence level to α when the optimal solution of the change of scope, will model (FG1) is decomposed into pessimistic programming model and optimistic programming model[12].

Pessimism model (P-FG):

$$\max \sum_{i=1}^{m} w_i \left(r_{ik}\right)_\alpha^L = \left(E_k\right)_\alpha^L$$

s.t. $\sum_{i=1}^{m} w_i \left(r_{ik}\right)_\alpha^L \le 1$

$$\sum_{i=1}^{m} w_i \left(r_{ij}\right)_\alpha^U \le 1, j-1,2,...,n, j \ne k; \tag{8}$$

$\mathbf{Cw} \le \mathbf{b}$;

$w_i \ge 0.$ ∘

Optimistic model（O-FP）:

$\max \sum_{i=1}^{m} w_i \left(r_{ik}\right)_\alpha^U = \left(E_k\right)_\alpha^U$

s.t. $\sum_{i=1}^{m} w_i \left(r_{ik}\right)_\alpha^L \le 1$

$$\sum_{i=1}^{m} w_i \left(r_{ij}\right)_\alpha^L \le 1, j=1,2,...,n, j \ne k; \tag{9}$$

$\mathbf{Cw} \le \mathbf{b}$;

$w_i \ge 0.$

Model (P-FG) and (O-FP) is deterministic linear programming model, which can be directly obtained solution, the optimal solution is $\left(E_k\right)_\alpha^L$ and $\left(E_k\right)_\alpha^U$. $\left(E_k\right)_\alpha^L$ and $\left(E_k\right)_\alpha^U$ respectively representation model in the confidence level of α when the objective function values of the minimum and maximum. In these two optimal solution for boundary constitute the interval number $\left[\left(E_k\right)_\alpha^L, \left(E_k\right)_\alpha^U\right]$ is k in namely for scheme for α confidence level when interval of assessment index. For any $k\left(k=1,2,...,n\right)$, repeat solution (P-FG) model and(O-FG)model, piecing get all the scheme in the confidence level as α when interval estimate index $\left(E_k\right)_\alpha^U$, based on this, judgment in the confidence level of each scheme for α when of the pros and cons. Therefore, the algorithm can overall recognition and understanding each high-performance concrete proportion schemes of comprehensive attributes.

TABLE II. AIRPORT CONSTRUCTION ENERGY-SAVING MATERIAL EVALUATION INDEX

INDEX NO.	Palisade structure strength	Flight planning rationality			Lighting sex	Heat preservation	Ventilated sex
		R_7	R_{28}	R_{90}			
1（x_1）	190	27.0	39.0	48.0	920	optimal	295.17
2（x_2）	180	39.3	46.7	60.5	782	optimal	294.695
3（x_3）	170	37.5	42.0	49.5	1005	fine	300.06
4（x_4）	180	35.5	48.0	55.0	980	middle	301.595
5（x_5）	180	36.5	47.5	57.0	950	fine	304.05

TABLE III. THE EVALUATION INDEX OF FUZZY INDEX

RATIO / INDEX	x_1	x_2	x_3	x_4	x_5
Palisade structure strength	1,1,1,1	0.5,0.5,0.5,0.5	0,0,0,0	0.5,0.5,0.5,0.5	0.5,0.5,0.5,0.5
Flight planning rationality	0,0,0,0	0.86,0.86,0.86,0.86	0.33,0.33,0.33,0.33	1,1,1,1	0.94,0.94,0.94,0.94
Lighting sex	0.38,0.38,0.38,0.38	1,1,1,1	0,0,0,0	0.11,0.11,0.11,0.11	0.25,0.25,0.25,0.25

Heat preservation	0.7,1.0,1.0,1.0	0.7,1.0,1.0,1.0	0,0.3,0.3,0.5	0.2,0.5,0.5, 0.8	0,0.3,0.3,0.5
Ventilated sex	0.95,0.95,0.95,0.95	1,1,1,1	0.43,0.43,0.43,0.43	0.26,0.26,0.26,0.26	0,0,0,0

TABLE IV. BASED ON THE RESULTS OF THE EVALUATION OF WEIGHT ORDER RELATION

	x_1	x_2	x_3	x_4	x_5
0.0	(0.5191,0.5491)	(0.8872,0.9172)	(0.2052,0.2552)	(0.4349,0.4949)	(0.3663,0.4163)
0.1	(0.5221,0.5491)	(0.8902,0.9172)	(0.2082,0.2532)	(0.4349,0.4949)	(0.3693,0.4143)
0.2	(0.5251,0.5491)	(0.8932,0.9172)	(0.2112,0.2512)	(0.4349,0.4949)	(0.3723,0.4123)
0.3	(0.5281,0.5491)	(0.8962,0.9172)	(0.2142,0.2492)	(0.4349,0.4949)	(0.3753,0.4103)
0.4	(0.5311,0.5491)	(0.8992,0.9172)	(0.2172,0.2472)	(0.4349,0.4949)	(0.3783,0.4083)
0.5	(0.5341,0.5491)	(0.90272,0.9172)	(0.2202,0.2452)	(0.4349,0.4949)	(0.3813,0.4063)
0.6	(0.5371,0.5491)	(0.9052,0.9172)	(0.2232,0.2432)	(0.4349,0.4949)	(0.3843,0.4043)
0.7	(0.5401,0.5491)	(0.9082,0.9172)	(0.2262,0.2412)	(0.4349,0.4949)	(0.3873,0.4023)
0.8	(0.5431,0.5491)	(0.9112,0.9172)	(0.2292,0.2392)	(0.4349,0.4949)	(0.3903,0.4003)
0.9	(0.5461,0.5491)	(0.9142,0.9172)	(0.2322,0.2372)	(0.4349,0.4949)	(0.3933,0.3983)
1.0	(0.5491,0.5491)	(0.9172,0.9172)	(0.2352,0.2352)	(0.4349,0.4949)	(0.3963,0.3963)

3.Case analysis

3.1.Airport construction energy conservation's indexes

According to the literature[7] provided data, conduct concrete with scheme evaluation, each index data in table II [13] .

Data preprocessing

According to the table II , quantified it as trapezoidal fuzzy number form, and the evaluation index of pretreatment method according to the standard treatment, the results as shown in TABLEIII.[14]

3.2.The determination of weight vectors

These five kinds of measures involved the palisade structure strength, flight planning rationality in engineering requirements within the permitted to engineering, less influence, but should not be ignored. And day lighting sex, heat preservation, ventilated sex three index importance quite, so as to determine weight vectors, 0.27 for (0.09, 0.27, 0.1, 0.27)[15].

By (0.09, 0.27, 0.27, 0.1, 0.27) knowable, five evaluation index, day lighting sex, heat preservation, ventilated sex is equal and value of the weight of the largest. For simplified sake, not consider the rest two indexes of the relative importance of relationship between, namely, known for weight information $w_2 = w_3 = w_5, w_2 - w_j \geq 0.15(j = 1,4)$ put $w_2 = w_3 = w_5, w_2 - w_j \geq 0.15(j = 1,4)$ and $\sum_{i=1}^{5} w_i = 1$ get together with $\mathbf{Cw} \leq \mathbf{b}$, then get the evaluation model.

3.3.Airport energy-saving index weight analysis

According to the above model and the weights of the order relation representation method, and separately calculated and five measures in different α confidence level under evaluation result, as shown in tableⅣ.

From the tableⅣ,for different α value, five measures based on the order relation of sorting and the weights of the sorting are exactly the same, all is $x_2 > x_1 > x_4 > x_5 > x_3$. As the evaluation result, the greater the scheme, so the better plan 2 is the optimum scheme, this result with literature[11] measure model using the obtained results consistent, proved the feasibility and effectiveness of this method. In addition, five measures based on order relation rank in the weights of the sorting identical also explain evaluation results of the confidence level α change not sensitive.

4.Conclusion

This paper applies a DEA method that is combined with AHP to jointly analyze Airport Construction Energy-saving several important conclusions are evident.. Based on the index, the index weight with incomplete information of Airport

Construction Energy-saving evaluation problems, and puts forward the improved fuzzy DEA evaluation model. This model will first index convert dimensionless fuzzy number, and then, with the converted fuzzy number as the basis, incomplete weight information as constraint, and fuzzy DEA model was improved, and established based on the improved fuzzy DEA of concrete proportion schemes evaluation model, and gives the corresponding solving algorithm. In case analysis view of, also contains deterministic quantitative indices and qualitative index of the problem, respectively based on interval Numbers weight, ordering relationship weight two incomplete weight information as an example, the validity of this method. For other forms of evaluation indexes and incomplete weight information, solving process is similar.

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