A SDV-MOORA Approach for Ranking Facility Locations

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Abstract: The suitability of a specific location for proposed facility operations depends largely on what location factors are selected and evaluated as well as their potential impact on corporate objectives and operations. Facility location problem is a typical Multi Criteria Decision Making (MCDM) problem which involves many conflicting attributes. In this paper we try to tackle this well known problem by combining the Standard Deviation to allocate the weights, then combining the proposed method to Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) technique. An international company's facility location problem of a new manner is illustrated. The new approach so-called SDV-MOORA is employed to solve the MCDM problem.

[Mohamed F. El-Santawy and Ramadan A. Zean El-Dean. **A SDV-MOORA Approach for Ranking Facility Locations.** *Life Sci J* 2012;9(2s):120-122]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 22

Keywords: Facility Locations; Multi-Criteria Decision Making; MOORA; Standard Deviation.

1. Introduction

Facility location problem implies more than one dimension, many factors should be considered when comparing alternatives to choose among or rank them. Factors involved are classified into financial, economic, location parameters and others. These conflicting criteria in the process of selecting a new facility location constitute a Multi-Criteria Decision Making (MCDM) problem [6]. Many organizations want to expand their operations through allocating new facilities. The facility location decision process combines the identification, analysis, evaluation of, and selection among alternatives [4]. The MCDM includes many solution techniques such as Simple Additive Weighting (SAW), Weighting Product (WP) [7], and Analytic Hierarchy Process (AHP) [9]. The problem of allocating the weights of criteria when no preference is an open research area. Many scholars tried to tackle this problem by various techniques like Information Entropy Weight method, the weighted average operator (OWA), and other several methods [5].

In this paper, a new facility location problem existing in a multi-national company is presented. In which we try to explore the applicability of the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method by employing the Standard Deviation to allocate weights, in order to solve the facility location problem presented when no preference exist. The new method so-called SDV-MOORA is applied for ranking alternatives in the case study given. The rest of this paper is organized as follows: Section 2 is made for the MOORA approach, the proposed Standard Deviation method is illustrated in section 3, the case study of the facility location problem is presented in section 4, and finally section 5 is made for conclusion.

2. MOORA

A MCDM problem can be concisely expressed in a matrix format, in which columns indicate criteria (attributes) considered in a given problem; and in which rows list the competing alternatives. Specifically, a MCDM problem with m alternatives ($A_1, A_2, \ldots, A_m$) that are evaluated by n criteria ($C_1, C_2, \ldots, C_n$) can be viewed as a geometric system with m points in n-dimensional space. An element x_{ij} of the matrix indicates the performance rating of the i^{th} alternative A_i, with respect to the j^{th} criterion C_j, as shown in Eq. (1):

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (1)$$

Brauers first introduced the MOORA method in order to solve various complex and conflicting decision making problems [3]. The MOORA method starts with a decision matrix as shown by Eq. (1). The procedure of MOORA for ranking alternatives can be described as following:

Step 1: Compute the normalized decision matrix by vector method as shown in Eq. (2)

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}, \quad i = 1, \ldots, m; \; j = 1, \ldots, n. \quad (2)$$

Step 2: Calculate the composite score as illustrated in Eq. (3)

$$z_i = \sum_{j=1}^{b} x_{ij}^* - \sum_{j=b+1}^{n} x_{ij}^*, \quad i = 1,...,m. \quad (3)$$

where $\sum_{j=1}^{b} x_{ij}^*$ and $\sum_{j=b+1}^{n} x_{ij}^*$ are for the benefit and non-benefit (cost) criteria, respectively. If there are some attributes more important than the others, the composite score becomes

$$z_i = \sum_{j=1}^{b} w_j x_{ij}^* - \sum_{j=b+1}^{n} w_j x_{ij}^*, \quad i = 1,...,m. \quad (4)$$

where W_j is the weight of j^{th} criterion.

Step 3: Rank the alternative in descending order.

Recently, MOORA has been widely applied for dealing with MCDM problems of various fields, such as economy control [2], contractor selection [1], and inner climate evaluation [8].

3. Standard Deviation for allocating weights

In this paper, the well known standard deviation (*SDV*) is applied to allocate the weights of different criteria. The weight of the criterion reflects its importance in MCDM. Range standardization was done to transform different scales and units among various criteria into common measurable units in order to compare their weights.

$$x'_{ij} = \frac{x_{ij} - \min_{1 \le j \le n} x_{ij}}{\max_{1 \le j \le n} x_{ij} - \min_{1 \le j \le n} x_{ij}} \quad (5)$$

$D'=(x')_{mxn}$ is the matrix after range standardization; max x_{ij}, min x_{ij} are the maximum and the minimum values of the criterion (j) respectively, all values in D' are ($0 \le x'_{ij} \le 1$). So, according to the normalized matrix $D'= (x')_{mxn}$ the standard deviation is calculated for every criterion independently as shown in Eq. (6):

$$SDV_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (x'_{ij} - \bar{x}'_j)^2} \quad (6)$$

where $\bar{x}'_j$ is the mean of the values of the j^{th} criterion after normalization and $j = 1,2,\ldots,n$.

After calculating (*SDV*) for all criteria, the weight (W_j) of the criterion (j) can be defined as:

$$W_j = \frac{SDV_j}{\sum_{j=1}^{n} SDV_j} \quad (7)$$

where $j = 1,2,\ldots,n$.

4. Facility Location Problem

A German multi-national company that works in hyper supermarkets has many branches in several countries like Turkey, Germany, France, Italy and more than 30 other countries. Three years ago, the strategic planning department in the German company had prepared a long-term plan to enter the Egyptian market; consequently the feasibility and economic aspects had been studied for constructing more than 40 branches all over Egypt of total investment exceeding 2 milliards. During the last two years the company had acquired 8 locations (lands of the branches); the company after prepared the feasibility study, budgets for each branch to be opened. The company employed many Egyptian consultants; expert houses as well as technical companies specialized in marketing analysis, surveys and decision support systems during the planning phase and preparing the feasibility study. As a part of this consulting the company wants to know what location (branch) is preferable to start with. Selecting accurately the branch to construct first will be reflected on the company's whole long-term plan to be achieved. The process of ranking the 8 branches in order to select optimally the branch to begin with is a typical facility location problem which is a MCDM problem. Table 1 shows the location of each branch acquired by the company and its given index for simplicity.

Table 1: Locations of branches

Index	Branch Location
B1	Alexandria
B2	Cairo-Alexandria desert road (kilo 17)
B3	El-Salam city
B4	El-Sherouk city
B5	Cairo-Alexandria agriculture road (kilo 30)
B6	6-October city
B7	Assiut
B8	Port-said

The criteria to be compared is limited by the company to be 5 criteria. The values of C_1 are extracted directly from the feasibility study prepared for each branch, and presented in millions of L.E. C_2 describes the number of expected customers to visit the branch in thousands per week. C_3 is computed as a rank from 1 to 9 by specialized consulting companies. C_4 is the distance in kilometres from the nearest industrial zone to the branch location; finally C_5 is the completion time of constructing each branch computed in days. Table 2 shows the criteria, their computation units as given by the company.

Table 2: Criteria and their relevant weights

Index	Branch Location	Units
C_1	Initial Costs	Millions of L.E.
C_2	Expected Customers	1000 customers
C_3	Infra-Structure	Grade from 1-9
C_4	Industrial zone Neighbourhood	Kilo meters
C_5	Completion Time	Days

The company presented the data included in the decision matrix found in Table 3 showing the 8 alternatives and their performance ratings with respect to all criteria.

Table 3: Decision matrix

Index	C_1	C_2	C_3	C_4	C_5
B1	11.2	10.6	7	5.4	103
B2	15.4	8.5	6.9	6.5	150
B3	13.2	14	5	2.3	143
B4	12	12	9	1.5	125
B5	14	5.3	8	6	166
B6	16	7.9	6.4	7	180
B7	17.4	6	5.5	4.5	135
B8	19.5	13.4	7.5	3.3	200

In the above example, the Standard Deviation method is employed to allocate the weights. Table 4 illustrates the range standardization done to decision matrix as in Eq.(5).

Table 4: Range standardized decision matrix

Index	C_1	C_2	C_3	C_4	C_5
B1	0	0.609	0.5	0.709	0
B2	0.506	0.368	0.475	0.909	0.485
B3	0.241	1	0	0.145	0.412
B4	0.096	0.77	1	0	0.227
B5	0.337	0	0.75	0.818	0.649
B6	0.578	0.299	0.35	1	0.794
B7	0.747	0.08	0.125	0.545	0.33
B8	1	0.931	0.625	0.327	1

Table 5 shows the values of the Standard Deviation (SDV_j), and the weight assigned to each criterion (W_j) as shown in Eqs. (6 and 7). The weights' assignment process is very sensitive which will be reflected on the final ranking of the alternatives.

Table 5: Weights assigned to criteria

	SDV_j	W_j
C_1	0.3366	0.1948
C_2	0.3788	0.2192
C_3	0.3247	0.1879
C_4	0.3672	0.2126
C_5	0.3205	0.1855

By applying the procedure of MOORA, the normalized decision matrix found in Table 4 is used. In Table 6, the benefit, cost, and composite scores are listed for all alternatives. The fourth location (El-Sherouk city) should be selected because it has the maximum composite score.

Table 6: Ranking lists and scores

	Benefit criteria	Cost criteria	Composite score	Rank
B1	0.13496816	0.0814	0.0535209	2
B2	0.10179664	0.2246	-0.1227639	5
B3	0.12527576	0.0947	0.03053382	3
B4	0.21377821	0.0383	0.17547259	**1**
B5	0.08797611	0.2115	-0.1235239	6
B6	0.07849425	0.2797	-0.2011938	8
B7	0.02474234	0.1958	-0.171078	7
B8	0.18994948	0.2799	-0.0899316	4

10/26/2012

5. Conclusion

In this paper, a new method to solve MCDM problems is presented and illustrated. A real-life facility location problem of a new manner existing in multi-national company is introduced. The Standard Deviation (SDV) is incorporated to Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) technique in order to determine weights when no preference exists. It might be combined to other MCDM techniques in further research.

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