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UCT Journal of Research in Science ,Engineering and Technology

UCT . J. Resea. Scien. Engineer.Techno.(UJRSET)

Volume 2,Issue 1

2(1): *17-31 (2014)*

ISSN:2382-977X

Providing a structured approach for evaluating and selecting suppliers in a supply chain

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ABSTRACT

Supply chain management (SCM) is one of the important competitive strategies used by modern organizations. The main objective of supply chain management is to integrate various suppliers in order to satisfy market demand. Selecting and evaluating suppliers plays an important role in creating a supply chain. The old method of selecting and evaluating suppliers is focused on the needs of businesses and considering it for the entire supply chain of an organization fails to work. So this study presents a structured approach for selecting and evaluating suppliers based on the integrated supply chain structure.

For establishing a procedure for the selection and evaluation of suppliers in supply chain, first the competitive strategy of the organization by analyzing the strengths, weaknesses, opportunities and threats (SWOT) is specified. Based on competitive strategy, supplier selection criteria and indicators in order to establish a framework for selecting suppliers are elected. Subsequently, potential suppliers through Data Envelopment Analysis (DEA) are monitored. Finally, the techniques of Multi Criteria Decision Making (MCDM) is used to rank suppliers. In this paper, a structured approach to select suppliers in an industry will be examined.

Original Article:

Received 04 Nov. 2013
Accepted 17 Dec. 2013
Published 30 Dec. 2013

Keywords:
supply chain ,structured approach selecting suppliers,

1.Introduction

SCM generally occurs when a few firms make their supply chains.These firms have to find more suppliers to enhance the competitiveness of the supply chain. Whether among the suppliers available, how to choose suppliers who are more involved , those who are able to extend long-term relationships is considered as a key issue in building a supply chain and enhance its performance.

In some of previous studies on supplier selection and evaluation, different definitions and evaluation criteria for supplier selection framework is proposed. For example, Dixon has examined vendors to identify factors that they consider in awarding contracts. More than 23 factors were considered, Dixon found that the quality, delivery and performance are three of the most important criteria.Another study conducted by Weber and colleagues have examined the key factors for selecting suppliers. The key factors have been taken from 74 related articles. Based on a comprehensive review of methods for evaluating vendors, they thought that the price is the highest ranking factor and its mode of delivery and quality are next. Empirical researches have shown that the relative importance of selection criteria such as price, quality and delivery performance, are similar. Increasing emphases on production strategies since 1980,the importance of strategic evaluating and multiple criteria of vendors has increased. Weber and colleagues considered more importance for the geographic location than of the Dixon said. Table 1, has summarized a number of criteria considered important by Dixon and Weber and colleagues, Weber and Current, Weber and Desai

Table 1. Rating Dixon and Weber

Evaluation criteria	Dickson importance ranking	Weber importance	Reference quantity
price	6	Very important	61
Deliver on time	2	Very important	44
Quality	1	Extremely important	40
Equipment and capability	5	Very important	23
Geographic location	20	Important	16
Technical capability	7	Very important	15

Management and organization	13	Important	10
Industrial reputation	11	Important	8
Financial situation	8	Very important	7
Financial situation	3	Very important	7
Maintenance service	15	Important	7
Service attitude	16	Important	6
Packing ability	18	Important	3
Production control ability	14	Important	3
Training ability	22	Important	2
Procedure legality	9	Very important	2
Employment relations	19	Important	2
Communication system	10	Very important	2
Mutual negotiation	23	Important	2
Previous image	17	Important	2
Business relations	12	Important	1
Previous sales	21	Important	1
Guarantee and compensation	4	Very important	0

According to the analysis methods applied to the selection process of suppliers, de Boer and colleagues have extensively examined decision procedures for selecting and evaluating suppliers. Hu and colleagues have investigated the literature of Multi Criteria Decision Making methods to select and evaluate suppliers. Decision methods used in various studies for the selection of qualified suppliers, are including certain procedures, EDA, cluster analysis and conclusionsystem on the basis of state.

Wu and his colleagues developed an implicit evolvedDEA for the selection of suppliers. This model is able to examine the underlying data (in order of ranking efficient suppliers) and to increase the ability of distinction (to discriminate between efficient suppliers and underperforming suppliers). Wadhwa and Ravindran had modeled the selection and evaluation of suppliers'problem as a multi-objective programming model, which had its three objective functions such as minimizing cost, time delay, and waste. Three methods of solving such as The objective weighting method, The objective programming method and compromise programming was used in order to compare answers. Hu and Su created a support system based on AHP for supplier selection problem in a large custom environment. Internal and external factors in order to address the market needs for global environmental changes were considered.

However, mainly the creation of a model to evaluate suppliers by those studies, from the perspective of the supply chain or the organization's strategy on the needs of end customers is not focused. Therefore, this study has presented a structured approach to selecting and evaluating suppliers based on the integrated supply chain with the aim of helping organizations to establish a systematic method to select and evaluate potential suppliers for the supply chain. In this method, there are five steps to selecting and evaluating suppliers.

1. Identify the organization's competitive strategy through techniques SWAT (analysis of strengths, weaknesses, opportunities and threats)

2. Choose the criteria for selecting suppliers in order to create a framework for selecting suppliers on the basis of outlined competitive strategy oforganization

3. Screening potential suppliers by the technique DEA (Data Envelopment Analysis is a technique that specifically addresses the evaluation of the relative efficiency of units)

4. Ranking potential suppliers through the use of techniques TOPSIS and SAW (Total Harmonic) and ELCTRE

5. Demonstrating the feasibility and applicability of the proposed method through a case study of an industry

2. Supplier selection and evaluation methodology

2.1.The process of selecting and evaluating suppliers

Based on the proposed approach for integrating suppliers, supplier evaluation and selection process can includes three steps. 1 - Requirements Analysis and Strategy 2 - Selection and evaluation of suppliers 3 - Evaluate supplier performance. Each phase consists of several steps and methods are given in Figure 1.

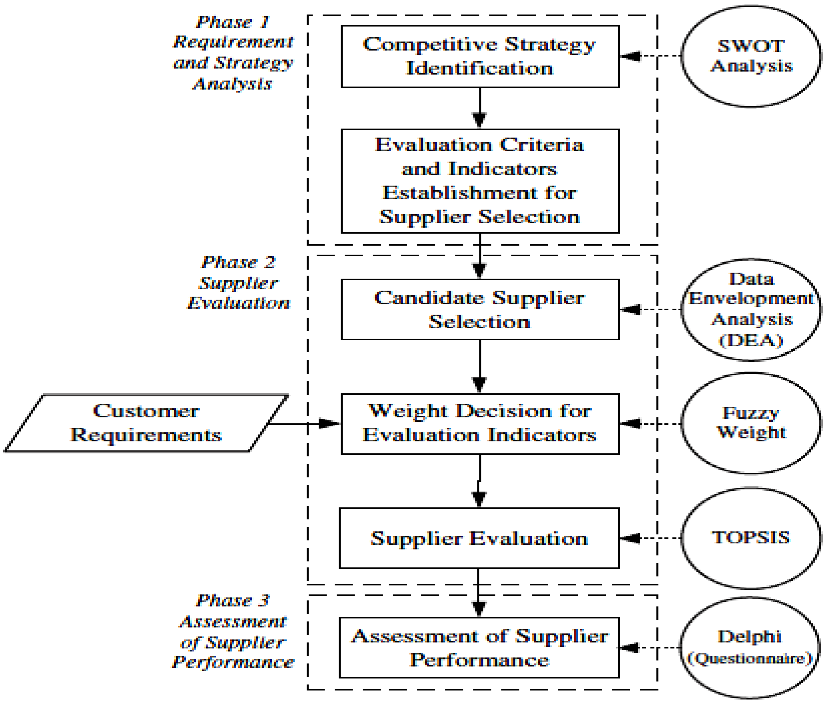

Figure 1. The process of selecting and evaluating suppliers

2.2Establishing evaluation criteria and indicators for selecting suppliers

Based on the analysis of strategies and key factors of their success, we can create a framework for evaluating their suppliers. Due to the easy use of the framework and evaluation criteria, also the development for increasing new criteria in the future, the supplier selection criteria is distinguish in the two main factors that are "competitive factors" and "organizational factors". Criteria relating to competitive factors includes quality, cost, delivery time and service, whilstcriteria relating to the organization factors includes manufacturing and technical capabilities, combined relationships and organization management.

2.3Candidates for selecting suppliers

To evaluate the relative efficiency of evaluation objectives for multiple inclusion and exclusion criteria,the mathematical programming model DEA in this study has been used to select candidates among suppliers..

Two types of suppliers output measures in the DEA for nominated suppliers selection process occurs which include: the less the better and the more the better. For example, suppliers' ability more is better, while the gap between suppliers and buyers less is better. In addition, some of these criteria can be properly transmitted and may be either the more is better or the less is better. For example, if the quality index is expressed by eligible products,naturally the bigger is better. On the other hand, if the quality index is expressed by unqualified products, so the smaller is better. Therefore, this study is using the indices of supplier evaluation (the smaller the better) as input items, while the index of supplier evaluation (the bigger the better) is used as the output item. DEA model established for selection of nominated suppliers is shown in Equation 1.

Equation 1

$$Max : h_0 = \frac{\sum_{r=1}^{s} u_r . y_{r0}}{\sum_{i=1}^{m} v_i . x_{i0}}$$

$$s.t : \frac{\sum_{r=1}^{s} u_r . y_{rj}}{\sum_{i=1}^{m} v_i . x_{ij}} \leq ; j = 1,....,n; u_r, v_i \geq \varepsilon ; r = 1,...,s; i = 1,...,m$$

Parameters used in equation (1) are as follows:

h_0: efficiency score of decision making units

Y_{rj}: performance index for the j-thsupplier (the bigger the better)

X_{ij}: performance index for the j-th supplier (the smaller the better)

U_r: Weight yr

V_i: Xi weight

n: number of suppliers

S: the number of suppliers' performance index (the bigger the better)

M: the number of suppliers' performance indicators (the smaller the better)

Therefore the first equation is a fractional programming model to become a linear programming model by converting charnes-cooper. For this purpose, the first requirement is $\sum_{i=1}^{m} V_i X_{i0} = 1$, then we add it to the equation constraint. Then the numerator and denominator of this inequality should be multiplied by $\sum_{i=1}^{m} V_i X_{ij} = 1$. So the linear programming model is shown in Equation 2

Equation 2

$$\max : h_0 = \sum_{r=1}^{s} u_r . y_{r0}$$

$$st : \sum_{r=1}^{s} u_r . y_{rj} - \sum_{i=1}^{m} v_i . x_{ij} \leq 0; j = 1,....,n$$

$$\sum_{i=1}^{m} v_i . x_0 = 1; u_r, v_i \geq \varepsilon ; r = 1,...,s; i = 1,...,m$$

2.4 weight giving decision on the basis of suppliers' evaluation indicator

In this section, the theory of fuzzy is used in order to make decisions about the strength of customers related to each criterion, for calculation the weights of supplier evaluation indicators.

2.4.1 Fuzzy linguistic variable

Linguistic variable is mainly used to express the size of a data sector. In this study five linguistic terms as control models for selection of appropriate linguistic variables are used. The following table shows linguistic variables formats and triangular fuzzy numbers.

Linguistic variables	**Triangular fuzzy numbers**
Very unimportant	**(0, 0, 0.25)**
Unimportant	**(0, 0.25, 0.5)**
Neutral	**(0.25, 0.5, 0.75)**
Important	**(0.5, 0.75, 1)**
Very important	**(0.5, 0.75, 1)**

Table 2. fuzzy numbers for linguistic variables

2.5 Evaluation of suppliers

Multi-criteria decision making is an analysis methodology for the identification of non-desirable responses or prioritized regular classification for possible designs based on multi-criteria evaluation and supremacy of decision makers. Hence, this study three multi-criteria decision method (ELECTRE-SAW-TOPSIS) has used to evaluate the candidate suppliers. TOPSIS method is discussed in more detail.

Step one:

Create the evaluation matrix: The evaluation matrix has n alternatives and m evaluation criteria. WhereX_{ij}refers to the evaluation value of scheme criteria under the evaluation criteria as shown in Equation 3.

Equation 3

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots \\ x_{1m} & \cdots & x_{mn} \end{bmatrix}$$

Step two:

Create a normalized evaluation matrix:Different attribute units should be converted into a matrix with same units. R is a normalized evaluation matrix and calculation equation for evaluation valuerijin matrix R is shown in Equation 4.

Equation 4

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Step 3:

Create the weighted evaluation matrix:Based on knowing the weight sum of weight vector w=(w_1,w_2,. . .,w_n)equals 1, and the vector sum of normalized evaluation matrix multiplication in the evaluation matrix of the scheme is given shown in Equation 5.

Equation 5

$$V = R \times W = \begin{bmatrix} w_1 r_{11} & \cdots & w_n r_{1n} \\ \vdots & \ddots & \vdots \\ w_1 r_{m1} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 4:

Decide the positive-ideal solution and the negative-ideal solution: a mathematical expression is shown in Equation 6.

Where j refers to the set of efficient property and j refers to the set of the cost property.

Equation 6

$$A^* = \{(\max v_{ij} \mid j \in J),(\min v_{ij} \mid j \in J') \mid i = 1,2,...,m\} = \{v_1^*, v_2^*, ..., v_n^*\}$$
$$A^- = \{(\min v_{ij} \mid j \in J),(\max(v_{ij} \mid j \in J') \mid i = 1,2,...,m\} = \{v_1^-, v_2^-, ..., v_n^-\}$$

Step 5:

Calculate the degrees of separation between each design and the positive/negative-ideal solution:Degrees of separation between schemes are calculated on the basis of Euclidean distance equation, the values between every evaluation matrix and every positive/negative-ideal solution iscalculated. The equations for determining the degrees of separation between each schemes and the positive-ideal solution $S_i^+$and negative-ideal solution $S_i$in Equations 7 and 8, respectively, are presented.

Equations 7 and 8

$$S^+_i = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, i = 1,..,m; j = 1,...n$$
$$S^-_i = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, i = 1,..,m; j = 1,...n$$

Step 6:

Calculate the relative closeness between each scheme and the positive-ideal solution: Equation 9 is the mathematical formula to calculate the relative closenessC_i. Relative closeness close to 1 shows that the scheme is closer to the positive-ideal solution, so that was taken into account. Vice versa the relative closeness farther from 1 shows that the plan is worse.

Equation9:

$$C_i = \frac{S_i^-}{S_i^- + S_i^+}; i = 1,2,...,m; 0 \le C_i \le 1$$

Step 7:

Ranking order of priority for all plans: the degree of relative closeness is calculated in Step six are ranked in descending order. The highest$C_i$represents the most distinctive plan.

3.Examples applications

The applications and possibility of this method was tested by conducting a case study of anindustry. In this section the weaving industry sectors including enterprise stream of the industry is selected as a leading organization for describing the process of selection and evaluation of suppliers for upper-stream textured yarn factories through the selection and evaluation of suppliers.

3.1Analysis of the internal and external environment of the industry in Taiwan

This industry is production and marketing system including a range industries from fiber material middle and downstream textile processing industries, and developing from the downstreamlabor-intensive textile processing industry to middle and upper-stream industries as synthetic fiber industry with a focus on technology and capacity

3.1.1 Analysis of the key success factors for the textile industry

Quality: Clothing is a functional product that allows consumers to express their personal taste and style, so it needs a high quality. Clothing business is highly competitive and a good brand image and high quality products can gain high addedvalue. So quality is a key factor determining the profitable suppliersin this business.

Product Diversity: Textiles products belonging to individual consumer products, customers do not buy the same products for a long time. Instead, they prefer to buy a variety of products, so diverse products meet consumers' needs better.

Delivery time: fashion trends can significantly affect sales of clothing. Fashion products lose their charm change with the seasons. With a big industrial chain, suppliers of textile industry must have the ability to respond quickly to the market.

Cost: textile industry is growing rapidly. So the issues that the industry is suffering from is low profit and the competition power of new industrialized nations. Suppliers are not able to separate themselves from their competition and success and failure management has acritical impact on their profits.

3.1.2 SWOT Analysis for Textile Industry

Strengths:

1. Adequate supply of fiber through high-stream

2. Complete industrial system
3. Fabricswith strength of low cost , on time delivery , product reputation , and competitive ability
4. High efficiency products for automation

Weaknesses:

1. Hard to escape from OEM
2. The lack of effective control and the ability to develop marketing channels
3. Cannot overcome the shortage of new fiber materials due to the insufficient investment, and prevent the spread of high-quality and high product diversification

Opportunities:

1. Reduce the dependence on the Chinese market by market access through WTO
2. Actively promote the use of e-commerce and update the efficiency and competitiveness of Taiwan's strengths in technology in electronic data
3. higher national income can increaseTaiwan's domestic demand for high-tech textile, market boost demand for Taiwanese suppliers

Threats:

1. Most suppliers have to establish factories overseas because of the increased threat of cheap goods from China and East Asia.
2. The clothing industry is facing increased competition before entering WTO
3. Medium and small organizations affect the improvement efficiency because of decrease in the degree of acceptance to information technology and the Internet.

3.2 Selection of suppliers as candidates for an industry

After creating indicators and evaluation criteria for textile industry suppliers, the DEA analysis is used to select the following suppliers:

Input and output parameters must be defined when the DEA method is used to analyze the data suppliers. In this case , the index of " bigger is better " of suppliers performance are selected as output items, including the rate of R & D, productivity, gross profit margins , quantity discount and inventory turnover ratio. On the other hand, the index of "The smaller the better" of supplier's performance is selected as input items, which include: the return rate, discount rate and operating expenses rate.

In Table 3 Input and output parameter values used in evaluating the performance of the 12 textile suppliers in Taiwan is illustrated, obtained from the Taiwan stock market system.

Table 3. Input and output 12 items of textile supplier

	Output items					**Input items**		
Supplier	R&D rate	Productivity	Gross profit rate	Quantity discount (%)	Inventory turnover ratio	Return rate	Discount rate	Operating expense rate
Supplier1	1.11	201	0.01	7	0.67	12:06	0.66	5.73
Supplier2	1.13	267	9.69	4	6.02	12:54	0.22	2.92
Supplier3	2.12	311	6.36	5	5.8	1.11	0.5	8.38
Supplier4	1.57	361	6.42	5	6.17	12:15	0.48	5.68
Supplier5	1.5	300	9.51	10	6.76	12:19	0.41	4.16
Supplier6	3.08	310	13.81	7	7.48	1.28	0.5	7.01
Supplier7	2	250	5.41	8	7.04	12:01	0.01	5
Supplier8	1.04	398	6.82	7	11:16	0.42	0.13	2.82

Supplier9	1.66	375	7.51	5	5.17	0.65	1.05	3.83
Supplier10	2.62	103	1.43	8	5.16	12:25	0.07	2.64
Supplier11	2.09	164	6.71	6	12:45	0.72	0.18	4.25
Supplier12	2.52	200	2.98	6	6.36	12:13	1.37	5.55

Based on the numerical data input and output items for each supplier are listed in Table 3. DEA linear programming model is shown in Equation 1 is used to determine their relative effectiveness. Linear programming model, and the results obtained by linear programming and analysis program LINDO is performedfor every 12 suppliersand relative efficiency values of 12 textile suppliers in Taiwan is obtained that the summary is visible in Table 4

Table 4. Relative efficiency of 12 textile suppliers

relative efficiency	supplier
0.6957	Supplier1
1.0000	Supplier2
0.4100	Supplier3
0.9757	Supplier4
1.0000	Supplier5
0.7822	Supplier6
1.0000	Supplier7
1.0000	Supplier8
0.8784	Supplier9
1.0000	Supplier10
0.8769	Supplier11
0.8457	Supplier12

3.3 Evaluation of textile industry suppliers

In this section, the weight of the performance indicators of suppliers have been identified by using customer preferences. Subsequently TOPSIS technique is applied to rank candidate suppliers specified in Section 2.5. The data obtained from using TOPSIS technique is implemented in the technique of SAW and ELCTRE. Operation steps are as follows:

1. **Create membership functions for fuzzy weighted performance indicators:**

Customers have different preferences regarding their supply chain performance indicators because people have different goals and mindsets. Organizations must consider customer preferences in the selection of suppliers to gain the customers' satisfaction in meeting their demand. In this example, 4 customers have been selected in order to assess supply chain evaluation indicators and the results are shown in Table 5.

Table 5. Testimonials of customers about the evaluation criteria

	Quality	**Technology and production**	**Cost**	**Organizational management**
Customer١	Neutral	Very important	Unimportant	**Unimportant**
Customer٢	Important	Neutral	Important	**Important**
Customer٣	Neutral	Important	Unimportant	**Very important**
Customer۴	Very important	Unimportant	Unimportant	**Neutral**

Due to the high uncertainty about customer evaluation criteria,it's Preferablethat customer preferences regarding the evaluation index primarily are expressed by fuzzy linguistic variables (previously offered). Then, to determine the fuzzy weights for each performance index, calculate by using fuzzy number operators.However, fuzzy numbers are obtained by utilizing the fuzzy operators for fuzzy numbers, which are not standard (fuzzy numbers not between zero and one). So evaluation index and fuzzy weights for suppliers' performance indicators are obtained, respectively.

Table 6. Fuzzy numbers for customers testimonials about the evaluation indicators

	Quality	**Technology and production**	**Cost**	**Organizational management**
Customer 1	(0.25, 0.5, 0.75)	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)
Customer 2	(0.5, 0.75, 1.00)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1.00)	(0.5, 0.75, 1.00)
Customer 3	(0.25, 0.5, 0.75)	(0.5, 0.75, 1.00)	(0.00, 0.25, 0.50)	(0.75, 1.00, 1.00)
Customer 4	(0.75, 1.00, 1.00)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)	(0.00, 0.25, 0.50)
Customer 1	(1.75, 2.75, 3.5)	(1.50, 2.50, 3.25)	(0.50, 1.50, 2.5)	(0, 0, 0.25)
Fuzzy weight normalization	(0.5, 0.79, 1.00)	(0.48, 0.71, 0.93)	(0.14, 0.43, 0.71)	(0.43, 0.71, 0.93)

Table 7. Fuzzy weight of performance indicators:

Performance indicators	**Weight**
R&D rate	**(0.43, 0.71, 0.93)**
Productivity	**(0.43, 0.71, 0.93)**

Gross profit rate	**(0.14, 0.43, 0.71)**
Quantity discount	**(0.14, 0.43, 0.71)**
Inventory turnover ratio	**(0.43, 0.71, 0.93)**
Return rate	**(0.5, 0.79, 1.00)**
Discount rate	**(0.5, 0.79, 1.00)**
Operating expense rate	**(0.43, 0.71, 0.93)**

2. Create evaluation matrix for candidate suppliers

Create evaluation matrix for the 5 suppliers by using the evaluated values of relative performance in table of study of 12 suppliers, are listed in the following table.

Table 8. Five Superior Supplier Evaluation Matrix

	Supplier2	**Supplier5**	**Supplier7**	**Supplier8**	**Supplier10**
R&D rate	300	1.50	1.43	103	2.62
Productivity	10	9.51	0.25	5.16	8
Gross profit rate	0.19	6.76	1.04	2.64	0.07
Quantity discount (%)	4.16	0.41	7	6.89	398
Inventory turnover ratio	267	1.13	0.13	0.42	11.16
Return rate	7	9.69	250	2.00	2.82
Discount rate	0.54	6.02	7.04	8	5.41
Operating expense rate	2.92	0.22	5.00	0.01	0.01

Table 9. Normalized evaluation matrix

	Supplier2	**Supplier5**	**Supplier7**	**Supplier8**	**Supplier10**
R&D rate	0.43	0.57	0.76	0.40	1.00
Productivity	0.67	0.75	0.68	1.00	0.26
Gross profit rate	1.00	0.98	0.56	0.70	0.15

Quantity discount (%)	0.70	1.00	0.80	0.70	0.80
Inventory turnover ratio	0.54	0.61	0.63	1.00	0.46
Return rate	0.02	0.05	1.00	0.02	0.04
Discount rate	0.05	0.02	1.00	0.08	0.14
Operating expense rate	0.90	0.63	0.53	0.94	1.00

3. **Normalization of evaluation Matrix for candidate suppliers**

If X_{ij} refers to an array of the evaluation matrix, the normalized evaluation matrix is listed in the table above. In addition, calculations for each evaluation is as follows:

$r_{ij} = \frac{x_{ij}}{x_j^*}$ For measures of efficiency attribute (x_j^* maximum criteria)

$r_{ij} = \frac{x_j^-}{x_{ij}}$ For measures of cost attribute (x_j^- minimum criteria)

4. **Create a weighted evaluation matrix**

Weighted evaluation matrix is shown in Table 10.

Criterion	Supplier2	Supplier5	Supplier7	Supplier8	Supplier10
R&D rate	(0.18, 0.31, 0.40)	(0.25, 0.40, 0.53)	(0.32, 0.53, 0.70)	(0.17, 0.28, 0.37)	(0.43, 0.71, 0.93)
Productivity	(0.29, 0.48, 0.62)	(0.32, 0.53, 0.70)	(0.27, 0.45, 0.59)	(0.43, 0.71, 0.93)	(0.11, 0.18, 0.24)
Gross profit rate	(0.14, 0.43, 0.71)	(0.14, 0.42, 0.72)	(0.08, 0.24, 0.40)	(0.10, 0.30, 0.50)	(0.02, 0.06, 0.11)
Quantity discount (%)	(0.10, 0.30, 0.50)	(0.14, 0.43, 0.71)	(0.11, 0.34, 0.57)	(0.10, 0.30, 0.50)	(0.11, 0.34, 0.57)
Inventory turnover ratio	(0.23, 0.38, 0.50)	(0.26, 0.43, 0.57)	(0.27, 0.45, 0.59)	(0.43, 0.71, 0.93)	(0.20, 0.33, 0.43)
Return rate	(001, 0.02, 0.02)	(0.03, 0.04, 0.05)	(0.50, 0.79, 1.00)	(0.01, 0.01, 0.02)	(0.02, 0.03, 0.04)
Discount rate	(0.03, 0.04, 0.05)	(0.01, 0.01, 0.02)	(0.50, 0.79, 1.00)	(0.04, 0.06, 0.08)	(0.07, 0.11, 0.14)
Operating expense rate	(0.39, 0.64, 0.84)	(0.27, 0.45, 0.59)	(0.23, 0.38, 0.49)	(0.40, 0.67, 0.87)	(0.43, 0.71, 0.93)

5. **Solving Fuzzy Matrix**

Positive-ideal solution A^+ and negative-ideal solution A^- for candidate suppliers is calculated using Equation 6 and the results are shown in the table below.

Table 11. Values of positive and negative ideal

Criterion	Supplier2	Supplier5	Supplier7	Supplier8	Supplier10	Positive-ideal solution (A*) *	Negative-ideal solution (Aے) $^-$
R&D rate	0.30	0.39	0.52	0.28	0.69	0.69	0.28
Productivity	0.46	0.52	0.43	0.69	0.18	0.69	0.18
Gross profit rate	0.43	0.42	0.24	0.30	0.06	0.43	0.06
Quantity discount (%)	0.30	0.43	0.34	0.30	0.34	0.43	0.3
Inventory turnover ratio	0.37	0.42	0.43	0.69	0.32	0.69	0.32
Return rate	0.02	0.04	0.76	0.02	0.03	0.76	0.02
Discount rate	0.04	0.02	0.76	0.06	0.11	0.76	0.02
Operating expense rate	0.62	0.43	0.37	0.65	0.69	0.69	0.037

6. **Calculate the degrees of separation between candidate suppliers and ideal positive / negative solution**

According to Equation 7 and 8 degrees of separation between any candidate supplierand the ideal-positive solution (Si+) and between each candidate supplier and the negative-ideal solution (Si-) is calculated and is listed in the following table.

Table 12. Separation degrees with the positive ideal solution:

Criterion	Supplier2	Supplier5	Supplier7	Supplier8	Supplier10
R&D rate	0.41	0.31	0.17	0.43	0.00
Productivity	0.24	0.18	0.27	0.00	0.53
Gross profit rate	0.00	0.01	0.21	0.15	0.41
Quantity discount (%)	0.15	0.00	0.10	0.15	0.10
Inventory turnover ratio	0.33	0.28	0.27	0.00	0.39
Return rate	0.77	0.75	0.00	0.77	0.76

Discount rate	0.75	0.77	0.00	0.73	0.68
Operating expense rate	0.07	0.27	0.34	0.04	0.00
R&D rate	2.72	2.57	1.35	2.27	2.87

Table 13. Separation degrees with the negative ideal solution:

Criterion	**Supplier2**	**Supplier5**	**Supplier7**	**Supplier8**	**Supplier10**
R&D rate	0.02	0.12	0.26	0.00	0.43
Productivity	0.30	0.35	0.27	0.54	0.00
Gross profit rate	0.41	0.40	0.20	0.27	0.00
Quantity discount (%)	0.00	0.14	0.05	0.00	0.05
Inventory turnover ratio	0.06	0.11	0.12	0.39	0.00
Return rate	0.00	0.02	0.77	0.00	0.01
Discount rate	0.02	0.00	0.77	0.05	0.09
Operating expense rate	0.27	0.07	0.00	0.29	0.34
R&D rate	1.08	1.23	2.45	1.54	0.94

7. Calculate the relative closeness between each candidate supplier and positive-ideal solution

Relative closenessdegree between each candidate supplier and ideal solution in the following table is calculated according to equation 9.

Table 14. Separation degree between each supplier and ideal solution

	Separation degree (*S)**	**Relative closeness degree (*C**)**
Supplier2	2.7220	0.2846
Supplier5	2.5715	0.3235
Supplier7	1.3546	0.6436
Supplier8	2.2683	0.4038
Supplier10	2.8700	0.2460

8. **Rank the candidate suppliers**

According to the relative closeness degree listed in Table 14, 5 candidate suppliers are ranked in descending order of relative closeness, that candidate supplier 7 is specified as suitable supplier in example.

0.6436(7) > 0.4038 (8) > 0.3235(5) > 0.2846(2) > (10)0.2460

3.4 SAW method

In this method, first consider the weighted evaluation matrix. Then, decide based on the sum of weighted values for each option. The supplier with bigger weighted sum is better than others. The advantage of this method is the simplicity of its implementation but in this method, the error is very large.

Result of implementing this method for textile industry suppliers are given in Table 15.

Table 15. Results of SAW method

Criterion	**Supplier2**	**Supplier5**	**Supplier7**	**Supplier8**	**Supplier10**
R&D rate	0.30	0.39	0.52	0.28	0.69
Productivity	0.46	0.52	0.43	0.69	0.18
Gross profit rate	0.43	0.42	0.24	0.30	0.06
Quantity discount (%)	0.30	0.43	0.34	0.30	0.34
Inventory turnover ratio	0.37	0.42	0.43	0.69	0.32
Return rate	0.02	0.04	0.76	0.02	0.03
Discount rate	0.04	0.02	0.76	0.06	0.11
Operating expense rate	0.62	0.43	0.37	0.65	0.69
Weighted sum	**2.55**	**2.67**	**3.85**	**2.40**	**2.42**

According to the values obtained for each option, the best supplier is supplier 7, the second best supplier is 5 and third best supplier is 2. Generally the superiority of this five suppliers by the method SAW is as follows:

(7) > (5) > (2) > (10) > (8)

3.5 Using ELECTRE 1

In this method, by creating harmony and disharmony matrices and defining minimum acceptable harmony and maximum acceptable disharmony, a comparison between the supplier and their superiority takes place. For using this method, the weighted decision matrix is used that information is presented in above sections. On the other hand, since criteria weights are considered as fuzzy, act like methodused for the non-fuzzy decision matrix and average of 3 presented fuzzy number for each criterion is considered as its decisive weight. We consider minimum acceptable harmony of 0.4 and maximum acceptable disharmony of 0.8. Finally, this method is coded in MATLAB environment. Program output is matrix below in which number 1 in each house indicates superiority of a supplier (row number to another supplier (column number).

$$e=\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Based on the above matrix, one can conclude that the supplier 7 is superior to other suppliers and then supplier 8 has a relative advantage over others. It should be noted thatdue to the dependence ofELECTRE method to its parameters, ELECTRE2 method is not used.

3.6 Comparison of three methods SAW and TOPSIS and ELECTRE

In methods TOPSIS and SAW an overall ranking of candidate suppliers is presented, but by ELECTRE method only the best supplier could be identified well. Every three above methods introduce supplier 7 as the best supplier, but the second best supplier is supplier 8 by TOPSIS method, and supplier 5by SAW method, and supplier 8 by ELECTRE method. The difference in ranking by TOPSIS and SAW methods showslack of sufficient accuracy of SAW method in suppliers ranking. As well, the results obtained in the ELECTRE methodbychanging minimum acceptable coordination and maximum acceptable imbalance shows that under various conditions, again supplier 7 is considered a superior supplier.

4.Conclusion

In this article, a structured methodology for supplier selection and evaluation in a supply chain is introduced.This method helps investors to implement a systematic approach in selecting and evaluating potential suppliers in the supply chain. Genera research done in this paper is summarized as follows:

- Develop a method for supplier evaluation and selection: In this article a two-stage method for evaluation and selection of suppliers based on integration approach for supply chain was introduced. In the first stage, the evaluation criteria of suppliers is studied, and in second stage by DEA and TOPSIS help, we try to filter, evaluate and select suppliers.

- A case study on choosing the best suppliers in the textile industry in Taiwan: Based on the proposed approach, first the key factors in Taiwanese textile industry for selection of suppliers, based on customers' opinions is introduced. Then most efficient candidates based on this criteria are specified and finally by giving effect of customers' opinions in criteria weights, these suppliers are ranked by the TOPSIS method.

The results of the studies in this article helps investors during the planning and design of supply chain, choose the best suppliers for their own chain. As well, the evaluation and selection of suppliers based on the method described improves the sufficiency and quality of product and reduce cycle time and costs, and ultimately increases product penetration in the market.

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