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Supplier Selection with Grey Relational Analysis

Tuğba Sarı
School of Business
Istanbul University, Turkey

Kasım Baynal
Dep.of Industrial Engineering
Kocaeli University, Turkey

Öznur Ergül
Dep.of Industrial Engineering
Kocaeli University, Turkey

Abstract-

It has become more complicated to select the best suppliers in today's competitive market. The monthly or yearly performance measurement of the selected suppliers has become a complex process. Supplier evaluation and selection process is a multi-criteria decision making problem that involves consideration of both qualitative and quantitative attributes. The purpose of this study is developing an alternative solution strategy for supplier selection problem under uncertain conditions. In this study, four main criteria are used for suppliers' performance measurement, which are delivery, quality, service and price. The performances of fifteen suppliers of a food manufacturing company are evaluated by grey relational analysis and the best supplier is selected.

Key Words- Grey Relational Analysis, Multi-criteria Decision Making, Supplier Selection

I. INTRODUCTION

Suppliers play a key role in supply chain, since they supply direct or indirect input materials to manufacturing process. The quality and cost of a product/service not only depend on manufacturing companies' ability, but also depend on suppliers of that company. The performance of suppliers, affects the whole supply chain from the main manufacturer to the last consumer. Today, one of the main goals of manufacturing companies is having zero defects in production. In order to achieve this goal, it is important to minimize supply chain based problems.

The performance measuring criteria in supplier selection process have become more complicated with increasing demand of producers in competitive market. The most characteristic attribute of the companies that survives in competitive market, is to measure their performance, to evaluate the results and to take actions for proactive solutions. Performance evaluation activities have key factor for the firms, since it helps firms to realize their position in the market. It also helps them to discover the areas that need improvement.

Supplier evaluation and selection process is considered as a multi criteria decision making problem. In literature, there are many different performance evaluation methods such as; discriminant analysis, factor analysis, principle component analysis, cluster analysis etc. More recently, new models like fuzzy theory, data envelopment analysis etc. are developed for performance evaluation. Nevertheless, such statistical methods need detailed data with normal distribution (Tsung and Hsien, 2009).

Supplier evaluation based on the qualitative criteria inherent recognitive uncertainty stems from having lack of information or lack of clearness about suppliers performances. In this situation grey system theory is suitable choice because it is developed to study the uncertainty problem of small samples and poor information (Memon et.al.,2015).

In this study, fifteen certificated suppliers of a food company are evaluated by grey relation analysis method. The scores of suppliers are determined by an expert team of the company. The scores used in evaluation process are the average of all scores from the experts.

II. LITERATURE SEARCH

Grey theory was first developed by Julong Deng in 1982 (Deng,1989). It has been used many different areas since that time. Grey theory was used by Hsu and Wen (2000), in order to design the traffic and flight frequency in airways. Feng and Wang (2000) used grey theory for measuring the financial performance of airway companies, and Yuan (2007) used it for defining the ratios which affect the performance of company. Chang (2006) has measured performance of the banks by grey relation analysis. Wang (2009) used grey relation analysis for measuring the performance of logistic companies. One of the methods used for optimization of wire erosion system is grey relation analysis method in the study of Lin and Lin in 2002. Palanikumar et.al.(2006) used grey relation analysis method to optimize the results of polymer material process.

Grey theory has become used in recent studies in selection of suppliers considering uncertainty. It has become a strong alternative to the methods Fuzzy Analytic Hierarchy, Fuzzy Analytic Network Process, Fuzzy TOPSIS and Fuzzy Preference Programming. In the study of Golmohammadi and Mellat-Parast in 2012, the supplier selection problem in automotive industry was held by using grey relational analysis. Dou et.al.(2014), introduced a grey analytical network process-based model to identify green supplier development programs. Rajesh and Ravi (2015) used grey relational analysis approach for supplier selection in resilient supply chains. Memon et.al.(2015), combined grey system theory and uncertainty theory for supplier selection, since which of them neither requires any probability distribution nor fuzzy membership function. Hashemi et.al (2015) used a hybrid model including analytic network process and grey relational analysis methods to solve a green supplier selection problem in automotive industry.

III. GREY RELATIONAL ANALYSIS METHOD

The grey theory was first developed by Julong Deng in 1982. The information that is either incomplete or undetermined is called grey information up to this theory. The model includes three types of information points; black, white or grey. The main goal is to transfer black points in the system to the grey points.

The grey system provides solutions to problems where the information is limited, incomplete and characterized by random uncertainty. In recent twenty years, the grey theory has become a popular technique providing multidisciplinary approaches.

Grey relation analysis is a multi-criteria decision making method that helps managers to take the right decision under circumstances with limited and uncertain data (Chan and Thong, 2007).

Yuan (2007), express the grey relation analysis process in figure 1:

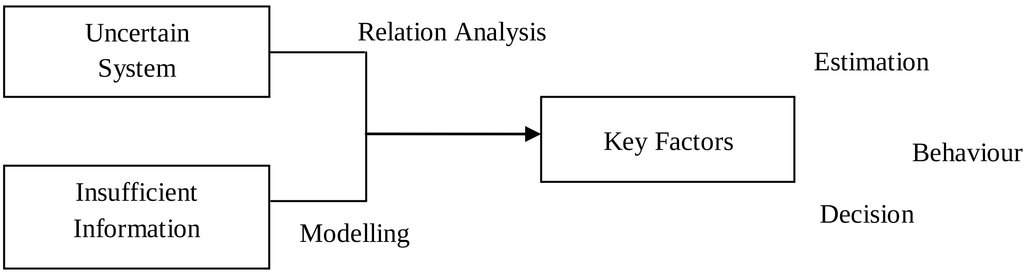

Figure 1 Grey Relation Analysis Process

Grey relation analysis includes six steps. These steps are explained below (Zhai et.al, 2009):

1. Step: Construction of Norm Matrix

An "m x n" norm matrix made up of "m" alternatives and "n" criteria is constructed as follows:

$$\begin{matrix} X_1(1) & X_1(2) & \dots & X_1(n) \\ X_2(1) & X_2(2) & \dots & X_2(n) \\ .. & .. & & .. \\ X_m(1) & X_m(2) & \dots & X_m(n) \end{matrix} \quad (1)$$

In the norm matrix (1), $X_i(k)$ value shows the "k"th criterion of supplier"i".

2. Step: Construction of Reference Sequence

The reference sequence can be changed up to the application area. The reference sequence of this study is defined as X_0= (1, 1,…,1). The aim is to find the closest sequence to the reference among the alternatives (18).

3. Step: Normalization

Since MCDM problems may contain a variation of different criteria, the solution needs normalization. Normalization process has following three equations (14):

$$X_i(k) = (x_i(k) - \min x_i(k)) / (\max x_i(k) - \min x_i(k)) \quad (2)$$

$$X_i(k) = (\max x_i(k) - x_i(k)) / (\max x_i(k) - \min x_i(k)) \quad (3)$$

$$X_i(k) = 1- | x_i(k) - u_i | / \max | x_i(k) - u_i | \quad (4)$$

Here, normalization based on the characteristics of three types of criteria, namely maximum the better (equation 2), minimum the better (equation 3) and nominal the best (equation 3)

4. Step: Calculation of Absolute Value Table

The difference between a normalized entity and its reference value is calculated. The difference is shown as ΔX_i.

$$\Delta X_i(k) = | Y_0(1) - X_1(1) |, | Y_0(2) - X_1(2) | \dots | Y_0(n) - X_1(n) | \quad (5)$$

5. Step: Construction ofGrey Relational Coefficient Matrix

In the difference matrix, Δ_{max} and Δ_{min} values are calculated, where,

Δ_{max} : maximum difference value in the matrix

Δ_{min} : minimum difference value in the matrix

$$K_{(j)} = (\Delta_{min} + \delta\Delta_{max}) / (\Delta_i(j) + \delta\Delta_{max}) \quad (6)$$

In equation 6,$\Delta_i(j)$; shows the "j"th value in $\Delta_i$difference data sequence. δ is known as distinguishing coefficient for the index for distinguishability and in most situations it takes the value 0,5 for good stability.

6. Step: Calculation of Grey Relational Degree

The grey relation degree of "i"th alternative is expressed as following eq.:

$$\acute{\tau}_i = 1/n \sum_{m=1}^{n} K(m) \quad (7)$$

If the criteria have different weights, the grey relation degree is formulated as:

$$\acute{\tau}_i = 1/n \sum_{m=1}^{n} K(m) w(m) \quad (8)$$

Where, w(m) refers to weight of "n"th. criterion.The sum of the weights of all criteria must equal to 1.

IV. THE MAIN CRITERIA FOR SUPPLIER PERFORMANCE EVALUATION

The indicators that are used to determine the effectiveness and efficiency of an activity are called performance criteria and the set of these criteria is performance measuring system (Neely et.al.,1995). The performance measuring criteria of suppliers depends on the sector, organization type or quality system of supplier. The effect of criterion may be equal to each other or differ from the others. In the second case the effect of each criterion on purchasing decision should be determined (Yahya and Kingsman, 1999). In the complex supply chains, it is difficult to balance the needs of the purchaser companies and suppliers. Evaluation and measurement activities are critical factors for long term relationship in supply chain. Supplier performance evaluation cycle is shown in figure 2.This cycle helps the supplier and the purchaser to improve the poor performance.

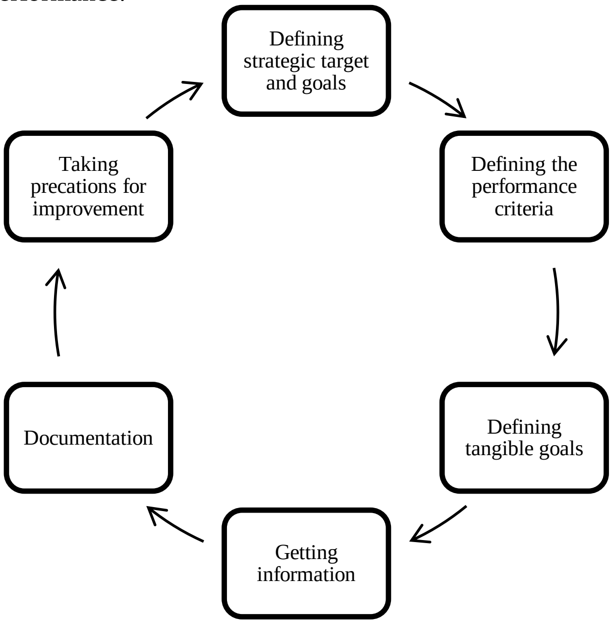

Figure 2 The Steps of Performance Evaluation Process (Grandy, 1991)

Delivery

On time delivery is an important criterion for evaluation and selection of suppliers. It is also important for strong, long term supplier-buyer relationship. A delivery criterion includes delivery of products on time and in a reliable way. The way of delivery (plane - ship) also affects the performance of delivery.Suppliers should have flexibility for the changes in production and order, and have adequate capacity to match the buyer's needs. The shipping cost is also effective in on time delivery of products.

Nowadays, the increase in just- in- time production modeling, causes the manufacturing companies to work with minimum stocks. Therefore the importance of on time and exact amount of delivery becomes more important than before especially in food manufacturing industry.

Quality

Along the way from the supplier to the customer, a small defect in quality may cause serious problems in the whole supply chain cycle. Because of that, the quality problems causing from suppliers are great concern to the manufacturing firms. The rejected product ratio is an important factor, since it may cause insufficient amount of manufacturing. It may cause also defects or cuts in production. Suppliers should be in continuous enhancement, in order to supply the best product to manufacturer.

Quality or performance loss in a product, may cause production and order cuts. It may cause time and money loss for the buyer by increasing the repairment costs. A supplier which is selected for its minimum cost can lose its cost advantage because of poor quality or poor performance. The quality criterion includes the quality control methods and quality certificates of the supplier. It also includes defective product ratio. The certificates which are taken in to consideration in assessment process are the documentations like migration tests, TSE, ISO, analysis certificates etc.

Service

The service criterion is one of the most difficult criteria for transferring quantitative values and it can be separated to many sub-criteria according to customer needs (Baynal et.al, 2014). A supplier needs modern communication channels and tools to cooperate with buyer. Recovery of defective products, technical support, warranty conditions and customer service productivity will increase the efficiency of cooperation. After sales, support and accessory security should also be taken in to consideration.

Technical support is required for development of new products or reengineering. The innovation proposals from supplier are important to catch new trends in the sector. The capacity of supplier is a critical factor for selection process. Problem solving ability and having preventive and corrective activities put the supplier forward on among others.

Price

Price criterion includes the real price and quantity discounts of the product that is purchased from the supplier. Purchaser companies usually prefer lower price products in order to minimize their purchasing costs and hence maximize their profits. The price criterion is very critical for manufacturing companies in order to get competitive advantage in the sector. Therefore, the total cost of a product or service is one of the most important factors in supplier evaluation and selection process for a purchasing company.

V. SUPPLIER PERFORMANCE EVALUATION BY USING GREY RELATION ANALYSIS METHOD

In application part of this study, grey relation analysis method is used in order to evaluate the suppliers in a food manufacturing company. It is aimed to measure the performance of fifteen suppliers and then to select the best performing supplier. The reason for using grey relational analysis method is that, the selection of supplier's characteristics and preference for each type of procurement depend on decision maker's subjective judgment. And therefore the whole process deals with uncertainty. The information loss of supplier's attributes arising from lack of knowledge about alternatives and subjective judgment of decision makers will be covered by grey relational analysis in this study.

The performance evaluation and selection is based on four main criteria and fifteen sub criteria. These criteria which are determined by experts of the food manufacturing company are shown in table 1. The hierarchical presentation of these criteria can be seen in figure 3. The weights of these criteria are also determined by the same expert team of the company by using Delphi technique. In Delphi technique; the weight of a criterion is calculated by taking average of the weights coming from each expert for that specific criterion.

Table 1 Supplier Performance Evaluation Criteria

Target	Criteria	Sub-criteria
Supplier Performance Evaluation via Grey Relation Analysis	Delivery	On time delivery
		Delivery appropriate to order quantity
		Ability to supply urgent orders
	Quality	Ratio of rejected products
		Quality improvement performance
		Having necessary documentation
		Food safety inspection score
	Service	Customer satisfaction
		Technical support
		Having adequate capacity
		Innovation proposals
		Preventive and corrective activities
	Price	Best price
		Cost reducing activities

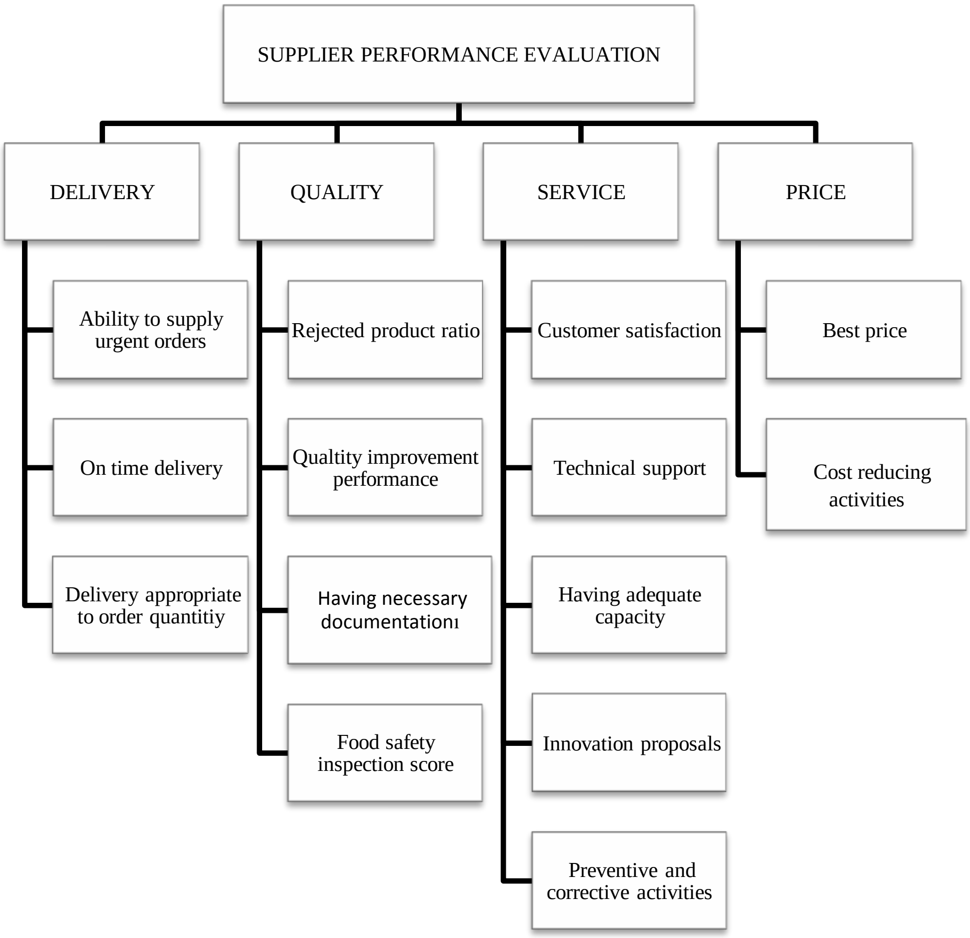

Figure 3 Supplier Performance Criteria Hierarchy

All the criteria in this study are expressed in quantitative values. Criteria are named as C1, C2,.....,C14, and suppliers are named as S1, S2,......,S15. The evaluations of criteria C4 and C5 are based on the minimum is better principle, while the other criteria are evaluated by maximum is better principle. Table 2 shows the performance criteria with their explanations.

Table 2 Performance Criteria with Explanations

Criteria	Name of Criteria	Explanation	Evaluation Principle
C1	On time delivery	If a supplier delivers on time, he gets the score 2, otherwise he gets 1	Max. is better
C2	Delivery appropriate to order quantity	If a supplier delivers exact amount, he gets score 2, otherwise he gets 1	Max. is better
C3	Ability to supply urgent orders	Amount of urgent supply / Amount of urgent order (in a year)	Max. is better
C4	Ratio of rejected products	Rejected product amount / Order amount (in a year)	Min. is better
C5	Quality improvement performance	Complaintment number / Order amount (in a year)	Min. is better
C6	Having necessary documentation	Existing Documents / Requested Documents	Max. is better
C7	Food safety inspection score	Maximum score is 1000. The score is divided by 1000.	Max. is better
C8	Customer satisfaction	The % score in the customer satisfaction survey.	Max. is better
C9	Technical support	Technical support / Demanding support	Max. is better
C10	Having adequate capacity	Monthly order / Monthly capacity of supplier	Max. is better
C11	Innovation proposals	Innovation proposals by supplier in a year	Max. is better
C12	Preventive and corrective activities	Preventive and corrective activities / Supplier based problem	Max. is better
C13	Best price	Number of auction winning in a year	Max. is better
C14	Cost reducing activities	Number of cost reducing activities in a year	Max. is better

The six step of grey relational analysis is performed in the following order:

1. **Step:** For the solution of supplier evaluation problem the first step is construction of the norm matrix. The norm matrix formation with (m x n) elements are given below in the table 3.

Table 3 The Norm Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
S1	1	2	0,4	0,10	0,30	0,40	0,97	0,7	1	1	2	1	6	1
S2	2	1	1	0,02	0,53	0,40	0,40	0,75	0,8	1	1	1	4	2
S3	1	2	0,6	0,08	0,41	0,95	0,89	0,55	0,66	1	3	0,8	8	1
S4	1	2	0,8	0,05	0,30	0,25	0,89	0,6	1	1	2	1	23	6
S5	2	2	1	0,00	0,03	1,00	1,00	0,9	1	1	4	1	20	5
S6	2	2	0,8	0,02	0,05	0,95	0,95	0,95	0,24	1	4	1	1	2
S7	1	2	0	0,10	0,08	0,85	0,74	0,75	0,74	0,8	1	0,6	2	1
S8	2	1	0,2	0,01	0,09	0,90	0,56	0,85	1,00	0,65	1	0,5	1	1
S9	1	1	0	0,10	0,02	0,15	0,30	0,55	0,13	0,55	0	0,55	1	0
S10	1	2	1	0,05	0,07	0,55	0,50	0,8	0,75	1	3	1	4	1
S11	2	1	0,4	0,05	0,15	0,80	0,69	0,7	0,92	0,8	2	1	2	2
S12	2	2	0,6	0,00	0,02	0,90	0,70	0,95	1,00	0,9	3	0,9	21	2
S13	1	2	0,8	0,01	0,11	0,75	0,88	0,65	0,00	1	1	0,8	3	3
S14	2	1	0,4	0,25	0,33	0,80	0,71	0,55	0,50	1	1	0,65	2	2
S15	1	2	0,6	0,17	0,40	1,00	0,40	0,65	0,13	1	1	0,55	2	1

2. **Step:** After formation of the norm matrix, the reference sequence is constructed in order to find comparable sequence of alternatives which gives the closest result to reference sequence. (Table 4)

Table 4 Reference Sequence

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
RS	2	2	1	0,95	0	1	0,95	0,95	1	0,85	4	1	100	12
S1	1	2	0,4	0,10	0,30	0,40	0,97	0,7	1	1	2	1	6	1
S2	2	1	1	0,02	0,53	0,40	0,40	0,75	0,8	1	1	1	4	2

S3	1	2	0,6	0,08	0,41	0,95	0,89	0,55	0,66	1	3	0,8	8	1
S4	1	2	0,8	0,05	0,30	0,25	0,89	0,6	1	1	2	1	23	6
S5	2	2	1	0,00	0,03	1,00	1,00	0,9	1	1	4	1	20	5
S6	2	2	0,8	0,02	0,05	0,95	0,95	0,95	0,24	1	4	1	1	2
S7	1	2	0	0,10	0,08	0,85	0,74	0,75	0,74	0,8	1	0,6	2	1
S8	2	1	0,2	0,01	0,09	0,90	0,56	0,85	1,00	0,65	1	0,5	1	1
S9	1	1	0	0,10	0,02	0,15	0,30	0,55	0,13	0,55	0	0,55	1	0
S10	1	2	1	0,05	0,07	0,55	0,50	0,8	0,75	1	3	1	4	1
S11	2	1	0,4	0,05	0,15	0,80	0,69	0,7	0,92	0,8	2	1	2	2
S12	2	2	0,6	0,00	0,02	0,90	0,70	0,95	1,00	0,9	3	0,9	21	2
S13	1	2	0,8	0,01	0,11	0,75	0,88	0,65	0,00	1	1	0,8	3	3
S14	2	1	0,4	0,25	0,33	0,80	0,71	0,55	0,50	1	1	0,65	2	2
S15	1	2	0,6	0,17	0,40	1,00	0,40	0,65	0,13	1	1	0,55	2	1

3. **Step:** In this step, the data are normalized. For the criteria C4 and C5, minimum is better normalization is used, while the other twelve criteria are normalized with maximum is better principle. In the table 5, the normalized data is given.

Table 5 Normalization of the Data

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
RS	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
S1	0,00	1,00	0,40	0,60	0,45	0,29	0,95	0,38	1,00	1,00	0,50	1,00	0,23	0,17
S2	1,00	0,00	1,00	0,93	0,0	0,29	0,14	0,50	0,80	1,00	0,25	1,00	0,14	0,33
S3	0,00	1,00	0,60	0,67	0,23	0,94	0,84	0,00	0,66	1,00	0,75	0,60	0,32	0,17
S4	0,00	1,00	0,80	0,80	0,45	0,12	0,84	0,13	1,00	1,00	0,50	1,00	1,00	1,00
S5	1,00	1,00	1,00	1,00	0,97	1,00	0,99	0,88	1,00	1,00	1,00	1,00	0,86	0,83
S6	1,00	1,00	0,80	0,94	0,94	0,94	0,93	1,00	0,24	1,00	1,00	1,00	0,00	0,33
S7	0,00	1,00	0,00	0,60	0,88	0,82	0,62	0,50	0,74	0,56	0,25	0,20	0,05	0,17
S8	1,00	0,00	0,20	0,95	0,86	0,88	0,36	0,75	1,00	0,22	0,25	0,00	0,00	0,17
S9	0,00	0,00	0,00	0,60	1,00	0,00	0,00	0,00	0,13	0,00	0,00	0,10	0,00	0,00
S10	0,00	1,00	1,00	0,80	0,90	0,47	0,29	0,63	0,75	1,00	0,75	1,00	0,14	0,17
S11	1,00	0,00	0,40	0,78	0,74	0,76	0,56	0,38	0,92	0,56	0,50	1,00	0,05	0,33
S12	1,00	1,00	0,60	1,00	0,99	0,88	0,57	1,00	1,00	0,78	0,75	0,80	0,91	0,33
S13	0,00	1,00	0,80	0,96	0,82	0,71	0,83	0,25	0,00	1,00	0,25	0,60	0,09	0,50
S14	1,00	0,00	0,40	0,00	0,38	0,76	0,59	0,00	0,50	1,00	0,25	0,30	0,05	0,33
S15	0,00	1,00	0,60	0,33	0,25	1,00	0,14	0,25	0,13	1,00	0,25	0,10	0,05	0,17

4. **Step:** Measuring differences and constructing the absolute value table.

Table 6 Table of Absolute Values

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
RS	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
S1	1,00	0,00	0,60	0,40	0,55	0,71	0,05	0,63	0,00	0,00	0,50	0,00	0,77	0,83
S2	0,00	1,00	0,00	0,07	1,00	0,71	0,86	0,50	0,20	0,00	0,75	0,00	0,86	0,67
S3	1,00	0,00	0,40	0,33	0,77	0,06	0,16	1,00	0,34	0,00	0,25	0,40	0,68	0,83
S4	1,00	0,00	0,20	0,20	0,55	0,88	0,16	0,88	0,00	0,00	0,50	0,00	0,00	0,00
S5	0,00	0,00	0,00	0,00	0,03	0,00	0,01	0,13	0,00	0,00	0,00	0,00	0,14	0,17
S6	0,00	0,00	0,20	0,06	0,06	0,06	0,07	0,00	0,76	0,00	0,00	0,00	1,00	0,67
S7	1,00	0,00	1,00	0,40	0,12	0,18	0,38	0,50	0,26	0,44	0,75	0,80	0,95	0,83
S8	0,00	1,00	0,80	0,05	0,14	0,12	0,64	0,25	0,00	0,78	0,75	1,00	1,00	0,83

S9	1,00	1,00	1,00	0,40	0,00	1,00	1,00	1,00	0,87	1,00	1,00	0,90	1,00	1,00
S10	1,00	0,00	0,00	0,20	0,10	0,53	0,71	0,38	0,25	0,00	0,25	0,00	0,86	0,83
S11	0,00	1,00	0,60	0,22	0,26	0,24	0,44	0,63	0,08	0,44	0,50	0,00	0,95	0,67
S12	0,00	0,00	0,40	0,00	0,01	0,12	0,43	0,00	0,00	0,22	0,25	0,20	0,09	0,67
S13	1,00	0,00	0,20	0,04	0,18	0,29	0,17	0,75	1,00	0,00	0,75	0,40	0,91	0,50
S14	0,00	1,00	0,60	1,00	0,62	0,24	0,41	1,00	0,50	0,00	0,75	0,70	0,95	0,67
S15	1,00	0,00	0,40	0,67	0,75	0,00	0,86	0,75	0,88	0,00	0,75	0,90	0,95	0,83

5. **Step:** In this step, the differences between reference sequence and measured values are calculated. The coefficient differences are found a grey relational coefficient matrix is formulated.

Table 7 Calculation of Δ_{min} and Δ_{max}

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
RS	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
S1	0,00	1,00	0,40	0,60	0,45	0,29	0,95	0,38	1,00	1,00	0,50	1,00	0,23	0,17
S2	1,00	0,00	1,00	0,93	0,00	0,29	0,14	0,50	0,80	1,00	0,25	1,00	0,14	0,33
S3	0,00	1,00	0,60	0,67	0,23	0,94	0,84	0,00	0,66	1,00	0,75	0,60	0,32	0,17
S4	0,00	1,00	0,80	0,80	0,45	0,12	0,84	0,13	1,00	1,00	0,50	1,00	1,00	1,00
S5	1,00	1,00	1,00	1,00	0,97	1,00	0,99	0,88	1,00	1,00	1,00	1,00	0,86	0,83
S6	1,00	1,00	0,80	0,94	0,94	0,94	0,93	1,00	0,24	1,00	1,00	1,00	0,00	0,33
S7	0,00	1,00	0,00	0,60	0,88	0,82	0,62	0,50	0,74	0,56	0,25	0,20	0,05	0,17
S8	1,00	0,00	0,20	0,95	0,86	0,88	0,36	0,75	1,00	0,22	0,25	0,00	0,00	0,17
S9	0,00	0,00	0,00	0,60	1,00	0,00	0,00	0,00	0,13	0,00	0,00	0,10	0,00	0,00
S10	0,00	1,00	1,00	0,80	0,90	0,47	0,29	0,63	0,75	1,00	0,75	1,00	0,14	0,17
S11	1,00	0,00	0,40	0,78	0,74	0,76	0,56	0,38	0,92	0,56	0,50	1,00	0,05	0,33
S12	1,00	1,00	0,60	1,00	0,99	0,88	0,57	1,00	1,00	0,78	0,75	0,80	0,91	0,33
S13	0,00	1,00	0,80	0,96	0,82	0,71	0,83	0,25	0,00	1,00	0,25	0,60	0,09	0,50
S14	1,00	0,00	0,40	0,00	0,38	0,76	0,59	0,00	0,50	1,00	0,25	0,30	0,05	0,33
S15	0,00	1,00	0,60	0,33	0,25	1,00	0,14	0,25	0,13	1,00	0,25	0,10	0,05	0,17
Δ_{min}	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Δ_{max}	1,00	1,00	1,00	1,00	1,00	1,00	0,99	1,00	1,00	1,00	1,00	1,00	1,00	1,00

All the elements in the table7, are subtracted from reference values and, Δ_{min} and Δ_{max} values are obtained. After that, these values are analyzed assuming x = 0, 5.

Table 8 Grey Relation Coefficient Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
W	0,0250	0,0056	0,0070	0,2670	0,3050	0,0015	0,0368	0,0012	0,0001	0,0009	0,0126	0,0470	0,2730	0,0173
S1	1,0000	0,3333	0,5556	0,4545	0,5272	0,6296	0,3426	0,5714	0,3333	0,3333	0,5000	0,3333	0,6875	0,7500
S2	0,3333	1,0000	0,3333	0,3501	1,0000	0,6296	0,7760	0,5000	0,3846	0,3333	0,6667	0,3333	0,7857	0,6000
S3	1,0000	0,3333	0,4545	0,4286	0,6882	0,3469	0,3708	1,0000	0,4310	0,3333	0,4000	0,4545	0,6111	0,7500
S4	1,0000	0,3333	0,3846	0,3846	0,5243	0,8095	0,3700	0,8000	0,3333	0,3333	0,5000	0,3333	0,3333	0,3333
S5	0,3333	0,3333	0,3333	0,3333	0,3391	0,3333	0,3327	0,3636	0,3333	0,3333	0,3333	0,3333	0,3667	0,3750
S6	0,3333	0,3333	0,3846	0,3482	0,3483	0,3469	0,3477	0,3333	0,6790	0,3333	0,3333	0,3333	1,0000	0,6000
S7	1,0000	0,3333	1,0000	0,4545	0,3622	0,3778	0,4434	0,5000	0,4035	0,4737	0,6667	0,7143	0,9167	0,7500
S8	0,3333	1,0000	0,7143	0,3444	0,3688	0,3617	0,5761	0,4000	0,3333	0,6923	0,6667	1,0000	1,0000	0,7500
S9	1,0000	1,0000	1,0000	0,4545	0,3336	1,0000	1,0000	1,0000	0,7895	1,0000	1,0000	0,8333	1,0000	1,0000
S10	1,0000	0,3333	0,3333	0,3846	0,3560	0,5152	0,6340	0,4444	0,4000	0,3333	0,4000	0,3333	0,7857	0,7500
S11	0,3333	1,0000	0,5556	0,3896	0,4030	0,3953	0,4705	0,5714	0,3529	0,4737	0,5000	0,3333	0,9167	0,6000
S12	0,3333	0,3333	0,4545	0,3333	0,3346	0,3617	0,4642	0,3333	0,3333	0,3913	0,4000	0,3846	0,3548	0,6000
S13	1,0000	0,3333	0,3846	0,3429	0,3781	0,4146	0,3740	0,6667	1,0000	0,3333	0,6667	0,4545	0,8462	0,5000
S14	0,3333	1,0000	0,5556	1,0000	0,5660	0,3953	0,4580	1,0000	0,5000	0,3333	0,6667	0,6250	0,9167	0,6000
S15	1,0000	0,3333	0,4545	0,6000	0,6636	0,3333	0,7760	0,6667	0,8000	0,3333	0,6667	0,8333	0,9167	0,7500

6. Step: Determination of grey relation degrees

In this study, since each criterion has different importance degree, grey relation degree is obtained by multiplying the grey relation coefficient of the criterion with the importance degree of the same criterion.

If the reference sequence includes, max is better, min is better and nominal is best evaluations according to the types of the criteria, the calculated grey relation degree shows that the criteria match the needs. In other words, the factor sequence (alternative) which has maximum grey relation degree will be the best alternative in the decision problem.

Table 9 Grey Relation Degrees

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	GRD
W	0,0250	0,0056	0,0070	0,2670	0,3050	0,0015	0,0368	0,0012	0,0001	0,0009	0,0126	0,0470	0,2730	0,0173	
S1	1,000	0,333	0,556	0,455	0,527	0,630	0,343	0,571	0,333	0,333	0,500	0,333	0,688	0,750	0,5251
S2	0,333	1,000	0,333	0,350	1,000	0,630	0,776	0,500	0,385	0,333	0,667	0,333	0,786	0,600	0,5733
S3	1,000	0,333	0,455	0,429	0,688	0,347	0,371	1,000	0,431	0,333	0,400	0,455	0,611	0,750	0,5430
S4	1,000	0,333	0,385	0,385	0,524	0,810	0,370	0,800	0,333	0,333	0,500	0,333	0,333	0,333	0,4838
S5	0,333	0,333	0,333	0,333	0,339	0,333	0,333	0,364	0,333	0,333	0,333	0,333	0,367	0,375	0,3412
S6	0,333	0,333	0,385	0,348	0,348	0,347	0,348	0,333	0,679	0,333	0,333	0,333	1,000	0,600	0,4325
S7	1,000	0,333	1,000	0,455	0,362	0,378	0,443	0,500	0,404	0,474	0,667	0,714	0,917	0,750	0,5997
S8	0,333	1,000	0,714	0,344	0,369	0,362	0,576	0,400	0,333	0,692	0,667	1,000	1,000	0,750	0,6101
S9	1,000	1,000	1,000	0,455	0,334	1,000	1,000	1,000	0,789	1,000	1,000	0,833	1,000	1,000	0,8865
S10	1,000	0,333	0,333	0,385	0,356	0,515	0,634	0,444	0,400	0,333	0,400	0,333	0,786	0,750	0,5002
S11	0,333	1,000	0,556	0,390	0,403	0,395	0,470	0,571	0,353	0,474	0,500	0,333	0,917	0,600	0,5211
S12	0,333	0,333	0,455	0,333	0,335	0,362	0,464	0,333	0,333	0,391	0,400	0,385	0,355	0,600	0,3866
S13	1,000	0,333	0,385	0,343	0,378	0,415	0,374	0,667	1,000	0,333	0,667	0,455	0,846	0,500	0,5496
S14	0,333	1,000	0,556	1,000	0,566	0,395	0,458	1,000	0,500	0,333	0,667	0,625	0,917	0,600	0,6393
S15	1,000	0,333	0,455	0,600	0,664	0,333	0,776	0,667	0,800	0,333	0,667	0,833	0,917	0,750	0,6520

According to the values in table 9, Supplier T14, has the best performance. T15 is second and T2 is the third. The supplier with minimum performance is chosen as supplier T5. The suppliers having relatively lower performance are determined. And the lower criteria of those suppliers are improved.

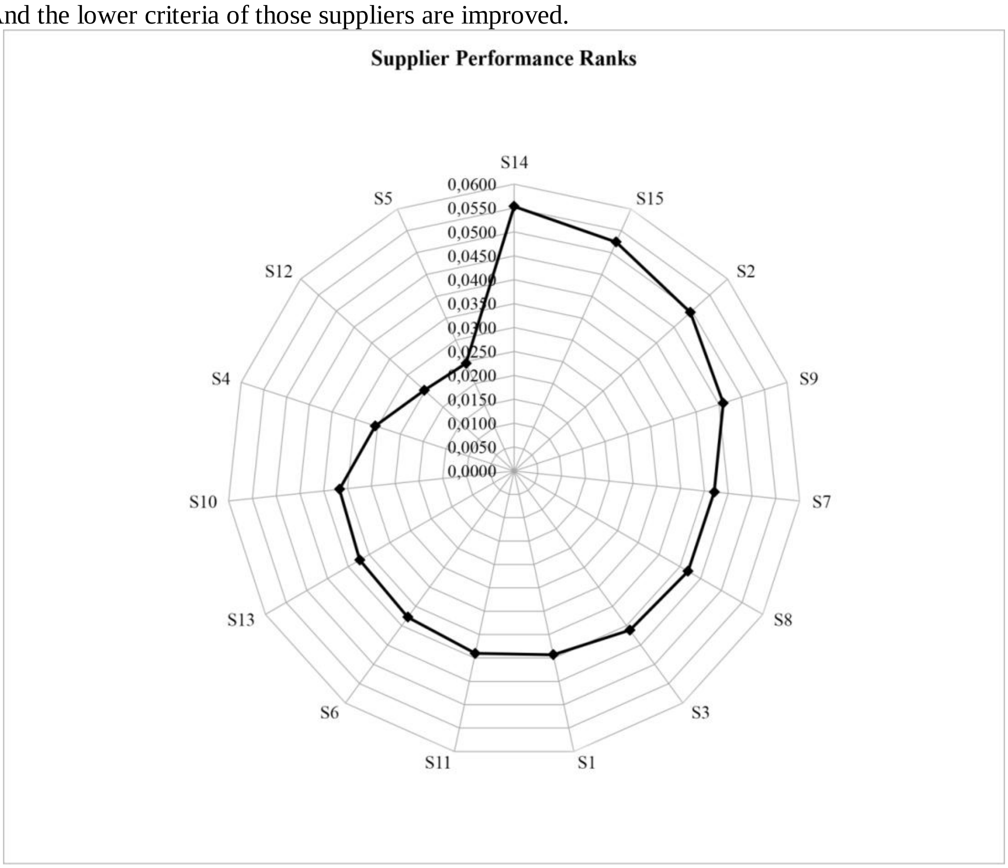

Figure 4 Radar Graphic Presentation of the Results of Grey Relation Analysis

In figure 4, the radar graphic presentation of the results of grey relation analysis can be seen. The graphic shows the relative performance of suppliers with respect to each other.

VI. RESULTS AND SUGGESTIONS

In this study, fifteen certified suppliers of a food manufacturing company are evaluated based on the specialized criteria for that company. The result of the analysis gives the best performing supplier among fifteen suppliers of the company. The manufacturing company can get chance to improve its long term relationship with good performing suppliers to get higher performance. This study also helps the company to determine the poor performing suppliers and to improve their poor performing areas.

Grey relational analysis method is used in this study, because, the selection of supplier's characteristics and preference for each type of procurement depend on decision maker's subjective judgement. And therefore the whole process deals with uncertainty. Grey relation analysis, is a mathematical multi criteria decision making model. In this method, the data is not necessarily fit to any statistical distribution. The grey relation analysis technique can give high performance in the solution of problems having multi criteria and multi alternative but limited data sequence.

Supplier evaluation based on the qualitative criteria inherent recognitive uncertainty stems from having lack of information or lack of clearness about suppliers performances. In this situation grey systems theory is suitable choice because its developed lto study the uncertainty problem of small samples and poor information (Memon, 2015).

The main advantage of grey system theory is that it can achieve satisfactory outcomes using a rather small amount of data or with a large amount of variability in the factors (Hashemi et.al, 2015). The grey system theory is used to quantify the linguistic variables. The method includes both quantitative and qualitative factors related to supplier selection problem. Where there is poor or lack of information (such as ratings) regarding available suppliers, the grey theory gives reliable and objective results with limited information.

The grey relation analysis can help decision makers in finding optimum solutions to complex multi criteria decision making problems by evaluating all the alternatives in an easier manner.Grey relation analysis gives realistic results, since the weights of the criteria are included in the model. In the future studies, TOPSIS, ELECTRE, Analytic Network Process, PROMETHEE methods can be combined or compared with the results of this study.

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