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A CASE STUDY OF SUPPLIER SELECTION FOR A STEELMAKING COMPANY IN LIBYA BY USING THE COMBINATIVE DISTANCE-BASED ASSESSMENT (CODAS) MODEL

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Abstract: *Multi-Criteria Decision Making (MCDM) problems have received considerable attention from various researchers over the past decades. A great variety of methods and approaches has been developed in this field. The aim of this paper is to use a new COmbinative Distance-based ASsessment (CODAS) method to handle MCDM problems for a steelmaking company in Libya. So far no literature dealing with supplier selection using the (CODAS) method in the steelmaking company in Libya has been found. The concept of this method is based on computing the Euclidean distance and the Taxicab distance in order to determine the desirability of an alternative. The Euclidean distance is used as a primary measure, while the Taxicab distance as a secondary one. The developed method was applied to a real-world case study for ranking the suppliers in the Libyan Iron and Steel Company (LISCO). An attempt in this regard could enhance a decision-making technique for selecting the best suppliers for the selected case company. The results showed that the proposed method was effectively able to select the best supplier among six alternative ones.*

Key words: *Criteria, CODAS, Combinative, Supplier, Selection, Assessment.*

1. Introduction

Today's competitive manufacturing sector presents a challenge to provide high quality products while offering competitive prices to the final customers. Goffin et al. (1997) have indicated that the supplier management is one of the key issues of the supply chain management because the total cost of raw materials constitutes the final cost of a product, and most of the companies have to spend a considerable amount of

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their budget on them. In most industries, the cost of raw materials constitutes the main cost of a product so that in some cases it can account for up to 70% (Kilincci & Onal, 2011). Thus, the financial department can play a key role in the firm's efficiency and effectiveness since this department has a direct effect on the final cost reduction and profitability of a company by selecting suitable suppliers. Hence, selecting the best suppliers involves much more than scanning a series of price lists, and choices will depend on a wide range of criteria which involve both qualitative and quantitative ones. Recently, supplier evaluation and selection have received significant attention from various researchers in the literature (De Boer et al., 2001; Govindan et al., 2015; Chai et al., 2013; Prakash et al., 2015; Ghorabaee et al., 2015). Supplier selection is a multi-criteria problem which includes both qualitative and quantitative factors (Liang et al., 2013). Generally, the criterion for supplier selection is highly dependent on individual industries and companies. Therefore, different companies have different management strategies, enterprise culture and competitiveness. Furthermore, company background causes a huge difference and impacts supplier selection. Thus, the identification of the supplier selection criteria largely requires the domain expert's assessment and judgment. To select the best supplier, it is necessary to make a trade-off between these qualitative and quantitative factors (weights) some of which may conflict (Ghodsypour & O'Brien, 1998). The traditional supplier selection methods are often based on the quoted price, which ignores significant direct and indirect costs associated with quality, delivery, and service cost of purchased materials. Uncertainty occurs because the future can never be predicted. The selection of the best supplier is based on quoted price and considering all the possibilities of the analysis. However, there is always uncertainty about indirect costs associated with quality, delivery time, and others. One of the key problems in supplier selection is to find the best supplier among several alternatives according to various criteria, such as service, cost, risk, and others. After identifying the criteria, a systematic methodology is required to integrate experts' assessments in order to find the best supplier. At present, various methods have been used for supplier selection such as analytic network process (ANP) (Porras-Alvarado et al., 2017) and analytical hierarchy process (AHP) (Porras-Alvarado et al., 2017).The following paragraphs will introduce a discussion of important and widely used MCDM techniques most of which aim at selecting the best supplier.

AHP is a common multi-criteria decision- making (MCDM) method. It is developed by Saaty (Saaty, 1990; Saaty, 1979) to provide for a flexible and easily understood way of analyzing complex problems. It breaks a complex problem into hierarchy or levels, and then makes comparisons between all possible pairs in a matrix to give a weight for each factor and a consistency ratio. According to (Chai et al., 2013) the AHP method is found to have been used more than any other MCDM method. However, the AHP methodology is focused on weighting relative importance of the criteria, while dependencies among them are neglected. Chan & Chan (2004) have used the AHP to evaluate and select suppliers. The AHP hierarchy consists of six evaluating criteria and 20 sub-factors, of which the relative importance ratings are calculated based on the customer needs. Chan et al. (2007) also researched this area by developing an AHP approach to solve the supplier selection problem. Possible suppliers were evaluated based on fourteen criteria. A sensitivity analysis using the "Expert Choice" software was performed to examine the response of alternatives when the relative importance rating of each criterion was changed. Jiang et al. (2007) developed an AHP-based decision support system for the supplier selection problem in a mass customization environment. Factors from external and internal influences were taken into consideration in order to meet the needs of the markets in the global changing environment. Each cluster at the same level in a pairwise manner was compared by experts based on their own knowledge.

Mathematically and philosophically, the AHP is capable of providing for an easily understandable method to practitioners; however, it is insufficient to explain uncertain conditions in an especially pair-wise comparison stage. Most of human's judgments are not represented as exact numbers. Since some of the evaluation criteria are subjective and qualitative in nature, it is very difficult for the decision-maker to express his preferences in exact numerical values and to provide exact pair-wise comparison judgments. As a result, to tackle these problems, the AHP has been integrated with other methods, including the ANN (Kuo et al., 2002), fuzzy set theory (Jain et al., 2016; Gold & Awasthi, 2015; Pamučar et al., 2012; Božanić et al. 2016), grey relational analysis (Liang et al., 2015; Yang & Chen; 2006, Bali et al., 2013), and a combination of different methods (Zakeri & Keramati, 2015). It seems, however, that the growth of AHP applications may derive more from a simplification perspective rather than from a robust theoretical mathematical perspective.

The Grey systems theory, introduced by Deng in the early 1980s (Deng, 1982), is another methodology that focuses on solving problems involving incomplete information. The technique works on uncertain systems with partially known information by generating, mining, and extracting useful information from available data. The Grey theory considers that although the objective system appears complex, with a small amount of data, it always has some internal laws governing the existence of the system and its operation (Liu et al., 2010). A grey number is a kind of figure whose range of values we know only – without knowing an exact value (Liu et al., 2012). This number can be an interval or a general number set to represent the degree of uncertainty of information. Grey systems theory in a decision-making process is very useful to tackle the disadvantage of AHP. Abdulshahed et al. (2017) used an integrated model by combining the Grey model and Grey numbers and examined the feasibility of their approach to select the best suppliers. They applied a Grey model to calculate relative importance weightings of qualitative criteria. A supplier with the highest value was regarded as the best supplier in an outsourcing manufacturing organization.

All the above-mentioned MCDM methods have their own privilege, strength, and weakness for certain applications; however, their estimate is not the aim of this paper. In general, the best supplier selection is still an ill-defined problem. It generally relies on uncertain information, which is not easy to model and is based on the experiences of specialists. This work uses a new developed method to handle multi-criteria decision making problems by Ghorabaee et al. (2015); this method is named CODAS, and has a number of features that have not been considered in the other MCDM methods. For instance, in (Keshavarz Ghorabaee et al., 2016), the CODAS method has been compared with some of the existing MCDM methods. According to their analysis, the CODAS method was efficient to deal with MCDM problems. Ghorabaee et al. (2017) also used an integrated model by combining the fuzzy logic theory and the CODAS method to select the best suppliers. In their work, a fuzzy extension of the CODAS method was developed to deal with multi-criteria decision-making problems in an uncertain environment. They used linguistic variables and trapezoidal fuzzy numbers to extend the CODAS method and propose a multi-criteria group decision-making approach. A numerical example of a shoe company was utilized to show the applicability of their method in multi-criteria market segment evaluation and selection. The results indicate that the fuzzy CODAS method was consistent with the results of the other method in the literature. Panchal et al. (2017) applied an integrated MCDM framework based on the fuzzy AHP and a fuzzy CODAS approach for solving the maintenance decision problem in a process industry. In order to overcome vagueness in human judgment, they have incorporated a fuzzy set theory within the proposed framework. The sensitivity results confirmed the stability of their framework. In the CODAS method, the overall performance of an alternative is measured by the Euclidean and Taxicab distances from the negative-ideal point. The CODAS use the Euclidean distance as the primary measure of assessment. If the Euclidean distances of two alternatives are very close to each other, then the Taxicab distance is used to compare them. The degree of closeness of Euclidean distances is set by a threshold parameter. The Euclidean and Taxicab distances are measures for norm and norm indifference spaces, respectively. Therefore, in the CODAS method, first the alternative in a norm indifference space is assessed. If the alternatives are not comparable in this space, then an -norm indifference space is chosen. To perform this process, each pair of alternatives should be compared. In this study, the CODAS method is presented in detail, and a numerical example will be illustrated. Moreover, a comparative sensitivity analysis is performed to measure the validity and stability of this method.

The proposed CODAS method will be implemented to evaluate the suppliers of raw materials to the Libyan Iron and Steel Company (LISCO). LISCO is a large scale, government owned company. The production capacity of the company is about 1,324,000 tons of liquid steel (Taib, 2011). In the last two decades, the company had almost met the demand for its products in the local market, and managed to compete globally. It has started to export its products to Egypt, Tunisia, Qatar and others. LISCO is working against the odds to help rebuild the country’s economy after the 2011 revolution and is doing so with a carefully considered strategy to expand its 60% iron and steel market share in Libya. The importation of raw material is an important step towards maintaining and improving its market share in a competitive environment. Quality and cost of its final products are intimately connected to the proper selection of a supplier of sponge iron to the direct reduction, mega-scale factories. LISCO usually imports sponge iron from India, Brazil, Canada, Sweden. Suppliers from other countries also consider LISCO as a potential customer. Since suppliers have variable strengths and weaknesses, careful assessment and evaluation by the client is crucial before orders could be placed.

2. Research Methodology

In this section, a new method (CODAS) is introduced to deal with multi-criteria decision-making problems. In this method, the desirability of alternatives is determined by using two measures. The main and primary measure is related to the Euclidean distance of alternatives from the negative-ideal. Using this type of distance requires an -norm indifference space for criteria. The secondary measure is the Taxicab distance, which is related to the -norm indifference space. Clearly, the alternative which has greater distances from the negative-ideal solution is more desirable. In this method, if two alternatives are incomparable according to the Euclidean distance, then the Taxicab distance is used as a secondary measure. Although the -norm indifference space is preferred in the CODAS, two types of indifference space could be considered in its process. Based on the assumption that alternatives and criteria are available, the steps of the proposed method can then be presented as follows:

Step 1. Construct the decision-making matrix as follows:

$$X = \left[x_{ij}\right]_{n\times m} = \begin{bmatrix} x_{11}x_{12} & \cdots & x_{1m} \\ x_{21}x_{22} & \cdots & x_{2m} \\ . \quad . & . & . \\ x_{n1}x_{n2} & \cdots & x_{nm} \end{bmatrix}$$

where x_{ij} ($x_{ij} \geq 0$) denotes the performance value of i th alternative on j th criterion ($i \in \{1,2,\dots,n\}$ and $j \in \{1,2,\dots,m\}$).

Step 2. Calculate the normalized decision matrix. Linear normalization of performance values is used as given by equation (1).

$$n_{ij} = \begin{cases} \frac{x_{ij}}{max_i x_{ij}} & if\ j \epsilon N_b \\ \frac{min_i x_{ij}}{x_{ij}} & if\ j \epsilon N_c \end{cases} \tag{1}$$

where N_b and N_c represents the sets of benefit and cost criteria, respectively.

Step 3. Calculate the weighted normalized decision matrix. The weighted normalized performance values are calculated as given by equation (2).

$$r_{ij} = w_j n_{ij} \tag{2}$$

Where w_j ($0 < w_j < 1$) denotes the weight of j *th* criterion, and $\sum_{j=1}^{m} w_j = 1$.

Step 4. Determine the negative-ideal solution (point) as given in equation (3).

$$ns = \left[ns_j\right]_{1\times m}$$

$$ns_j = min_i r_{ij} \tag{3}$$

Step 5. Calculate the Euclidean and Taxicab distances of alternatives from the negative-ideal solution as given in equations (4) and (5), respectively.

$$E_i = \sqrt{\sum_{j=1}^{m} \left(r_{ij} - ns_j\right)^2} \tag{4}$$

$$T_i = \sum_{j=1}^{m} \left|r_{ij} - ns_j\right| \tag{5}$$

Step 6. Construct the relative assessment matrix as given in equation (6).

$$R_a = [h_{ik}]_{n\times n} \tag{6}$$

$$h_{ik} = (E_i - E_k) + \left(\psi(E_i - E_k) \times (T_i - T_k)\right)$$

Where $k \in \{1, 2, \dots, n\}$ and ψ denotes a threshold function to recognize the equality of the Euclidean.

$$\psi(x) = \begin{cases} 1 & if\ |x| \geq \tau \\ 0 & if\ |x| < \tau \end{cases}$$

In this function, τ is the threshold parameter that can be set by the decision-maker. It is suggested to set this parameter at a value between 0.01 and 0.05. If the difference between Euclidean distances of two alternatives is less than τ, these two alternatives are also compared by the Taxicab distance. In this study, it is assumed that $\tau = 0.02$ for the calculations.

Step 7. Calculate the assessment score of each alternative as given by equation (7).

$$H_i = \sum_{k=1}^{n} h_{ik} \tag{7}$$

Step 8. Rank the alternatives according to the decreasing values of assessment score (H). The alternative with the highest H is the best choice among the alternatives.

To describe the proposed method, a simple situation with seven alternatives and two criteria is used. Suppose that weighted normalized performance values (r_{ij}) have been calculated. These values are dimensionless and between 0 and 1. Fig. 1 shows the position of all alternatives according to these values.

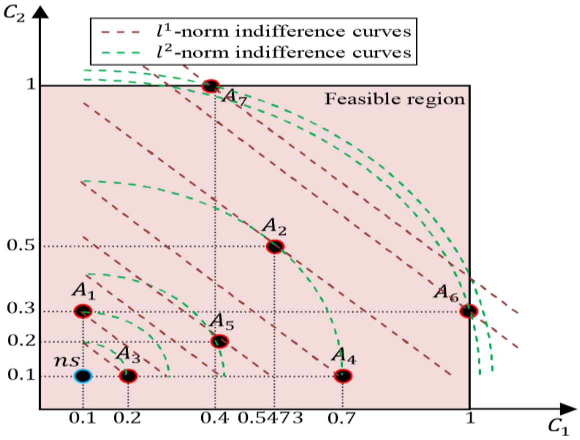

Figure 1. A simple graphical example with two criteria(Keshavarz Ghorabaee et al., 2016)

It can be seen in Figure 1, that A_2 has greater Taxicab distance from the negative-ideal point. This fact is clear according to the indifference curves, which is presented in Figure 1. Therefore, we can say that A_2 is more desirable than A_4, and the final ranking is $A_3 < A_1 < A_5 < A_4 < A_2 < A_6 < A_7$.

3. Results

Establishing the criteria is the first step in the process of supplier selection. In this paper, qualitative criteria are identified based on questionnaire forms. In order to facilitate the solution process for the supplier selection problem, macros in MS Excel were used to compute the model based on the questionnaire forms that have been filled in by the experts and managers who work in LISCO.

Four different criteria which are considered in this supplier selection problem are: Quality (in points) Direct Cost (in $), Lead time (in days), Logistics services (in points). All these criteria are defined as benefit criteria, except that the cost is defined as a cost criterion. This problem consists of six suppliers, and the corresponding data are given in Table 1. Every criterion has been given weight by experts, and the total weight of all criteria is 1.0. Experts also give weights for the suppliers for each criterion.

Based on Table 1, the decision matrix can be constructed. Then the normalized decision matrix is calculated as shown in Table 2.

Table 1. Data of the case study

	Weights of	0.2857	0.3036	0.2321	0.1786
Alternatives	Suppliers	Quality	Direct Costs ($)	Lead Time (Days)	Logistics service
	S1	45	3,600	45	0.9
	S2	25	3,800	60	0.8
	S3	23	3,100	35	0.9
	S4	14	3,400	50	0.7
	S5	15	3,300	40	0.8
	S6	28	3,000	30	0.6

For each criterion, this can be done by dividing each weight of the suppliers by the maximum weight of this criterion.

Table 2. The normalized decision matrix

Alternatives	Quality	Direct Costs ($)	Lead Time (Days)	Logistics Service
	1.000	0.833	0.750	1.000
	0.556	0.789	1.000	0.889
	0.511	0.968	0.583	1.000
	0.311	0.882	0.833	0.778
	0.333	0.909	0.667	0.889
	0.622	1.000	0.500	0.667

Using weights of criteria that are given in Table 1, the weighted normalized performance values can be calculated, and then the negative-ideal solution is determined. According to the obtained values, the Euclidean and Taxicab distances of alternatives from the negative-ideal solution are also computed. The results are presented in Table 3.

Table 3. The weighted normalized decision matrix and the negative-ideal solution

Alternatives	Quality	Direct Costs ($)	Lead Time (Days)	Logistics Service	Distances	
					Euclidean	Taxicab
	0.2857	0.2530	0.1741	0.1786	0.2141	0.3277
	0.1587	0.2397	0.2321	0.1588	0.1411	0.2256
	0.1460	0.2938	0.1354	0.1786	0.1006	0.1901
	0.0889	0.2679	0.1934	0.1389	0.0847	0.1254
	0.0952	0.2760	0.1547	0.1588	0.0666	0.1210
	0.1778	0.3036	0.1161	0.1191	0.1095	0.1528
Negative-ideal	0.0889	0.2397	0.0719	0.1191		

The relative assessment matrix and the assessment scores (H) of alternatives can be calculated by using Table 3 and Eq. (6). Table 4 represents the results. It should be noted that the calculations are performed with $\tau = 0.02$.

Table 4. The relative assessment matrix and the assessment scores of alternatives

S1	S2	S3	S4	S5	S6	H
0.00	0.175	0.2511	0.3317	0.3540	0.2790	1.3914
-0.175	0.00	0.0760	0.1566	0.1790	0.1040	0.3411
-0.2511	-0.0760	0.00	0.0159	0.1030	-0.0090	-0.2170
-0.3316	-0.1570	-0.0159	0.00	0.0180	-0.0520	-0.5381
-0.3542	-0.1790	-0.1031	-0.0181	0.00	-0.075	-0.7292
-0.2795	-0.104	0.0089	0.0521	0.0750	0.00	-0.2481

As can be seen from Table (4), the highest H is supplier1. Therefore, S1 is the best supplier with respect to the assessment of the CODAS method. In addition, a sensitivity analysis has been conducted to demonstrate the validity and stability of the CODAS method. According to the results of the sensitivity analysis, it was found that the CODAS method is stable and efficient to deal with multi-criteria decision-making problems.

Fourteen values of τ ranged between 0.01 and 1.00 are used to evaluate their effect on suppliers ranking. Table 5 shows the values of τ and their effect on suppliers ranking.

Table 5. Suppliers ranking with different values of τ

Scen.	τ										
	0.01	0.02	0.03	0.04	0.05	...	0.10	0.15	0.30	0.50	1.00
S1	1	1	1	1	1	...	1	1	1	1	1
S2	2	2	2	2	2		2	2	2	2	2
S3	3	3	3	4	4		4	4	4	4	4
S4	5	5	5	5	5		5	5	5	5	5
S5	6	6	6	6	6		6	6	6	6	6
S6	4	4	4	3	3		3	3	3	3	3

Figure 2 shows the effect graphically, which is clear that the first supplier (S1) is the best regardless of τ value. Changing parameter τ has a minor effect on the ranking of alternatives that can undermine the validity of the results.

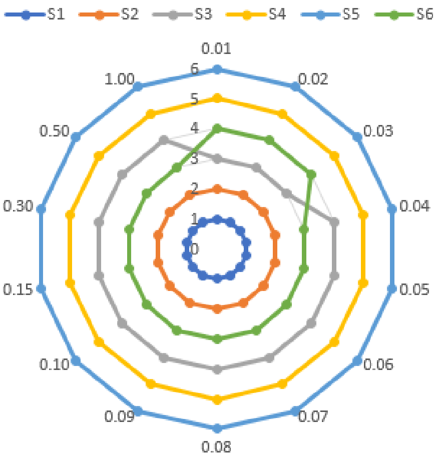

Figure 2. Suppliers ranking with different values of τ

4. Conclusion

The aim of this paper is to select the best supplier in the LISCO in Libya using the CODAS method. It is well known that MCDM techniques are gaining popularity in solving supplier evaluation and selection problems. This work includes both quantitative and qualitative criteria though some of them may include uncertainty and sometimes they may be conflicting. The CODAS method has some features that have not been considered in the other MCDM methods. In this paper, the CODAS method is applied to a real-world case study for ranking the suppliers in the LISCO. The results have revealed that supplier S1 was the most suitable choice with respect to all recognized criteria, as seen in the relevant sensitivity analysis. The performance of the suppliers based on the criteria mentioned earlier is a robust one similar to the synthesis results. Consequently, the CODAS method is capable of enhancing quality decision by making its process more rational, explicit and efficient. Furthermore, the CODAS method can be used in the future for other applications of MCDM.

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