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Evaluation of Supplier Selection in Manufacturing Industries using Grey Relational Analysis- A Case Study

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Abstract – Selection of supplier is one of the most critical activities performed by the organizations because of its strategic importance. Over the years a number of quantitative approaches have been applied to supplier selection problems. The selection process is commonly based on their previous performance records, so the ranking determines which supplier will get their supply contract. However a survey on current evaluation methods shows that they are all less objective and lack accurate data processing. These evaluation criteria often conflict, however and it is frequently impossible to find a supplier that excels in all areas. In addition some of the criteria are quantitative and some are qualitative. Thus a methodology is needed that can capture both subjective and objective evaluation measures. In this paper, we presented AHP and Grey Relational Analysis to establish a complete and accurate evaluation model for selecting suppliers based on multiple criteria and places the order quantities among them for a spinning industry

Keywords- *Supplier Selection, Grey Relational Analysis, AHP.*

I. INTRODUCTION

Any organization in business today is under pressure to stay competitive and make profit. Traditionally organizations have been divided in operative functions such as marketing, planning, production, purchasing, finance etc. Supply chain is a strategy that integrates these functions creating a general plan for the organizations, which satisfies the service policy, maintaining, and the lowest possible cost level due to the incredible competition environment that they are exposed to retailers. The purchasing function has gained great importance in the supply chain management due to factors such as globalization, increase value added in supply and accelerated technological change. Purchasing involves buying the raw material, supplies, and components for the organization. The activities associated with it include selecting and qualifying suppliers, rating supplier performance, negotiating contracts, comparing price, quality and service, etc. Considerable importance has focused on vendor selection in recent years as more managers have come to the firm's competition advantage.

Selecting the best supplier has become a critical problem for the company. The major objective of this paper is to evaluate the best supplier in a corporate environment using Analytical Hierarchical Process and Grey Relational Analysis.

Chin-Nung Liao [2010] proposed supplier selection project is one of the most important decision-making problems for many firms. This paper presents an integrated modified Delphi technique, Analytic Hierarchy Process and Taguchi loss functions systems to valuation and selection suppliers. Sanjay Kumar, Neeraj Parashar, Dr. Abid Haleem[2009] proposed that AHP helped to conclude the expert views as obtained through questionnaire for supplier selection in industries. Vorawit Kachainchai and Waressara Weerawat[2007] proposed the linkage between manufacturers and their suppliers in Thailand is not strong enough to compete in the aggressive international market. The purpose of this paper is to develop the evaluation model to compare suppliers that located in Thailand with suppliers that located elsewhere. In order to identify the criteria and the method in the model, the reviews of literature and the face-to-face interview with experts in the industry are employed in this study. The criteria have been divided into 5 main clusters: delivery, quality, cost, reliability, and flexibility. The explanations of each criterion are also described in this paper. The methods of this model are the Weight-point method and AHP. Deng has proposed Grey Relational Analysis that was proved to be simple and accurate method for multiple attributes decision problems.

II. SUPPLIER EVALUATION METHODS

Supplier evaluation methods are the models that commonly use in supplier selection process. Each method has advantages and disadvantages. In order to select the most qualified supplier, it is necessary to employ the appropriate method (or a literature related in supplier selection and evaluation models. Most of methods have to set supplier performance criteria which discussed in previous section. There are three types of common supplier evaluation models being used for supplier selection. They consist of the linear weighting model, the total cost model, and the mathematical programming model.

A. The Linear Weighing Model

The linear weighing model measures suppliers by rating their performance in many criteria and calculating into single score. The methods that are categorized as linear weighing models are the categorical method, the weigh point method, and the analytical hierarchy process.

B. Total Cost Model

Another set of methods is classified as total cost approach. The idea of this approach is mainly interested in all costs which are related to the selection of a supplier. This type of model includes the cost ratio method and the total ownership method.

C. Mathematical Programming Model

The purpose of this model is to select several suppliers while optimizing objective function which subject to supplier and buyer constraints. This type consists of two methods: the neural network and the data envelopment analysis (DEA).

III. GREY RELATIONAL ANALYSIS

A survey on current evaluation methods shows that they are all less objective and lack accurate data processing. This methodology will significantly reduce the purchasing cost and increase the production efficiency and overall competitiveness.

Those evaluation methods are based on various characteristics of a good vendor as measurement parameters. Despite the characteristics are quantitative or qualitative, the methods use a rating scale for each characteristic. The numeric score for each characteristic will be weighted by a factor, and then summing all scores together. As a result, achieving the highest grade would imply the best vendor candidate. Hence, the selection of the best vendor in this traditional method is based on various characteristics as evaluation factors, which belongs to multiple attributes decision problems.

1) Grey Relational Analysis

The Grey Relational Analysis (GRA) associated with the Taguchi method represents a rather new approach to optimization. The grey theory is based on the random uncertainty of small samples which developed into an evaluation technique to solve certain problems of system that are complex and having incomplete information. A System for which the relevant information is completely known is a 'white' system, while a system for which the relevant information is completely unknown is a 'black' system. Any system between these limits is a 'grey' system having poor and limited information. Grey Relational Analysis (GRA) a normalization evaluation technique is extended to solve the complicated multi-performance characteristics optimization effectively.

Data Pre-Processing: Data Pre-Processing is normally required, since the range and unit in one data sequence may differ from others. It is also necessary when the sequence scatter range is too large, or when the directions of the target in the sequences are different. The formulae are

Larger the better value

$$Z_{ij} = \frac{y_{ij} - \min(y_{ij}, i = 1, 2, \dots, n)}{\max(y_{ij}, i = 1, 2, \dots, n) - \min(y_{ij}, i = 1, 2, \dots, n)}$$

Smaller the better value

$$Z_{ij} = \frac{\max(y_{ij}, i = 1, 2, \dots, n) - y_{ij}}{\max(y_{ij}, i = 1, 2, \dots, n) - \min(y_{ij}, i = 1, 2, \dots, n)}$$

Where y_{ij} is the i^{th} performance characteristic in the j^{th} experiment. $\max y_{ij}$ and $\min y_{ij}$ are the maximum and minimum values of i^{th} performance characteristic for alternate j , respectively.

By normalizing, grey relational co-efficient (GRC) is calculated as

$$\gamma(y_o(k), y_i(k)) = \frac{\Delta \min + \xi \Delta \max}{\Delta_{oj}(k) + \xi \Delta \max}$$

Where;

$j = 1, 2, \dots, n$; $k = 1, 2, \dots, m$, n is the number of experimental data items and m is the number of responses. $y_o(k)$ is the reference sequence ($y_o(k) = 1, k = 1, 2, \dots, m$); $y_j(k)$ is the specific comparison sequence.

$\Delta_{oj} = |y_0(k) - y_j(k)|$ = The absolute value of the difference between $y_0(k)$ and $y_j(k)$

$\Delta \min = \min_{\forall j \in i} \min_{\forall k} |y_0(k) - y_j(k)|$ is the smallest value of $y_j(k)$

$\Delta \max = \max_{\forall j \in i} \max_{\forall k} |y_0(k) - y_j(k)|$ is the largest value of $y_j(k)$

Where ξ is the distinguishing coefficient, which is defined in the range $0 \leq \xi \leq 1$.

The grey relational grade is determined by averaging the grey relational coefficient corresponding to each performance characteristic. The overall performance characteristic of the multiple response process depends on the calculated grey relational grade. The grey relational coefficient can be expressed as:

$$\bar{\gamma} = \frac{1}{k} \sum_{i=1}^m \gamma_{ij}$$

Where $\bar{\gamma}$ the grey relational grade for the j^{th} experiment and k is the number of performance characteristics.

IV. RESULTS AND ANALYSIS

A. Implementation with evaluation factors and measure parameters

Since the evaluation factors are much dependent on the enterprise environment, the top management of the enterprise may invite the members of the department of purchasing, production control, and quality control to meet together, and decide the appropriate evaluation factors and measure parameters for vendor evaluation. Traditionally, quality, price, delivery date, quantity, and services are chosen to be typical evaluation factors. The measure parameters for these five evaluation factors are shown in Table I.

Regarding the services of evaluation factors, the corresponding measure parameter can be determined by (1) operated as better methods for defects elimination, and active involvement with vendors and customers; (2) delivery speed; (3) service condition. A qualitative ranking will be given by a review committee, then convert these qualitative ranking into a rating scale of 1 to 5 (larger-the-better).

TABLE I. EVALUATION FACTORS AND MEASUREMENT PARAMETERS

Evaluation Factors	Units
Quality	Strength
Price	Unite Price
Quantity	Kgs
Fright Charges	Rs
Lead Time	Days

B. The corresponding weighting value for evaluation factors

Once the evaluation factor has been determined, we are in a position to find the corresponding weighting value for each individual evaluation factor. The weighting value determination can be done by Delphi Method or Eigenvector. Table II shows the corresponding weighting value for each evaluation factor.

TABLE II : WIEGHTAGES OF EVALUATION FACTORS:

Evaluation factors	Quality	Price	Quantity	Fright charges	Lead time
Weightage	0.35	0.25	0.2	0.15	0.1

C. Data rationalizing

The expected goal can be rationalized according to each attribute. A group of assumptions are made for the following:

- (1) Quality: Larger the better.
- (2) Price: Smaller the better.
- (3) Delivery date: Smaller the better.
- (4) Quantities: Larger the better.
- (5) Freight charges: Smaller the better. The measure value of each attribute is further standardized based on above-mentioned expected goal. The matrix for comparative series is obtained as shown in Table IV.

TABLE III : EXPERIMENTAL DATA FOR EVALUATION FACTORS

S.No.	Supplier	Quantity	Price per kg	Quality	Freight charges (Rs)	Lead time
		(kgs)	(Rs)	strength	(*1000)	(days)
1	A	16180	121.33	21.8	18500	5
2	B	16515	118	22.4	10000	3
3	C	16080	120.4	22	32500	7
4	D	16515	115.23	22.9	10000	3
5	E	16380	119.91	22.4	10000	3
6	F	17125	122.1	22.5	17500	3
7	G	16370	110.69	22.4	18500	5
8	H	14486	114.33	22	13500	3
9	I	17155	159.94	26.7	25000	7
	Total	146806	1101.93	205.1	155500	39

TABLE : IV : RATIONALIZED DATA

S. No	Suppliers	Quality	Lead time	Quantity	Freight charges	Price
1	A	0	0.5	0.63469	0.64444	0.7839
2	B	0.122	1	0.7602	1	0.85257
3	C	0.04	0	0.59722	0	0.80284
4	D	0.244	1	0.7602	1	0.90782
5	E	0.1222	1	0.70962	1	0.81279
6	F	0.1428	1	0.98875	0.66666	0.76832
7	G	0.12244	0.5	0.705882	0.64444	1
8	H	0.0408	1	0	0.84444	0.92609
9	I	1	0	1	0.3333	0

$$\begin{aligned} \Gamma_{01} &= 0.6894 & \Gamma_{02} &= 0.5998 & \Gamma_{03} &= 0.8284 \\ \Gamma_{04} &= 0.581 & \Gamma_{05} &= 0.6553 & \Gamma_{06} &= 0.6086 \\ \Gamma_{07} &= 0.6502 & \Gamma_{08} &= 0.7044 & \Gamma_{09} &= 0.7500 \end{aligned}$$

TABLE V . THE GREY RATIONAL COEFFICIENT (Γ):

S. No.	Suppliers	Quality	Lead time	Quantity	Freight charges	Price	Grade
1	A	1	0.66	0.6117	0.6081	0.5605	0.6894
2	B	0.891	0.5	0.5681	0.5	0.5400	0.5998
3	C	0.9615	1	0.6268	1	0.5546	0.8284
4	D	0.8167	0.5	0.5681	0.5	0.5241	0.5817
5	E	0.8911	0.5	0.5842	0.5	0.5516	0.6553
6	F	0.875	0.5	0.5028	0.6002	0.5655	0.6086
7	G	0.8909	0.66	0.5862	0.6081	0.5	0.6502
8	H	0.9607	0.5	1	0.5428	0.5191	0.7044
9	I	0.5	1	0.5	0.75	1	0.7500

The ranking is given for each supplier is as follows

Because of $\Gamma_{03} > \Gamma_{09} > \Gamma_{08} > \Gamma_{01} > \Gamma_{05} > \Gamma_{07} > \Gamma_{06} > \Gamma_{02} > \Gamma_{04}$ the ranking order for all the candidate vendor is: **1-C, 2-I, 3-H, 4-A, 5-E, 6-G, 7-F, 8-B, 9-D**. It is noted that the ranking order will change while we change the weighting value for each evaluation factor. In other words, the owner of an enterprise may select a suitable vendor based on his own requirements.

V. ANALYTIC HIERARCHY PROCESS:

The analytic hierarchy process (AHP) is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It has been applied to a wide variety of decision areas, including research and development project selection, evaluating alternative product formulation and selecting microcomputer. This method allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. Generally, the hierarchy has at least three levels, the goal, the criteria, and the alternatives. For supplier selection problem the goal is to select the best overall supplier. Examples of the criteria that might be considered are quality, price, quantity and delivery. The alternatives are the different proposals supplied by the suppliers.

The AHP offers a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each alternative. For this reason, AHP is ideally suited for the supplier selection problem.

The problem hierarchy lends itself to an analysis based on the impact of a given level on the next higher level. The process begins by determining the relative importance of the criteria in meeting the goals. Next, the focus shifts to measuring extent to which the alternatives achieve each of the criteria. Finally, the results of the two analyses are synthesized to compute the relative importance of the alternatives in meeting the goal. Managerial judgments are used to drive the AHP approach. These judgments are expressed in terms of pair-wise comparisons of items on a given level of the hierarchy with respect to their impact on the next higher level. Pair wise comparisons express the relative importance of one item versus another in meeting a goal or a criterion. Each of the pair-wise comparisons represents an estimate of the ration of the weights of the two criteria being compared. This ratio scale for processing human judgments has been applied to a variety of decision-making problems in other fields, and it has been validated in situations where standard measures already exist. Because AHP utilizes a ratio scale for human judgments, the alternative weights

reflect the relative importance of the criteria in achieving the goal of the hierarchy.

TABLE-VI : MEASUREMENT SCALE

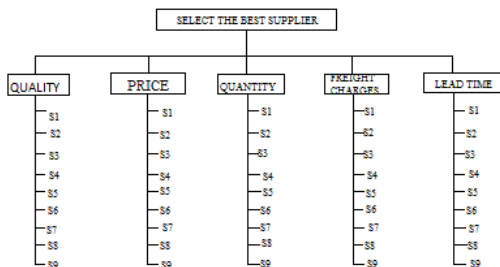
Verbal judgment or preference	Numerical rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate level	2,4,6,8

VI. SUPPLIER SELECTION USING AHP

The AHP approach, as applied to the supplier selection problem, consists of the following five steps:

1. Specify the set of criteria for evaluating the supplier’s proposals.
2. Obtain the pair-wise comparisons of the relative importance of the criteria in achieving the goal, and compute the priorities or weights of the criteria based on the information.(TABLE 8)
3. Obtain measures that describe the extent to which each supplier achieves the criteria.
4. Using the information in step 3, obtain the pair-wise comparisons of the relative importance of the suppliers with respect to criteria, and compute the corresponding priorities.(TABLE 9)
5. Using the results of steps 2 and 4, compute the priorities of each supplier in achieving the goal of the hierarchy.(TABLE10).

TABLE VII. SUPPLIER SELECTION HIERARCHY



EVALUATION CRITERIA:

TABLEVIII . PAIR-WISE COMPARISON MATRIX

A. ORIGINAL MATRIX

	Quality	Price	Quantity	Freight	Lead Time
Quality	1	3	5	4	2
Price	0.33	1	2	3	4
Quantity	0.2	0.5	1	4	3
Freight	0.25	0.33	0.25	1	3
LeadTime	0.5	0.25	0.33	0.33	1
Column TOTAL	57/25	127/25	429/50	1233/100	13

TABLEIX. SUPPLIER PAIR-WISE COMPARISON MATICES AND PRIORITIES WITH RESPECT TO QUALITY

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	1	1.027	1.0091	1.0504	1.027	1.0321	1.027	1.0091	1.224
S2	0.9737	1	0.982	1.0223	1	1.0044	1	0.982	1.1919
S3	0.9909	1.0181	1	1.049	1.0181	1.0227	1.0181	1	1.2136
S4	0.9487	0.9977	0.9606	1	0.978	0.982	0.978	0.96	1.1659
S5	0.9737	1	0.982	1.0224	1	1.044	1	0.982	1.1919
S6	0.9688	0.9956	0.977	1.0177	0.9956	1	0.9955	0.9777	1.1866
S7	0.9737	1	0.982	1.0224	1	1.0044	1	0.982	1.1919
S8	0.9909	1.0183	1	1.041	1.0181	1.0227	1.0181	1	1.2136
S9	0.8165	0.8389	0.823	0.857	0.838	0.842	0.8389	0.823	1

VII.CONCLUSIONS

In order to seek a proper supplier meeting the requirements of enterprise itself subjectively, it is important to develop an accurate evaluation method. Due to the advantages of Grey multiple attributes decision, this paper tries to propose an evaluation method to determine the overall performance for each candidate vendor. The optimum decision can then be made based on the overall performance. Moreover, from the equation derivation and a numeric example for vendor evaluation, this study obtains the following advantages:

1. For new supplier evaluation, it is very convenient to perform overall measurement based on each enterprise’s requirements. The overall performance can determine the order for selecting the suitable vendors.
2. The enterprise can choose its own appropriate goal and weighting value for each evaluation factor based on the characteristic demand of raw materials in order to select the most suitable vendors.
3. Based on the preceding discussion, it is judged that the proposed Grey multiple attributes decision method is very precise on the whole. It can overcome the ambiguity arising from the measured parameters of each attribute. Therefore, the result of this study represents a further advance in the method of evaluating vendors.

AHP

- 1) AHP avoids the arbitrary assignment of weights for the factors concerned by the decision maker which results in more accurate evaluation of the vendor.
- 2) The concept of relative pair wise comparison has been used between any two alternatives and two factors made this vendor rating technique as the best one the current corporate environment.

It can be concluded that from both AHP and Grey Relational Analysis supplier3 will be the best selection based on multi criteria decision making.

In actual applications, managers must carefully select the factors that best represent their competitive priorities, goals and objectives, and also construct pair wise comparison matrices in order to obtain more objective weights. Such procedures will make the application of the model more robust and realistic.

Discussion:

1. Grey relational technique is applied for the group wise comparison of the factors.
2. Analytical hierarchy process is applied for the individual pair wise comparison of the factors.
3. By applying both the techniques we have found out that the third supplier is the best supplier.
4. If the number of supplier is increased we can calculate it from the program below, in which any number of supplier can be added and we can find out the best supplier.

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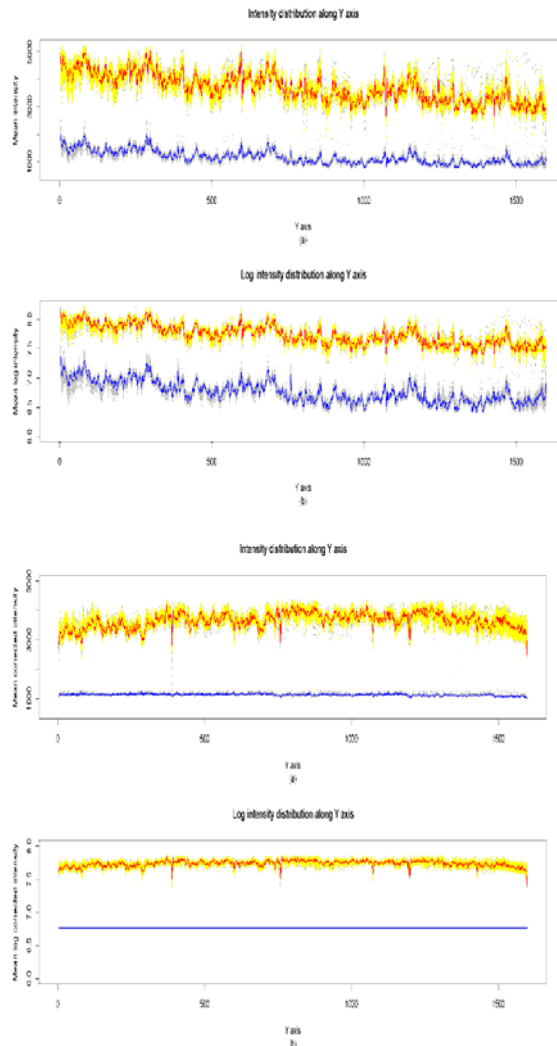


Figure 1. Example of a TWO-COLUMN figure caption: (a) this is the format for referencing parts of a figure.

