Using multi-criteria decision-making methods in supply chain management for selecting the appropriate criteria in the evaluation of suppliers of raw materials

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Abstract

Effective supplier selection and evaluation are important responsibility that should always be considered by commercial section managers. Suppliers should be selected appropriately because they can create more positive or harmful Effects in the overall performance of a organization. Thus proper management of supply chain is important to evaluate and select material suppliers. In this regard, supplier selection and evaluation and selection are a serious and important topic. Thus in this research, primarily through library studies, including Latin and Persian texts and also review of various articles in the field, 27 important criteria were identified for selecting suppliers and then by questionnaire and Delphi method, it was distributed among 30 managers of ceramic and tile industry in Yazd and then 20 criteria were confirmed by data analysis using statistical tests that these indicators were classified as acceptable convergence and formed as Demantel questionnaire and distributed to 15 managers of ceramic and tile industry. After that information converted to fuzzy and then CFCS algorithm was codified using MATLAB 2012 software and the relationship between indicators and the level of effect and affected by criteria for selecting providers was investigated using Demantel fuzzy method. finally The results show that the indicator of logistics planning and management has more effect, the indicator of reducing resistance to change the amount of order has less effect and more affected and the indicator of mutual trust and communication between buyer and seller has less affected.

Keywords: Fuzzy Demantel, development of supplier selection criteria, effective suppliers selection and evaluation, supply chain.
1. Introduction

One of the most important purchasing activities is to evaluate and select suppliers. In the traditional view, the managers select the supplier based on the lowest inquiry from 3 inquiries. Supplier selection and evaluation are very important for the present and future needs. Philip Crosby says "about 50 percent of the companies qualitative problems are caused by poor management of the supply chain (Gol mohammadi et al, 2012). Control and monitor the supplier after selecting are necessary. For the evaluation and selection, no way is the best. If a company aims to achieve excellence level, but ignores the quality improvement of their suppliers, it will be frustrated in achieving the objectives. Examining the facility of suppliers is up to cross-section and specialized teams. One of the important objectives is to optimize the supply chain and reduce the number of suppliers (Shaw et al, 2012).

Supplier evaluation is a process that takes place prior to buying. Manufacturers allocate 60 percent of their time to supply raw materials, components and parts. In addition, 70 percent of the production costs are related to purchasing goods and services. Supervisory requirements to evaluate suppliers are as follows:

1. The standard requirement of ISO 9001: according to the standard, supplier evaluation has great importance and performance of suppliers will have the great effect on the final quality of products or services, b) inspect requirement by Ministry of Health (Moshiri et al., 2006).

Supplier selection criteria according to Dixson model is as follows: price, technical capability, on-time delivery, guarantee, after-sales service, how to treat, friendly-market, quality services, training aids, past performance (past business), financial stability, the status of colleagues (reputation and position in the industry), labor relations, close relations, management and organization, ability to problem solving, customer communication systems, respond to customer, ability to product, the ability to pack, operation control, re-creation, perceive specific conditions, business efforts, the ability to keep and store, market size, environment cleanliness, quality uniform.

The purpose of selection is to identify suppliers with the highest potential to meet the company's needs as compatible and cost-effective manner.

In general, for the decisions regarding the supplier selection, two issues are of particular importance. First, what other criteria should be used and second, what methods should be used to compare suppliers. The analysis of these two issues in supplier selection has attracted attention of many academics and purchasing managers. The first research was done by Dixon. He presented 23 criteria for evaluating suppliers, and ranked them in terms of importance. The new criteria have been proposed in the supplier selection literature that some of them are the development of the basic criteria of Dixon and others have been developed by management philosophy so that the delivery and quality are considered as an important selection criteria and design and development of product and flexibility are two criteria that have recently been brought to the related literature, along with development of supply chain management. There are different decision-making techniques to select supplier that include the network analysis process.
model, Rough theory, genetic algorithm model, the structure-based matrix, neural networks, clustering analysis, fuzzy-sets theory (Karbassian et al., 2011).

Supplier selection in supply chain is a multi-criteria decision-making issue that its used sets include: a) $E = \{D_1, D_2, ..., D_K\}$ shows $k$ is decision-maker.

a) $A = \{A_1, A_2, ..., A_M\}$ shows the number of $M$ suppliers should be ranked.

b) $C = \{C_1, C_2, ..., C_N\}$ shows $N$ is decision-making criteria that suppliers compare them as the same way (Shafii et al., 2011). Companies that recognize the importance of supplier selection, follow the initial evaluation of their suppliers. Lowering the total number of suppliers, selection process becomes more important. Initial evaluation criteria of suppliers have the important features: First, the evaluation must be comprehensive i.e., that the evaluation should include the classifications which are considered important in the process of evaluation and selection. The second feature is to be objective. This requires that one use a defined valuation system, or a numerical scale to evaluate the subjective criteria.

The third feature is that the evaluation criteria and cases are reliable. The above capability means is that if supplier was evaluated under certain conditions independently and frequently, results of its evaluation are the same. Evaluation reliability requires that issues are well understood and defined, clear and unambiguous. The lack of reliability affects on quality and stability of the entire evaluation process. The fourth feature is the flexibility of supplier evaluation. In a specific evaluation structure, a company should be flexible in a variety of shopping needs. For example, a buyer may focus on supplier technology and give it more weight. Thus, the more important group gets more weight in their total value. Assigned weights reflect the importance of each of the criteria (Shahroudii et al., 2011).

Statement of the problem:

The overall process of supplier selection and evaluation is according to the following steps:

Step one: recognize the need to select a supplier, step two: determine the supplier evaluation criteria, step three: determine sourcing strategies, step four: identify potential sources of supply, step five: limit the number of potential suppliers, step six: determine the methods of supplier evaluation and selection, step seven: supplier selection, step eight: ranking supplier (Ramanathan, 2007).

One of the most important steps in the purchasing process is to evaluate and select suppliers. In recent years, more attention was paid to importance of supplier selection and evaluation and selection suppliers. Effective supplier selection and evaluation are important responsibilities that should always be considered by purchasing managers (Naradimohan et al, 2001).

The importance of supplier evaluation and selection is influenced by the effects of elements related to final products of organizations. Suppliers are considered as a complement member of the supply chain process in an organization. Because supplier management is not the part of organization, she/he needs the specialized skill for negotiation (Lee et al, 2001).

Suppliers should properly be evaluated and selected because they can affect positively or negatively on overall performance of an organization positively or negatively. Thus evaluation and selection of a suitable supplier are the vital part of an organization (Zhang et al, 2007).
In evaluating and selecting suppliers of raw materials in the supply chain, the issues and problems such as the use of traditional methods in the supplier selection and evaluation, lack of purchasing high-quality materials, changes in delivering of materials that could interrupt or stop production process, the lack of proper response to customers and timely delivery of goods to the market in order to properly manage a supply chain for the supplier selection and evaluation are of particular importance. In this regard, the evaluation and selection of suppliers are a serious and important discussion in this field (Dadras, 2006).

In the present study, it is tried to meet the requirements listed in this section, a series of indicators and common ideals in the supplier selection and evaluation and also Dematel fuzzy method are used to select the best suppliers that eventually lead to a good result in this regard.

Review of literature

Shafie et al. (2001) presented a model in a research to select the best suppliers using multi-criteria decision-making methods. Selection of equipments provider problem is the basic issue in underground electric railway system in the city. In such problems, multiple and different criteria should usually be considered in final choice because these issues are the part of multi-criteria problems. With regard to the importance of supplier selection and evaluation especially those who involved in producing specific goods such as train specific equipments and also because of high cost and serious effect of these equipments on travel security, selection of the best supplier is determinator of travel security and better use of financial resource in railway transportation service companies.

As the mentioned, despite the required accuracy to purchase underground electric railway equipment, at the present time this is done solely on the basis of individual experiences of managers and observing some general principles of public regulation and using exact and scientific methods is not common to select the equipment suppliers. Therefore, because of the high cost of metro system, methods of selecting suppliers must be reviewed. In the present study after review of the related literature and identification of effective criteria in selecting the supplier, these criteria have been localized using the view of railway transportation industry experts and the most important criteria was used for multi-criteria decision-making.

In present study, analytical hierarchy analysis process, TOPSIS and Electere were applied to select the best supplier and each of the three methods yielded the same results. Also To validate the obtained results, a real decision about supplier selection was evaluated based on the proposed methods that the result shows conformity of real decision with proposed scientific methods. According to the price and the importance of security for underground railway transportation and metro development programs in metropolitan, it is necessary to require the employers to use the accurate and scientific methods for selecting the contractor. Moshiri et al. (2006) examine in a research the effective factors on selecting suppliers.
This article identifies the related criteria by interview with industry experts and field research and ranks them using analytical hierarchy model, while investigating effective factors on selecting suppliers in Iran distribution industry. Because there is not any research about Iran distribution industry, the obtained result can be used by the different departments of industry. Distribution channels are one of major combined components of marketing and supply chain. Because of high competition between distributors of goods, the important issue is how to select the suppliers such a way that buyer could be successful in competition level. Distribution channels are required to evaluate and select the proper suppliers in order to need to establish the effective relationships with own commercial partners including suppliers. However investigations show this did not take place in most of internal distribution companies as systematic manner. Supplier selection by distributor differs from selecting intermediate goods and material suppliers because one involve in producing the final production. The obtained results indicate that structural-fundamental criteria has the great importance in selecting suppliers of Iran distribution industry and then factors that play a role in economical – financial areas have the high priority and also, motivational-enhancement and trust criteria are located in lower priorities.

Comparison of the result and similar studies in English in 2014 showed that criteria such as technological-technical capabilities, quality fitness, and product price and supplier validity are the highest priorities for distribution channels to select suppliers. Also similar studies show that the basis of these differences depends on exiting strategies in companies. Lack of stability in market will have great effect on selection criteria. Therefore, it is recommended in order to identify local criteria of each industry, market should initially be studied and analyzed so that it is considerably true in distribution section. Attention to output of such studies can be useful for companies because it can be said that evaluation is a two-ways process and the effective relationship between members of a two-end chain can has the considerable effect on the effectiveness of overall process. Jafar Nejad et al. (2007) presented in a research a fuzzy decision-making method for problem of supplier selection in supply chain. At recent decade how to determine the most appropriate supplier was considered as strategic factor in supply chain. The nature of these decisions is usually complex and without defined structure. Some of qualitative and quantitative performance criteria such as quality, price, flexibility, and delivery time should be considered to determine the most appropriate supplier.

In the study verbal statements used by elites were applied to evaluate and determine the performance of each supplier relative to each criteria and determination of criteria weight. Verbal ranking was done by trapezoidal and triangular fuzzy numbers and finally a multi-criteria decision-making method was used in fuzzy setting to select the supplier and a method was presented to calculate weight and fuzzy multi-criteria decision-making. Some of researchers and scientists showed the benefits of supply chain management. In order to increase competitive benefit, some of companies consider the design and implementation of supply chain management as major and important tools. In these conditions establishing a close and long-term relationship between supplier and buyer is considered as a
successful and key factor to form supply chain. Therefore, supplier selection problem is the most important issue in successful implementation of a supply chain. In general, supplier selection problem faces vague and inaccurate data and the use of fuzzy-set theory seems suitable to deal with unreliability.

In other words, when performance indicators cannot be expressed using the numerical values, the use of variables and verbal statements is the more suitable to express the values of indicator. As the above mentioned, TOPSIS technique is more suitable and flexible to evaluate and select suppliers in fuzzy setting. Qualitative and quantitative criteria can be used simultaneously using TOPSIS technique in supplier selection process. By calculating relative close indicator, not only one can rank the suppliers and determine the best ones, but one can state the status of evaluating the different suppliers by variables and verbal statements.

Amiri et al. (2010) in addition to taking into account the characteristics of analytical hierarchy process and DEA provided a combination of these two methods to choose their suppliers. This method yields a complete ranking to select supplier based on their performance. Supplier selection and evaluation problem is fundamentally a multi-criteria decision-making issue. The specific feature of this problem is the presence of qualitative and quantitative criteria in evaluation that make decision-making more complex and difficult.

In the model, criteria are divided to input and output and each criterion is measured by experts. Effectiveness of each supplier is measured based on the calculated criteria using IDEA method and the results will be displayed in intersecting effectiveness matrix format. The resulted matrix is a pair–comparison matrix that one can rank the suppliers using analytical hierarchy process. Thereby, the problems of analytical hierarchy process and DEA will be solved.

Shahroudi and his colleagues (2011) examined in a research the selection and evaluation of auto parts providers using the concept of total cost of ownership. The suppliers are the vital member of an organization that can greatly affect on the performance of organization. By such various effects, review of supplier selection methods is necessary. Total cost of ownership approach is one of the new methods to select and evaluate suppliers.

This approach provides the information related to supplier selection and evaluation. In this research, in order to evaluate the performance of suppliers, DEA approach was used based on the multiple criteria of total cost of ownership concept. The Information related to auto industries was analyzed by a strategic approach that able to reduce the total cost of ownership. Indeed DEA technique introduces the most efficient supplier that has the lowest total cost and gives strategies to reach the other industries to effective performance. The new methods for evaluating performance of the suppliers provide the good information for managers. These approaches can greatly contribute to costs management. Managers can, through management of costs that have the high priority in production process, reduce total cost of production and choose suppliers who have more conformity with their criteria. One can use some approaches to choose these criteria. The new approaches such as costing based on the objective,
kaizen costing technique, costing based on the activity, balanced scorecard, and other techniques that are widely being used.

Chang et al. (2011) used in a research an experimental method of Dematel Fuzzy decision-making and evaluation to find the effective factors on selecting suppliers of supply chain management. Dematel method evaluates the performance of suppliers to find key factor to improve the performance and provides a new method for decision-making information to select the supplier of supply chain management. The results show that the sustained delivery of goods has the most effective and the strongest relation with other criteria. The results of this study can hopefully help companies to predict which supplier(s) is appropriate, focusing on the determined factors. The results show that the sustained delivery of goods had the highest effect on supplier selection. Although this factor did not have any value to evaluate, it can help effectively select the suppliers of supply chain management.

Chi Chu et al. (2012) used in a research the combination of fuzzy analytical hierarchy process and experimental method of Dematel decision-making and evaluation in human resources related to science and technology. In particular this study initially uses analytical hierarchy process to evaluate the weight of each criterion and then applies Dematel method to create conceptual relationships between these criteria.

This study uses analytical hierarchy process and dematel to evaluate human resources for science and technology applications. The results provided by the analytic hierarchy process can be used to improve the personnel and short-term performance. For human resources and science and technology, improvement of meta-structures may be a better choice for longer period. In addition, training, research and development costs and immediate output are the second-level criteria compared to value, participation, workplace, human capital and intermediate output. Therefore meta-structures must initially be improved, in practical identification of training, the costs of research and development and immediate outputs must be improved.

Shaw and colleagues (2012) used in a research carbon emission in the objective function and considered sourcing carbon emission threshold as a limitation to develop low-carbon supply chain. This study provides an integrated method for selecting appropriate suppliers in a supply chain so that it examines the emission using fuzzy analytical hierarchy process and fuzzy multi-objective linear programming. Fuzzy analytical hierarchy process was first used to analyze the weights of multiple factor. The factors included price, the percentage of rejection of quality, the percentage of late delivery, emission of greenhouse gases and demand.

The weight of multiple factors is used in fuzzy analytic hierarchy process and fuzzy multi-objective linear programming to select suppliers and rationing. In this model, the fuzzy analytic hierarchy process was used to calculate weight of criteria and then fuzzy multi-objective linear programming used to find the optimal solution to the problem. Being fuzzy in this model is managed effectively.
The proposed model is useful for solving practical problems. In practical solution, all objective functions have the same weight so the weights of the objective function can be modified according to the needs of managers. Individual priorities can be easily calculated using the fuzzy analytic hierarchy process. As a result it can be concluded that the proposed method can manage real situation, even when the information phase exists in input. This proposed method is a more useful decision-making tool to reduce the environmental challenges.

Chai and colleagues (2013) analyzed in a research the collected articles in terms of 4 aspects. The four aspects are: decision problems, decision-makers, decision-making environment and decision-making methods. Using cognitive decision analysis in terms of four aspects, they selected and studied 123 articles. In order to test methodology to select suppliers unreliable, these articles were divided into seven categories. Under such classification, 26 decision-making techniques were identified in terms of 3 aspects: (1) multi-criteria decision-making techniques, (2) mathematical programming techniques, and (3) techniques of artificial intelligence. They studied each of 26 techniques and analyzed the ability to integrate the techniques to select the supplier and finally concluded that the present study has two major limitations. First, the focus of our study is to apply the decision-making techniques to select the supplier and other important aspects such as criteria analysis and evaluation of supplier performance, because of the limited scope of our study, were ignored. Second, the reviewed articles were published from 2008 to 2012 and searched based on the keywords "supplier selection" and "decision-making ".

Dance and colleagues (2013) measure the purposes that lead to create a structure of faster procurements network to respond to supplier. The study also tries to determine whether this performance may have a common effect.

After testing a sample of 186 production companies, they concluded that integration of the suppliers and formation of a high-speed procurement network have highly positive effect on the intended performance goals (i.e. efficiency, planned access to objectives and flexibility). In addition, they work together to get the common effects on the efficiency and planned access. The results indicate that both types of action are useful to improve. In addition they affect efficiency and planned access to objectives through a common effect. Finally although FSNS structures have been tested and evaluated in past studies of supply chain management, it should be noted that two factors of the study eliminated due to their low-weight factor.

**Dematel fuzzy approach**

Dematel is a developed method for the construction and analysis of a structural model to analyze influential relationship among complex criteria. However, the decision-making in the fuzzy environment is very difficult for the factors of complex section. The present study uses Dematel fuzzy method to obtain the more detailed analysis. Fuzzy theory introduces concept of membership function in order to deal with linguistic different variables. There are the certain degrees of ambiguity, inference, and perception in people mind. The purpose of this theory is to solve fuzzy or uncertain data in environment. Unlike traditional Boolean logic that element of a separate set "1 or 0" may or may not be defined, the fuzzy set
defines a degree by the membership function. Fuzzy -set theory is a solution for stating uncertain or ambiguous spatial data.

Fuzzy set theory is with the sources of uncertainty or inaccuracy that involved in non-statistical and vague nature. Fuzzy-set theory has the advantage of close connection to classical logic but in many cases determine how the membership is assigned will be very difficult. In this study, fuzzy numbers were used to prevent the ambiguity caused by uncertainty in all stages of decision-making.

One of the scientists called Zade proposed fuzzy -set theory and identified the concept of membership function. Fuzzy set theory deals with the linguistic problems of variable in the real world. This study uses fuzzy triangular numbers to obtain the ideal solutions from decision groups. Let $a_{ij} = (l_{ij}^n, m_{ij}^n, r_{ij}^n)$ is the intermediate degree of criterion I that affects criterion j and fuzzy questionnaire n (n = 1, 2, 3, ..., h.). CFCS method includes a five-step algorithm is as follows:

**Step1: normalization**

$$x_{r_{ij}}^n = \frac{(r_{ij}^n - \min l_{ij}^n)}{\Delta_{\min}^{\max}}$$ (1)

$$x_{m_{ij}}^n = \frac{(m_{ij}^n - \min l_{ij}^n)}{\Delta_{\min}^{\max}}$$ (2)

$$x_{l_{ij}}^n = \frac{(l_{ij}^n - \min l_{ij}^n)}{\Delta_{\min}^{\max}}$$ (3)

where $\Delta_{\min}^{\max} = \max r_{ij}^n - \min l_{ij}^n$.

$\Delta_{\min}^{\max} = 1$

**Step2: calculate normalized values ls,rs**

$$x_{rs_{ij}}^n = \frac{x_{r_{ij}}^n}{1 + x_{r_{ij}}^n - x_{m_{ij}}^n}$$ (4)

$$x_{ls_{ij}}^n = \frac{x_{m_{ij}}^n}{1 + x_{m_{ij}}^n - x_{l_{ij}}^n}$$ (5)

**Step3: calculate the sum of normalized values separately**

$$x_{l_{ij}}^n = \frac{[x_{ls_{ij}}^n(1-x_{ls_{ij}}^n) + x_{rs_{ij}}^n] x_{rs_{ij}}^n}{[1-x_{ls_{ij}}^n] + x_{rs_{ij}}^n}$$ (6)

**Step4: calculate separate values**
\[ Z_{ij}^n = \min \ n_{ij}^n + x_{ij}^n \times \Delta_{\min}^{max} \]  \hspace{1cm} (7)

**Step 5: integrate separate values**

\[ Z_{ij}^n = \frac{1}{h \left( Z_{ij}^1 + Z_{ij}^2 + \cdots + Z_{ij}^h \right)} \]  \hspace{1cm} (8)

Codification of CFCS algorithm by Matlab 2012 software:
clc;
clear;
A=input('Enter A matrix : ');
B=input('Enter B matrix : ');
C=input('Enter C matrix : ');
minl=min(A);
maxr=max(C);
delta=maxr-minl;
h=15;
xri=(C-minl)/delta;
xmi=(B-minl)/delta;
xli=(A-minl)/delta;
xrsi=(xri./(1+xri-xmi));
xlsi=(xmi./(1+xmi-xli));
xi=(xlsi.*(1-xlisi)+xrsi.*xrsi)./(1-xlisi+xrsi);
zi=(minl+(xi.*delta));
zi2=sum(zi);
z=(1/h.*zi2)

**Methodology**

In this study, a survey was conducted to gather information because specialized publications, books and documents were used to cover theoretical material. The information collected from Dephi and Dematel questionnaires was used in field research and also the view of experts, sites and journals were used.

The sample:

The purpose of the study is to identify the effective factors on supplier selection in ceramic and tile industry in Yazd therefore opinions and attitudes of experts in ceramic industry were used to collect the data that has the following features:

a) Having 10 years of experience, b) at least 3 years experience in managerial posts, c) having higher degree in the fields of industry and management.
Research procedures

Necessary steps to carry out the research are as follows: Step 1) Prepare a list of the effective factors in supplier selection and evaluation: According to review of literature and various researches, 27 indicators were identified and would be considered completely.

Step 2) set Delphi questionnaire to identify the effective factors: according to the indicators identified in the first step, a questionnaire was designed based on the Delphi method and distributed to 30 ceramic and tile industry managers in Yazd.

Step 3) statistical tests to identify the effective factors: After completing the questionnaire and evaluating validity and reliability and being normal or abnormal in step 2, Binomial test in SPSS2 software was carried out to identify the important indicators in supplier selection and evaluation. With regard to significant level of p<0.05, the null hypothesis, indicating low –value indicators, was rejected and another hypothesis, indicating high-value indicators, approved.

Steps 4) prepare a Dematel questionnaire: According to studies in step3 and identify indicators, 20 indicators were approved and Dematel questionnaire designed to evaluate the relationship between the indicators and the amount of their effect.

Step 5) collect the required data to identify the relationship between the variables: the designed questionnaire was distributed among 15 managers of ceramic and tile industry in Yazd that 15 questionnaires were completed and reviewed.

Step6: convert the obtained data to fuzzy numbers and using CFCS algorithm and also Dematel technique to identify the relationship between factors: initially the obtained data was converted to fuzzy and then they would be explained and the problem would be solved by the algorithm using the obtained data. According to the results obtained from solving the algorithm, one explains Dematel technique and evaluates level of the relationship and intensity of influence of effective factors in supplier selection.

Step 7: conclusion and suggestions.

The following table shows extracted indicators through ratios tests:

| Table 1 |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| 1-mutual trust and relations between buyer and seller | 2-logistic planning and management | 3-reduce the cost(the cost of transferring material) | 4-improve quality(final product) | 5-customer satisfaction and introduce the new product |
| 6-improve and promote the product | 7-change to improve the product | 8-reduce delivery time and product durability and response to demand and new | 9-reduce production costs (in terms of material quality ) | 10-timely delivery( ability of supplier to access to delivery timing). |
Steps of solving CFCS algorithm
Step1: normalization

\[ x_{r_{ij}^n} = \frac{(r_{ij}^n - \min l_{ij}^n)}{\Delta_{\text{max}} - \Delta_{\text{min}}} \]  

(9)

<table>
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<th>Table 2</th>
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<td>0.75</td>
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\[ x_{m_{ij}^n} = \frac{(m_{ij}^n - \min l_{ij}^n)}{\Delta_{\text{max}} - \Delta_{\text{min}}} \]  

(10)

<table>
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\[ x_{l_{ij}^n} = \frac{(l_{ij}^n - \min l_{ij}^n)}{\Delta_{\text{max}} - \Delta_{\text{min}}} \]  

(11)

<table>
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<th>Table 4</th>
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where \( \Delta_{\text{max}} = \max r_{ij}^n - \min l_{ij}^n \),
\( \Delta_{\text{min}} = 1 \).
Step 2: calculate normalized values \( ls, lr \)

\[
xrs_{ij}^n = \frac{xrs_{ij}}{(1+xrs_{ij}-xmi_{ij})}
\]

(12)

Table 5

<table>
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<tr>
<th></th>
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\[
 xls_{ij}^n = \frac{xmi_{ij}}{(1 + xmi_{ij} - xli_{ij})}
\]

(13)

Table 6

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<th>0.4</th>
<th>0.2</th>
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Step 3: calculate sum of normalized values separately

\[
x_{ij}^n = \frac{xls_{ij}^n(1-xls_{ij}^n) + xrs_{ij}^n \times xrs_{ij}^n}{1-xls_{ij}^n + xrs_{ij}^n}
\]

(14)

Table 7

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<th>0.2667</th>
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</table>

Step 4: calculate separate values

\[
 Z_{ij}^n = \min \ l_{ij}^n + x_{ij}^n \times \Delta_{min}^{max}
\]

(15)

Table 8

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<th>0.2667</th>
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</table>

Step 5: integrate separate values

\[
 z_{ij} = \frac{1}{h(z_{ij}^1 + z_{ij}^2 + \cdots + z_{ij}^h)}
\]

(16)

\[
z_{ij} = 0.9133
\]

After calculating \( Z \), one solves Dematel technique.

Steps of solving Dematel method:
Step1: calculate K

\[ K = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^{n} a_{ij}} \]  

(17)

Table 9

<table>
<thead>
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</table>
| Row 10                    | 18.3514 | Max
|                           |     |
|                           | 18.3514 | K = \frac{1}{18.3514} = 0.0545
| Row 11                    | 17.6175 |
| Row 12                    | 17.8289 |
| Row 13                    | 16.0315 |
| Row 14                    | 16.9497 |
| Row 15                    | 14.7795 |
| Row 16                    | 16.898 |
| Row 17                    | 17.1808 |
| Row 18                    | 15.5248 |
| Row 19                    | 15.2952 |
| Row 20                    | 16.2677 |

Step2: calculate S

\[ S = K \times T \]  

(18)

Step3: calculate M

\[ M = X (1 - X)^{-1} \]  

(19)

Step4: calculate M
\[ M = m_{ij} \quad i, j = 1, 2, \ldots, n \quad (20) \]

**Table 10**

<table>
<thead>
<tr>
<th>Col 1</th>
<th>7.857</th>
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<td>8.2198</td>
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<td>Row 8</td>
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<td>Row 12</td>
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<tr>
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<td>Row 14</td>
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</tbody>
</table>

**Step 5,6: calculate R+D,R-D**

\[
\begin{align*}
D & = \left[ \sum_{j=1}^{n} m_{ij} \right]_{n \times 1} \\
R & = \left[ \sum_{i=1}^{n} m_{ij} \right]_{1 \times n}
\end{align*}
\]
Table 11

<table>
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<tr>
<th></th>
<th>Row + Col</th>
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</thead>
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<tr>
<td>C_6</td>
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<tr>
<td>C_7</td>
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<td>C_8</td>
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<tr>
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<td>C_{20}</td>
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</table>

After calculating the final step the following diagram is plotted. This diagram shows the level of effect and affected between indicators (important indicators in supplier selection) in a two-dimensional space.

Figure 1
Conclusion and suggestion

The purpose of concluding the research is to highlight the value of research so that the lack of a general conclusion makes worthless the research. New methods of evaluating suppliers provide good information for managers. Supplier selection and evaluation problem is considered substantially as a multi-criteria decision-making issue.

A special feature of this issue is the presence of quantitative and qualitative criteria to evaluate that makes difficult and complex decision-making. In this study, it is tried to extract the factors affecting supplier selection using initial questionnaire and then examine the effect of and affected indicators using the framework of CFCS algorithm. The results of this process will help the suppliers to choose the most effect and affected by indicators.

Despite of various qualitative indicators that cannot be measured by quantitative units, fuzzy logic was used to select an appropriate supplier. In addition these indicators are measured based on the different scales. Given that supplier selection is one of the most important components of successful company in business market, it is necessary to apply an appropriate system in order to select and evaluate them. Investigations show that supplier selection is multi-criteria problem and influenced by different factors such as industry context, activity scope of company.

Therefore, supplier selection problem is considered as the most important issue for successful implementation of supply chain. In general, supplier selection problem faces inaccurate and vague data and the use of fuzzy –set theory seems suitable to examine unreliability. The purpose of the study is to provide a model to evaluate the relation and effect of relevant indicators on supplier selection in ceramic and tile industry of Yazd. According to CFCS algorithm and Dematel fuzzy technique and cause-effect curve and position of each indicator and its role and importance, the results can be noted as follow:

According to the managers' point of view and CFCS algorithm and Dematel fuzzy technique, logistic planning and management indicator (c2) had the highest effect in implementing the project of selecting suppliers in ceramic industry. Reducing indictor of resistance to change the amount of intended order (c20) had the lowest effect and highest affected in this project. Also mutual trust and relation between buyer and seller (c1) had lower affected than other indicators. If cause and effect curve is divided into 4 areas, available indicators had lower effect in first quarter c4, c10, c11 and fourth quarter c5, c6, c12, c13, c20. According to studies and the results obtained from CFCS algorithm and Dematel fuzzy technique, ceramic and tile industry in Yazd must consider logistic planning and management indicator for selecting suppliers of the required material that having high effect and also reducing indicator of resistance to change amount of intended order had higher affected than the other indicators and it must be paid more attention to supplier selection.

In order to do future research in this area, it is recommended that pure and updated indicators will be examined to select suppliers in ceramic and tile industry of Yazd. Also using networking...
process analysis techniques and in order to improve quality services by material providers, improvement techniques of performance development should be used.
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