Develop Strategic Relationships via Supplier Segmentation Using Grey Relational Analysis: A Case Study

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Abstract: Strategic cooperation is a success key factor in modern supply chain. To make a platform in which the cooperation is formed effectively and efficiently to improve the organizations, it is essential to recognize the main components of cooperation and their effectiveness. So the suppliers should be identified based on their capacity and long-term relationships. Grey relational analysis (GRA) is the best method to help us through it. The application of the grey relational analysis in connection with consideration of the criteria in different managerial and operational issues has been referred to in many articles. In this paper, after reviewing literature, we tried to propose a two dimensions model for an effective and efficient decision, which offered solutions to optimize strategic relations after recognizing supplier's capabilities. This article has a strategic approach to supply chain and looks at it from policy perspective. We used the data from a company in the automotive industry to apply the proposed model and recent model for further analysis and discussion.

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1. Introduction

Globalization phenomenon intensifies the competition. In this environment companies have to optimize not only their internal process but also manage their members in supply chain and procurement management. Procurement management is one of the most important subjects in supply chain management which involves evaluation, selection, control the suppliers and their development. In addition it is obvious that the relationship between suppliers and manufacturers cannot be unique in all circumstances. The recent studies show that suitable supply chain management needs to manage the effectiveness of the members in the chain as well as evaluation of important factors like cost of part/materials, transportation, quality, delivery performance, etc. (Bensaou,1999). Kraljic (1983) presented a model in order to determine the purchasing strategies.

Kraljic point of view is based upon minimizing risk of supply and maximizing power of supply. In essence, his model is a lattice-space model which one side projects the profit impact and the other side projects supply risk. In such a model a point or a region within the lattice-space represent four different circumstances of purchased material. At the origin of the state-space model, the amount of both factors is in minimum level and when one deviate from the origin of the model and reaches the extremity of the model the amount of factors increased. In this state-space model four circumstances have been defined in which all purchased items can be classified in this four categories (Figure 1).

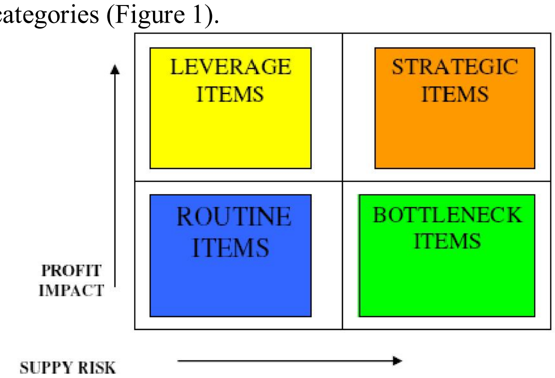


Figure 1: Classification of the purchasing items by Kraljic

The first category relates to the routine items. The routine items are noncritical items which are produced in standard configuration. The best method of control of these items is to keep the level of the inventory in optimal level and one does not need to think other attributes. The second groups are leverage items. The leverage items are the materials which purchaser has big maneuver to bargain and it is easy for him to find the best price by calling for tenders. The bottleneck items are the one which their supply involves various risks and problems. In this situation the guaranty of the contract, supplier control, and all plan in order to keep enough inventory is suggested. Finally, the strategic items are the group of materials which there is a strategic/long term relationship between buyer and supplier in order to have safe business. As it is explained in section four, buyer has different authorities and maneuvers to buy the particular materials.

Traditionally, decision makers select suppliers based on their experience and intuition. The weakness of these approaches has been addressed in previous studies (Shyur & Shih, 2006).Supplier selection has been considered as a complex problem due to several reasons (Kumar, Vrat, & Shankar, 2006). Within its nature, supplier selection is a Multi-Criteria Decision Making (MCDM) problem in which multiple criteria need to be carefully examined that can be both qualitative and quantitative. The MCDM provides an effective framework for supplier comparison, based on evaluation of multiple and often conflicting criteria. Moreover, supplier selection is an evaluation process that is unstructured and uses inaccurate or uncertain data. Full information about the suppliers on each criterion at the decision process is not known with certainty (Díaz-Madroñero, Peidro, & Vasant, 2010). Due to this vagueness and impreciseness of the information, selection of suppliers based on deterministic data is neither possible nor reasonable. Fuzzy set theory provides a framework for systematic handling the uncertainties of this type (Kumar, Vrat, & Shankar, 2006).

Grey theory is one of the methods used to study uncertainty, being superior in the mathematical analysis of systems with uncertain information. In grey theory, according to the degree of information, if the system information is fully known, the system is called a white system; if the information is unknown, it is called a black system. A system with information known partially is called a grey system. The advantage of grey theory over fuzzy theory is that grey theory considers the condition of the fuzziness; that is, grey theory can deal flexibly with the fuzziness situation (Deng, 1989).

People often employ natural language to express thinking and subjective perception; and in these natural languages the meaning of words is often vague. The meaning of a word might be well defined, when using the word as a label for a set, the boundaries with which objects do or do not belong to the set become uncertainty. Hence, the proposed method is using GRA to appropriately express the determination of human judgment in the proposed criteria (Tseng, 2009).

Golmohammadi & Mellat-Parast (2012) provided two-phase model which integrates the fuzzy pair wise comparison with a grey relational analysis. In the first phase, the proposed model utilizes the fuzzy pair wise comparisons technique to tackle some of the limitations in the current grey methodology. In the second phase, a method is proposed to mitigate the bias judgment and inconsistency in pair wise comparisons application in order to improve the results of the first phase.

Pitchipoo, Venkumar, & Rajakarunakaran (2012) developed an appropriate hybrid model by integrating the analytical hierarchy process and grey relational analysis for supplier evaluation and selection, which comprises three stages.

Wu (2009) used grey related analysis and Dempster–Shafer theory to deal with this fuzzy group decision making problem. First, in the individual aggregation, grey related analysis is employed as a means to reflect uncertainty in multi-attribute models through interval numbers. Second, in the group aggregation, the Dempster–Shafer rule of combination is used to aggregate individual preferences into a collective preference, by which the candidate alternatives are ranked and the best alternative(s) are obtained.

The advantages of the GRA over traditional tools in decision making and supplier selection is related to its ability to capture, process, and integrate uncertainty in the decision making process. While several tools and methodologies such as probabilistic analysis, stochastic programming, and chance-constraint programming have been developed to address, they are not capable of handling complex problems involving both complete and incomplete information. Since GRA uses original data, the results are more relevant to practice. For these reasons, GRA has been recommended as one the best methods to be used in making decisions in the business environment (Golmohammadi & Mellat-Parast, 2012).

In this paper, we offer a new method that used to classify suppliers under uncertainty and unsure conditions. The main steps of this method are explained as follows: at first, using grey numbers, we specify the attributes of all suppliers. Secondly, we rank all suppliers according to their degree of grey possibility. The uncertainty and inconsistency of the attributes should be considered in all steps. Finally, a real example of supplier selection in automotive factory is used to illustrate the proposed approach.

Dickson (1966) listed 23 criteria for suppliers' selection, based on a survey of 273 purchasing manager. The analysis showed that quality, delivery and performance history could be considered, in their respective order, the three most important criteria.

Ha and Krishnan (2008) updated this set of attributes as shown in Table 1. This attribute list provides a first flavor of the complexity of the problem: many factors should be taken into account, very often antithetical each other. Moreover, some of these factors can be easily measured, while some others are qualitative concepts: the aggregation of these attributes in a final judgment about a supplier can result in a tricky problem. Rezaei & Ortt (2013) mentioned there are two dimensions (capabilities and willingness) on the basis of which suppliers can be segmented. The dimensions, capabilities and willingness, are seen as multi-criteria concepts. For example, the capabilities of a supplier can be evaluated using different criteria such as the quality of the products, the technical capability of the supplier in question. Willingness of the supplier can be evaluated using multiple criteria, such as communication openness and commitment to continuous improvement in product and process.

Table 1. Supplier selection attributes according to Ha and Krishnan (2008) framework

After sales service	Geographical location	Product appearance
Amount of past business	Impression	Production facilities and capacity
Attitude	JIT capability	Quality
Catalog technology	Labor relations	Reciprocal arrangements
Communication system	Maintainability	Reputation and position in industry
Delivery	Management and Organization	Response to customer request
Ease-of-use	Operational controls	Technical capability
E-commerce capability	Packaging ability	Technical support
Environmentally friendly products	Performance history	Training aids
Financial position	Price	Warranties and claims

2. Grey relational analysis

A grey system is defined as a system containing uncertain information presented by a grey number and grey variables.

Let X is the universal set. Then a grey set *G* of *X* is defined by its two mappings:

$\overline{\mu}_G(x) \;:x \to [0,1]$, $\underline{\mu}_G(x) \;:x \to [0,1]$

$\overline{\mu}_G(x)$: Upper membership functions

$\overline{\mu}_G(x)$: Lower membership functions

$x \in X$, X=R.

The grey number can be defined as a number with uncertain information. For example, the ratings of attributes are described by the linguistic variables; there will be a numerical interval expressing it. This numerical interval will contain uncertain information. Generally, grey number is written as

$$\otimes G = G|_{\underline{\mu}}^{\overline{\mu}} \quad (1)$$

The lower and upper limits of G can be estimated and G is defined as an interval grey number.

$$\otimes G = [\underline{G}, \overline{G}] \quad (2)$$

Basic operation laws of grey numbers:

$$\otimes G_1 \pm \otimes G_2 = [\underline{G}_1 \pm \underline{G}_2, \overline{G}_1 \pm \overline{G}_2] \quad (3)$$

$$\otimes G_1 \times \otimes G_2 = [\text{Min}\,(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2), \text{Max}(\underline{G}_1\underline{G}_2, \underline{G}_1\overline{G}_2, \overline{G}_1\underline{G}_2, \overline{G}_1\overline{G}_2)] \quad (4)$$

$$\otimes G_1 \div \otimes G_2 = [\underline{G}_1, \overline{G}_1] \times \left[\frac{1}{\underline{G}_2}, \frac{1}{\overline{G}_2}\right]. \quad (5)$$

The length of grey number G is defined as:

$$L(\otimes G) = [\overline{G} - \underline{G}]. \quad (6)$$

The possibility degree of ⨂G1≤⨂G2 can be expressed as follows:

$$P\{\otimes \text{G1} \leq \otimes G_2\} = \frac{\text{Max}(0, L^* - \text{Max}\,(0, \overline{G}_1 - \underline{G}_2))}{L^*} \quad (7)$$

Where $L^* = L(\otimes \text{G1}) + L(\otimes G(2\,)$ (8)

3. Proposed methodology

As mentioned, according to Rezaei & Ortt (2013), selection criteria were classified into the following divisions which can be seen in Table 2. In the end, all of the suppliers were evaluated, classified, and categorized in terms of quality using fuzzy theory.

In the current article, capabilities and willingness criteria is evaluated by GRA.. The case study for the same model is conducted in the real environment in an automotive manufacturing unit, and the company's managers were provided with the results for decision-making.

In each dimensions (capabilities and willingness criteria), the following steps should be done:

Table 2. Selected capabilities and willingness criteria

Selected capabilities criteria	Selected willingness criteria
Price	Commitment to quality
Delivery	Communication openness
Quality	Reciprocal arrangement
Reserve capacity	Willingness to share information
Geographical location	Supplier's effort in promoting JIT principles
Financial position	Long term relationship

3.1 Evaluation of the suppliers using GRA:

3.1.1 At first, weight of each of the criteria was mentioned according to the linguistic variables. Linguistic variables are determined based on a grey number as follows:

$\otimes W_i=[\overline{w_i}, \underline{w_i}]$ (9)

$$W_i = \frac{1}{K}\left[W_i^1 + W_i^2 + \cdots + W_i^k\right] \quad (10)$$

$1 \leq i \leq m$

In which K, the decision maker of each criteria of i, using linguistics variables and mentions self-weights. The respective weight of each criterion is worked out from the weight average related to the decision makers.

The scale of criteria may be considered according to the Table 3.

Table 3. The scale of criteria weights

Scale	$\otimes W$
Very low (VL)	[0.0, 0.1]
Low (L)	[0.1, 0.3]
Medium low (ML)	[0.3, 0.4]
Medium (M)	[0.4, 0.5]
Medium high (MH)	[0.5, 0.6]
High (H)	[0.6, 0.9]
Very high (VH)	[0.9, 1.0]

3.1.2 For each of the suppliers, the decision makers present their scores using the linguistic variables. The weight average is used in order to calculate the final weight:

Where G_{ij}^k is rank of supplier j at the criteria i in the Kith decision maker's view.

$$G_{ij}=\frac{1}{K}\left[G_{ij}^1 + G_{ij}^2 + \cdots + G_{ij}^k\right] \quad (11)$$

$1 \leq i \leq m$

$1 \leq j \leq n$

The decision-making matrix is as follows:

$$D = \begin{bmatrix} G_{11} & \cdots & G_{1m} \\ \vdots & \ddots & \vdots \\ G_{n1} & \cdots & G_{nm} \end{bmatrix} \quad (12)$$

The table of linguistic variables to score the suppliers is as follows (see Table 4).

Table 4. Linguistic variables to score the suppliers

Scale	$\otimes G$
Very poor (VP)	0, 1]
Poor (P)	[1, 3]
Medium poor (MP)	[3, 4]
Fair (F)	[4, 5]
Medium good (MG)	[5, 6]
Good (G)	[6, 9]
Very good (VG)	[9,10]

3.1.3 The acquired matrix must be normalized

$$D = \begin{bmatrix} \otimes G^*_{11} & \cdots & \otimes G^*_{1m} \\ \vdots & \ddots & \vdots \\ \otimes G^*_{n1} & \cdots & \otimes G^*_{nm} \end{bmatrix} \qquad (13)$$

$$\otimes G^*_{ij} = \left[\frac{\underline{G}_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}} \right]$$

$$G_j^{max} = \max\left[\overline{Gij}\right] \ 1 \le i \le m \qquad 1 \le j \le n \, .$$

For a cost criterion

$$\otimes G^*_{ij} = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}} \right]$$

3.1.4 The grey decision-making matrix is result of normalized grey decision-making matrix multiplied by factor weights

$$D = \begin{bmatrix} \otimes V_{11} & \cdots & \otimes V_{1m} \\ \vdots & \ddots & \vdots \\ \otimes V_{n1} & \cdots & \otimes V_{nm} \end{bmatrix} \qquad (14)$$

$$\otimes V_{ij} = \otimes G^*_{ij} \times \otimes W_j \quad .$$

3.1.5 In order to compare and rank the options (suppliers), the ideal option is worked out according to the following items:

$$S^{max} = \{\otimes \mathrm{G}_1^{\max}, \otimes \mathrm{G}_2^{\max}, \ldots, \otimes \mathrm{G}_n^{\max}\}. \quad (15)$$

3.1.6 The grey possibility degree between compared alternatives is calculated.

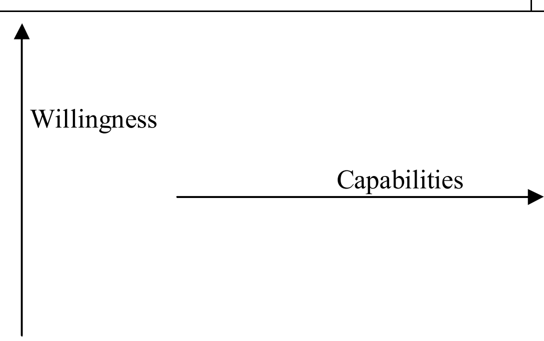
$$P\{S_i \le S^{max}\} = \frac{1}{n}\sum_{j=1}^{n} P\{\otimes \mathrm{V}_{\mathrm{ij}} \le \otimes G_j^{max}\} \ . \ (16)$$

The less grey possibility degree is, the better, and ordering is done based on the same.

3.1.7 The solutions can be divided into four following groups as shown Table 5.

Table 5. Four groups Based on two dimensions

The suppliers are at their worst condition based on capacity criteria and some optimization processes are needed in order to optimize capacity sub-criteria.	The suppliers are at their best criteria condition and strategic relations should be developed with them.
The suppliers are at their worst criteria condition and should be replaced if possible.	The suppliers are at their worst condition based on Willingness criteria and some optimization processes are needed in order to optimize sub-criteria to cooperate with them.



4-Adaptation of the model to select suppliers in the automotive company:

The above model was reviewed in Zamyad Company (an automotive company). This company, according to the type of industry and varied supplied parts, uses a large number of suppliers, and the company's managers admitted the need for a model for decision-making. In this regard, some suppliers are selected for assessment. In order to acquire weights pertinent to the criteria and their assessment, at first, a number of check lists were employed for which the senior managers were responsible, and the scoring was carried according to Tables 6 and 7 and the results in the following table were obtained. (See Tables 8 to 13).

Table 6. Criteria weights based on four Decision makers' ranking

Willingness criteria	Manager 1	Manager 2	Manager 3	Manager 4	w_i	
					$\underline{w}_i$	$\overline{w}_i$
Commitment to quality	VH	MH	H	VH	0.73	0.88
Communication openness	H	H	M	VH	0.63	0.83
Reciprocal arrangement	H	H	H	H	0.60	0.90
Willingness to share information	H	H	MH	VH	0.65	0.85
Supplier's effort in promoting JIT principles	H	H	VH	VH	0.75	0.95
Long term relationship	H	H	VH	MH	0.65	0.85

Capabilities criteria	Manager 1	Manager 2	Manager 3	Manager 4	w_i	
					$\underline{w}_i$	$\overline{w}_i$
Price	VH	VH	VH	VH	0.9	1.0
Delivery	VH	VH	VH	VH	0.9	1.0
Quality	H	H	H	H	0.60	0.90
Reserve capacity	H	H	VH	VH	0.75	0.95
Geographical location	H	VH	H	VH	0.75	0.95
Financial position	MH	MH	MH	MH	0.5	0.6

Table 7. Criteria rating values for suppliers based on four Decision makers' ranking according to Equation (11).

Willingness criteria		Manager 1	Manager 2	Manager 3	Manager 4	G_{ij}	
						$\underline{G_{ij}}$	$\overline{G_{ij}}$
Commitment to quality	S1	MP	MP	MP	MP	3	4
	S2	G	G	MG	MG	5.5	7.5
	S3	MG	MG	MG	MG	5	6
	S4	G	MG	MG	G	5.5	7.5
Communication openness	S1	G	G	G	G	6	9
	S2	VG	VG	G	G	7.5	9.5
	S3	MG	MG	G	G	5.5	7.5
	S4	MG	MG	MG	MG	5	6
Reciprocal arrangement	S1	MG	MG	MG	MG	5	6
	S2	F	MG	F	MG	4.5	5.5
	S3	G	G	G	MG	5.75	8.25
	S4	MG	MG	MG	MG	5	6
Willingness to share information	S1	MP	F	F	F	3.75	4.75
	S2	MG	MG	MG	F	4.75	5.75
	S3	MP	MP	MP	MP	3	4
	S4	F	F	F	F	4	5
Supplier's effort in promoting JIT principles	S1	G	G	G	G	6	9
	S2	MG	MG	MG	F	4.75	5.75
	S3	F	MG	MG	MG	4.75	5.75
	S4	G	G	MG	MG	5.5	7.5

Long term relationship	S1	G	G	MG	MG	5.5	7.5
	S2	F	F	F	F	4	5
	S3	MG	MG	MG	MG	5	6
	S4	MG	MG	MG	MG	5	6

Table 8. Grey normalized table according to Equation (13).

Capabilities criteria		Manager 1	Manager 2	Manager 3	Manager 4	G_{ij}	
						$\underline{G_{ij}}$	$\overline{G_{ij}}$
Price	S1	F	F	F	F	4	5
	S2	MG	MG	MG	MG	5	6
	S3	F	F	F	F	4	5
	S4	G	MG	MG	MG	5.25	6.75
Delivery	S1	F	F	F	F	4	5
	S2	G	G	G	G	6	9
	S3	G	G	G	G	6	9
	S4	MG	MG	MG	MG	5	6
Quality	S1	MP	MP	MP	MP	3	4
	S2	F	MG	MG	MG	4.75	5.75
	S3	MG	MG	MG	MG	5	6
	S4	MG	MG	MG	MG	5	6
Reserve capacity	S1	F	F	F	F	4	5
	S2	MG	MG	MG	F	4.75	5.75
	S3	F	F	F	F	4	5
	S4	MP	MP	MP	MP	3	4
Geographical location	S1	VG	VG	VG	VG	9	10
	S2	G	G	MG	MG	5.5	7.5
	S3	F	MG	MG	MG	4.75	5.75
	S4	F	F	MP	MP	3.5	4.5
Financial position	S1	G	G	F	F	5	7
	S2	F	F	F	F	4	5
	S3	F	F	F	F	4	5
	S4	F	F	F	F	4	5

Table 9. Grey normalized table according to Equation (13) for willingness criteria.

Willingness criteria		S1	S2	S3	S4
Commitment to quality	$\frac{\underline{G_{1j}}}{G_j^{max}}$	0.533333	1	0.8	1
	$\frac{\overline{G_{1j}}}{G_j^{max}}$	0.4	0.733333	0.666667	0.733333
Communication openness	$\frac{\underline{G_{2j}}}{G_j^{max}}$	0.947368	1	0.789474	0.631579
	$\frac{\overline{G_{2j}}}{G_j^{max}}$	0.631579	0.789474	0.578947	0.526316
Reciprocal arrangement	$\frac{\underline{G_{3j}}}{G_j^{max}}$	0.727273	0.666667	1	0.727273
	$\frac{\overline{G_{3j}}}{G_j^{max}}$	0.606061	0.545455	0.69697	0.606061
Willingness to share information	$\frac{\underline{G_{4j}}}{G_j^{max}}$	0.826087	1	0.695652	0.869565

	$\frac{\overline{G}_{4j}}{G_j^{max}}$	0.652174	0.826087	0.521739	0.695652
Supplier's effort in promoting JIT principles	$\frac{\underline{G}_{5j}}{G_j^{max}}$	1	0.638889	0.638889	0.833333
	$\frac{\overline{G}_{5j}}{G_j^{max}}$	0.666667	0.527778	0.527778	0.611111
Long term relationship	$\frac{\underline{G}_{6j}}{G_j^{max}}$	1	0.666667	0.8	0.8
	$\frac{\overline{G}_{6j}}{G_j^{max}}$	0.733333	0.533333	0.666667	0.666667

Table 10. Grey normalized table according to Equation (13) for capabilities criteria.

Capabilities criteria		S1	S2	S3	S4
Price	$\frac{G_j^{min}}{\overline{G}_{ij}}$	0.8	0.666667	0.8	0.592593
	$\frac{G_j^{min}}{\underline{G}_{ij}}$	1	0.8	1	0.761905
Delivery	$\frac{\underline{G}_{2j}}{G_j^{max}}$	0.444444	0.666667	0.666667	0.555556
	$\frac{\overline{G}_{2j}}{G_j^{max}}$	0.555556	1	1	0.666667
Quality	$\frac{\underline{G}_{3j}}{G_j^{max}}$	0.5	0.791667	0.833333	0.833333
	$\frac{\overline{G}_{3j}}{G_j^{max}}$	0.666667	0.958333	1	1
Reserve capacity	$\frac{\underline{G}_{4j}}{G_j^{max}}$	0.695652	0.826087	0.695652	0.521739
	$\frac{\overline{G}_{4j}}{G_j^{max}}$	0.869565	1	0.869565	0.695652
Geographical location	$\frac{\underline{G}_{5j}}{G_j^{max}}$	0.9	0.55	0.475	0.35
	$\frac{\overline{G}_{5j}}{G_j^{max}}$	1	0.75	0.575	0.45
Financial position	$\frac{\underline{G}_{6j}}{G_j^{max}}$	0.714286	0.571429	0.571429	0.571429
	$\frac{\overline{G}_{6j}}{G_j^{max}}$	1	0.714286	0.714286	0.714286

Table 11. Weighted normalized grey according to Equation (14).

Willingness criteria		S1	S2	S3	S4
Commitment to quality	$\underline{V}_{1j}$	0.292	0.535	0.487	0.535
	$\overline{V}_{1j}$	0.469	0.880	0.704	0.880
Communication openness	$\underline{V}_{2j}$	0.398	0.497	0.365	0.332
	$\overline{V}_{2j}$	0.786	0.830	0.655	0.524
Reciprocal arrangement	$\underline{V}_{3j}$	0.364	0.327	0.418	0.364
	$\overline{V}_{3j}$	0.655	0.600	0.900	0.655
Willingness to share information	$\underline{V}_{4j}$	0.424	0.537	0.339	0.452
	$\overline{V}_{4j}$	0.702	0.850	0.591	0.739
Supplier's effort in promoting JIT principles	$\underline{V}_{5j}$	0.500	0.396	0.396	0.458
	$\overline{V}_{5j}$	0.950	0.607	0.607	0.792
Long term relationship	$\underline{V}_{6j}$	0.477	0.347	0.433	0.433
	$\overline{V}_{6j}$	0.850	0.567	0.680	0.680

Capabilities criteria		S1	S2	S3	S4
Price	$\underline{V}_{1j}$	0.720	0.600	0.720	0.533
	$\overline{V}_{1j}$	1.000	0.800	1.000	0.762
Delivery	$\underline{V}_{2j}$	0.400	0.600	0.600	0.500
	$\overline{V}_{2j}$	0.556	1.000	1.000	0.667
Quality	$\underline{V}_{3j}$	0.300	0.475	0.500	0.500
	$\overline{V}_{3j}$	0.600	0.863	0.900	0.900
Reserve capacity	$\underline{V}_{4j}$	0.522	0.620	0.522	0.391
	$\overline{V}_{4j}$	0.826	0.950	0.826	0.661
Geographical location	$\underline{V}_{5j}$	0.675	0.413	0.356	0.263
	$\overline{V}_{5j}$	0.950	0.713	0.546	0.428
Financial position	$\underline{V}_{6j}$	0.357	0.286	0.286	0.286
	$\overline{V}_{6j}$	0.600	0.429	0.429	0.429

Table 12. S^{max} for alternatives according to Equation (15).

Willingness criteria	S^{max}
Commitment to quality	0.535
	0.88
Communication openness	0.497
	0.83
Reciprocal arrangement	0.418
	0.9
Willingness to share information	0.537
	0.85
Supplier's effort in promoting JIT principles	0.5
	0.95
Long term relationship	0.477
	0.85

Capabilities criteria	S^{max}
Price	0.72
	1
Delivery	0.6
	1
Quality	0.5
	0.9
Reserve capacity	0.62
	0.95
Geographical location	0.675
	0.95
Financial position	0.357
	0.6

Table 13. Grey possibility degree according to Equation (16):

	Grey possibility degree	1- (Grey possibility degree)	Ranking of suppliers
C	P (S_1<=SMAX) =0.672037 P (S_2<=SMAX) = 0.564957 P (S_3<=SMAX) = 0.580504 P (S_4<=SMAX) =0.750892	1-P (S_1<=SMAX) =0.327963 1-P (S_2<=SMAX) = 0.435043 1-P (S_3<=SMAX) =0.419496 1-P (S_4<=SMAX) =0.249108	$S_4 \leq S_1 \leq S_3 \leq S_2$
V	P (S_1<=SMAX) = 0.668897 P (S_2<=SMAX) = 0.657549 P (S_3<=SMAX) = 0.726801 P (S_4<=SMAX) = 0.68424	1-P (S_1<=SMAX) = 0.331103 1-P (S_2<=SMAX) =0.342421 1-P (S_3<=SMAX) = 0.273199 1-P (S_4<=SMAX) = 0.31576	$S_3 \leq S_4 \leq S_1 \leq S_2$

The less grey possibility degree, the better this criteria's result is. As it is shown in Table13, the suppliers can be shown in two dimensions. The suppliers are shown based on the probability value in column 2. The second Supplier is at the best condition, so has the highest value of column 2 and the lowest value of column 1. The third Supplier is in a good condition based on capacity, but it is weak in willingness dimension. The first Supplier is in a good condition on willingness dimension, but it is weak in capacity. The forth Supplier is weak on both willingness and capacity dimensions. Positions of suppliers are shown in two dimensions based on Figure 2. Improvement programs are also presented in Table 5.

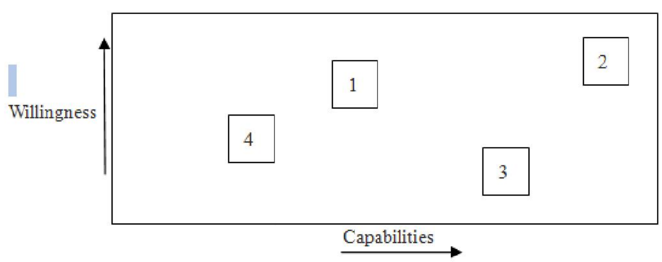


Figure 2: Positions of suppliers based on two dimensions

The final responses were made available to commercial and procurement managers, and the mentioned individuals approved majority of the responses. Needless to mention that, since the designed model is in fact responsible for simulation of the current situation and according to the defined logical relationship, system's optimization is done. In other cases, acceptable responses may be also presented.

5. Conclusions

The present study tries to propose a two dimensions GRA-based platform to categorize suppliers. Current model tries to identify supplier's features, recognize their weakness and provides some solutions or replaces them. Finally, this technique emphasizes on developing strategic relations based on Kraljic model. One of the biggest advantages of the grey theory is converting human judgments, particularly managers' experiences, and utilizing them in scoring the criteria and suppliers' alternatives and this was one of the items that were welcomed by the senior managers in the case study. This model was utilized in a big automotive company, which deals with many suppliers and supplying items and could prove efficiency and effectiveness as well as boosting the speed of decision-making. On the other hand, this would be achievable in an environment such as car manufacturing, which needs a huge number of suppliers and strategic relations.

Developing this model in further dimensions and considering limitations can be mentioned in future studies.

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