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Supplier evaluation in manufacturing environment using compromise ranking method with grey interval numbers

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ABSTRACT

Evaluation of proper supplier for manufacturing organizations is one of the most challenging problems in real time manufacturing environment due to a wide variety of customer demands. It has become more and more complicated to meet the challenges of international competitiveness and as the decision makers need to assess a wide range of alternative suppliers based on a set of conflicting criteria. Thus, the main objective of supplier selection is to select highly potential supplier through which all the set goals regarding the purchasing and manufacturing activity can be achieved. Because of these reasons, supplier selection has got considerable attention by the academicians and researchers. This paper presents a combined multi-criteria decision making methodology for supplier evaluation for given industrial applications. The proposed methodology is based on a compromise ranking method combined with Grey Interval Numbers considering different cardinal and ordinal criteria and their relative importance. A 'supplier selection index' is also proposed to help evaluation and ranking the alternative suppliers. Two examples are illustrated to demonstrate the potentiality and applicability of the proposed method.

1. Introduction

Supplier selection is a continuous procedure for acquiring necessary component materials to support production process as well as for the desired output of an organization. It has been a well known fact that the cost of purchased raw materials or component parts or services dominates the final product cost by approximately 60%. Also, it has been a major setback for the manufacturing organization, if the received materials or services are not as per standards as it directly affects the final output of the said organization. Thus, supplier selection problem is one of the most important decisions for organizations to make a good amount of profit and for a successful supply chain system. There are many selection criteria identified by the previous researchers, but it is not necessary that all the criteria fulfill the requirements of the organization during purchasing activity. For example, the supplier cost of product may be lowest but quality may be inferior. On the other hand, the supplier product may have high quality but the delivery performance may be the worst. According to Wu and Olson (2008), a proper balance among the available criteria is to be taken into account while selecting the best supplier. Also according to Almeida (2007) in this globalize industrial era, each organization

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wants to grab appreciable amount of market share by providing quality product at low cost and also quick after sales service.

2. Review of the past researches

Various approaches like the analytic hierarchy process (AHP), analytic network process (ANP), data envelopment analysis (DEA), fuzzy set theory, mathematical programming, case-based reasoning (CBR), simple multi-attribute rating technique (SMART) have already been proposed by the past researchers to solve the problem of proper supplier selection. Multi-criteria decision making (MCDM) methods give an effective framework for supplier comparison based on the evaluation of multiple conflicting criteria. Kasilingam and Lee (1996) proposed a mixed-integer programming model to select suppliers and determine the order quantities. Weber et al. (1998) described the non-cooperative supplier negotiation strategies where the selection of one supplier results in another being left out of the solution. Ghodsypour and Brien (1998) integrated the analytical hierarchy process and linear programming to consider both tangible and intangible factors in choosing the best suppliers and placing the optimal order quantities among them such that the total value of purchasing (TVP) becomes maximum. Kumar et al (2000) developed a fuzzy multi-objective integer programming model for supplier selection problems. In the proposed model, various input parameters are treated as vague with a linear membership function of fuzzy type. Liu et al. (2000) proposed a simplified DEA model to evaluate the overall performances of suppliers with respect to three input and two output criteria. Talluri and Narasimhan (2003) proposed a max–min productivity based approach that derives the supplier performance variability measures, which are then utilized in a nonparametric statistical technique in identifying supplier groups for effective selection. Liu and Hai (2005) presented a novel weighting procedure in place of AHP's paired comparison for selecting suppliers. Bayazit (2006) proposed an ANP model to tackle the supplier selection problem. Perçin (2006) applied an integrated AHP–GP approach for supplier selection. Chou et al. (2007) attempted to present a fuzzy decision-making approach to deal with the supplier selection problem in supply chain system. Here, linguistic values are used to assess the ratings and weights for selection factors.

Pi and Low (2007) provided an accurate and easier method for quantifying the supplier's attributes to quality losses using a Taguchi loss function, and then these quality losses are transferred into a variable for decision-making by analytical hierarchy process (AHP). Chou and Chang (2008) presented a strategy-aligned fuzzy simple multi-attribute rating technique (SMART) for solving the supplier/vendor selection problem from the perspective of strategic management of the supply chain. Sanayei et al (2010) proposed a hierarchy MCDM model based on fuzzy sets theory and VIKOR method to deal with the supplier selection problems in the supply chain system. Feng et al (2011) developed a multi-objective algorithm based on Tabu search for solving the supplier selection problem. Extensive computational experiments were also conducted to test the performance of the proposed algorithm. Liao and Kao (2011) proposed an integrated fuzzy TOPSIS (techniques for order preference by similarity to ideal solution) and multi-choice goal programming (MCGP) approach to solve the supplier selection problem.

Although a good amount of research works have already been carried out by the past researchers on supplier selection, there is still a need for a simple as well as systematic mathematical approach to guide the decision-makers in taking a proper supplier selection decision. In this research work, an attempt is made to discover the potentialities and applicability of the Compromise Ranking Method combined with Grey Interval Numbers for real time uncertain environments while selecting the most suitable suppliers for two different industrial situations. A Grey supplier selection index is also proposed to rank the alternative suppliers. Two real-time examples are cited to demonstrate and compare the relative performances of the proposed approach with that used by the past researchers. The first example deals with the selection of the most appropriate supplier for an agricultural and construction equipment manufacturing firm (Rao, 2007) whereas, the second example considers the choice of the best suited supplier for an industrial organization (Lin et al., 2007).

3. Compromise ranking method

The VIKOR (the Serbian name is 'Vlse Kriterijumska Optimizacija Kompromisno Resenje' which means multi-criteria optimization (MCO) and compromise solution) method was mainly established by Zeleny (2002) and later advocated by Opricovic and Tzeng (2002, 2003, 2004, 2007)**.** This method is developed to solve MCDM problems with conflicting and non-commensurable (attributes with different units) criteria, assuming that compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and the alternatives can be evaluated according to all the established criteria. It focuses on ranking and selecting the best alternative from a set of alternatives with conflicting criteria, and on proposing compromise solution (one or more). The compromise solution is a feasible solution, which is the closest to the ideal solution, and a compromise means an agreement established by mutual concessions made between the alternatives. A detailed description of the method is available in (Chatterjee et al., 2009).

4. Grey Interval Numbers

Most of the real time multi-attribute decision-making problems can not be determined or predicted with certain and exact attribute values, but it can be expressed in terms of fuzzy values or with values in some intervals. So, it becomes necessary to extend the applications from white number (crisp values) to grey numbers is necessary for real-world applications. Grey number is basically a concept of grey theory, developed by Deng (19982) to deal with the insufficient and incomplete information. White number, grey number and black number are three classifications to distinguish the uncertainty level of information.

Let $\otimes X = [\underline{x}, \overline{x}] = \{x | \underline{x} \le x \le \overline{\underline{x}}$ and $\overline{x} \in R$, then $\otimes X$ which has two real numbers $\underline{x}$ (the lower limit of $\otimes X$) and $\overline{x}$ (the upper limit of $\otimes X$) is defined as follows (Deng, 1988, Lin et al., 2008):

a). If $\underline{x} \rightarrow -\infty$and $\overline{x} \rightarrow \infty$, then $\otimes X$ is called the black number which means it has no meaningful information.

b). Else if $\underline{x} = \overline{x}$, then $\otimes X$ is called the white number which means with complete information.

c). Otherwise, $\otimes X = [\underline{x}, \overline{x}]$ is called the grey number which means insufficient and uncertain information.

A detail description about the different operations related to Grey interval numbers can be found in Lin et al. (2008).

5. Mathematical modelling of the proposed compromise ranking method with grey interval numbers (VIKOR-G)

The main idea of Compromise Ranking Method with Grey Interval Numbers (VIKOR-G) method is based on the real conditions of decision-making situations and applications of the Grey systems theory and Grey decision-making systems (Deng, 1988). The following multiple attribute merit for compromise ranking is developed from the L_p-metric as used in the traditional compromise programming method**.**

$$L_{p,i} = \left\{ \sum_{j=1}^{M} \left(w_j \left[(m_{ij})_{max} - m_{ij} \right] / \left[(m_{ij})_{max} - (m_{ij})_{min} \right] \right)^p \right\}^{1/p} \quad 1 \le p \le \infty;\ i = 1,2,...,N \tag{1}$$

where M is the number of criteria and N is the number of alternatives. The m_{ij} values (for i = 1,2,..., N; j = 1,2,...,M) indicate the values of criteria for different alternatives. In the VIKOR method, $L_{1,i}$

and $L_{\infty,i}$ are used to formulate the ranking measure. The procedural steps for the VIKOR-G method are enlisted as follows

Step 1: Identify the major supplier selection criteria for the given problem and short-list alternatives on the basis of the identified criteria satisfying the requirements. A quantitative or qualitative value is assigned to each identified criterion to construct the Grey decision matrix $\otimes X$.

$$\otimes X = \begin{bmatrix} \otimes x_{11} & \otimes x_{12} & \cdots & \otimes x_{1m} \\ \otimes x_{21} & \otimes x_{22} & \cdots & \otimes x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ \otimes x_{n1} & \otimes x_{n2} & \cdots & \otimes x_{nm} \end{bmatrix} = \begin{matrix} \lfloor x_{11}, m_{11} \rfloor & \lfloor x_{12}, m_{12} \rfloor & \ldots\ldots & \lfloor x_{1m}, m_{1m} \rfloor \\ [x_{21}, m_{21}] & [x_{22}, m_{22}] & \ldots\ldots & [x_{2m}, m_{2m}] \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots,, \\ [x_{n1}, m_{n1}] & [x_{n2}, m_{n2}] & \ldots\ldots & [x_{nm}, m_{nm}] \end{matrix} \tag{2}$$

where $\otimes x_{ij}$ is the interval performance value of i^{th} alternative on j^{th} criterion, n is the number of alternatives compared and m is the number of criteria. The value of $\otimes x_{ij}$ is determined by m_{ij} (the lower limit) and x_{ij} (the upper limit).

Step 2: After short-listing the alternatives and development of the initial decision matrix, determine the best, $(m_{ij})_{max}$ and $(x_{ij})_{max}$ and the worst, $(m_{ij})_{min}$ and $(x_{ij})_{min}$ values of all the criteria.

Step 3: The relative importance of the considered criteria are determined using any subjective or objective weighting method.

Step 4: Calculate the $\overline{E_i}$ and $\overline{\overline{E_i}}$ values for m_{ij} and x_{ij} respectively as follows.

$$\overline{E_i} = L_{1,j} = \sum_{j=1}^{M} w_j \left[\left(m_{ij}\right)_{max} - m_{ij} \right] / \left[\left(m_{ij}\right)_{max} - \left(m_{ij}\right)_{min} \right] \tag{3}$$

$$\overline{\overline{E_i}} = L_{1,j} = \sum_{j=1}^{M} w_j \left[\left(x_{ij}\right)_{max} - x_{ij} \right] / \left[\left(x_{ij}\right)_{max} - \left(x_{ij}\right)_{min} \right] \tag{4}$$

Eq. (3) and Eq. (4) are applicable to beneficial criteria (whose higher values are desirable for a given application). For non-beneficial criteria (whose lower values are preferable for a given application), $[(m_{ij})_{max} – m_{ij}]$ and $[(x_{ij})_{max} – x_{ij}]$ in Eq. (3) and Eq. (4) are to be replaced by $[m_{ij} – (m_{ij})_{min}]$ and $[x_{ij} – (x_{ij})_{min}]$ respectively.

Step 5: Calculate E_i

$$E_i = \frac{1}{2}\left[\overline{E_i} + \overline{\overline{E_i}}\right] \tag{5}$$

Step 6: Calculate F_i values for $\overline{E_i}$ and $\overline{\overline{E_i}}$ elements.

$$\overline{F_i} = L_{\infty i} = \text{Max}^m \text{ of } \left\{ w_j \left\lfloor \left(m_{ij}\right)_{max} \quad m_{ij} \right\rfloor / \left\lfloor \left(m_{ij}\right)_{max} \quad \left(m_{ij}\right)_{min} \right\rfloor \right\} j=1,2,...,M \tag{6}$$

$$\overline{\overline{F_i}} = L_{\infty i} = \text{Max}^m \text{ of } \left\{ w_j \left\lfloor \left(x_{ij}\right)_{max} \quad x_{ij} \right\rfloor / \left\lfloor \left(x_{ij}\right)_{max} \quad \left(x_{ij}\right)_{min} \right\rfloor \right\} \quad j=1,2,...,M \tag{7}$$

Step 7: Calculate F_i

$$F_i = \frac{1}{2}\left[\overline{F_i} + \overline{\overline{F_i}}\right] \tag{8}$$

Step 8: Calculate the value of "supplier selection index" (P_i).

$$P_i = v\,((E_i - E_{i\text{-min}}) / (E_{i\text{-max}} - E_{i\text{-min}})) + (1 - v)\,((F_i - F_{i\text{-min}}) / (F_{i\text{-max}} - F_{i\text{-min}})), \tag{9}$$

where $E_{i\text{-max}}$ and $E_{i\text{-min}}$ are the maximum and minimum values of E_i respectively, and $F_{i\text{-max}}$ and $F_{i\text{-min}}$ are the maximum and minimum values of F_i respectively. v is introduced as weight of the strategy of 'the majority of attributes' (or 'the maximum group utility'). The value of v lies in the range of 0 to 1. Normally, the value of v is taken as 0.5. The compromise can be selected with 'voting by majority' ($v > 0.5$), with 'consensus' ($v = 0.5$) or with 'veto' ($v < 0.5$).

Step 9: Arrange the alternative suppliers in the ascending order, according to the values of "supplier selection index" (P_i). Compromise ranking list for a given v can be obtained by ranking with the P_i measure. The best alternative supplier is the one having the minimum P_i value. The proposed VIKOR-G method is an effective multi-criteria decision making tool, specifically applicable to those situations when the decision maker is not able, or does not know to express his/her preference at the beginning of the decision making process. The obtained compromise solution can be accepted by the decision maker because it provides a maximum group utility of the 'majority' and a minimum individual regret of the 'opponent'. The compromise solutions can be the base for negotiations, involving the decision maker's preference on criteria weights (Rao, 2008). The VIKOR-G results depend on the ideal solution, which stands only for a given set of alternatives. Inclusion (or exclusion) of an alternative can affect the VIKOR-G ranking of the new set of alternatives.

6. Illustrative example 1

This example deals with the selection of the most appropriate supplier for an agricultural and construction equipment manufacturing firm (Rao, 2007). The organization has divided all its purchased parts into 18 commodity groups, like hydraulic valves, fasteners, electrical components etc. To collect data in each commodity group, the company first listed all the parts supplied by each supplier to obtain the supply variety of the vendors. If a supplier supplies more than one commodity group, the supply variety of this supplier in each group is the sum of the number of parts in all the groups. Here five criteria were considered, i.e. price, quality, delivery performance, distance and supply variety. Among these five criteria, price and distance are non-beneficial attributes where smaller values are often preferable, whereas quality, delivery performance and supply variety are the beneficial attributes where higher values are desirable. Eighteen suppliers comprising are considered as the alternatives. Thus, the MCDM problem consists of 18 alternative suppliers and 5 supplier selection criteria. The original decision matrix (Rao, 2008) is expressed in Grey intervals as shown in Table 1. Now this supplier selection problem for the agricultural and construction equipment manufacturing firm is solved using the proposed VIKOR-G method. At first, Grey decision matrix is developed from original decision matrix. The interval range of grey number depends on the uncertainty of the obtained information from each subcontractor and depends on the decision maker. Then the best and the worst values of all the criteria are identified. Rao (2008) employed the AHP method to determine the weights of the considered criteria, as w_P= 0.1361, w_Q= 0.4829, w_{DP}= 0.2590 and w_D= 0.0438 and w_{SV} = 0.0782. These criteria weights are used here for all the analysis. Now, the values of E_i and F_i are calculated using Eqs. (3), (4), (5) and (6) respectively, as given in Table 2. Table 2 also exhibits the values of "supplier selection index" (P_i) for v = 0.5 and the compromise ranking list of the considered alternative suppliers. The candidate suppliers are arranged in ascending order, according to the values of P_i. The best choice of supplier is supplier 15. Supplier 17 is the second choice and the last choice is supplier 14. Rao (2008) obtained a ranking of the alternative suppliers as 10-17-15-6-5-8-13-11-12-9-2-1-16-14-3-18-4-7 by applying TOPSIS method, whereas, using the proposed VIKOR-G method, the compromise ranking of suppliers is 17-15-12-8-11-16-10-

13-1-9-3-4-7-18-5-6-2-14. It is observed that in the VIKOR-G method, the best choice of supplier is supplier alternative 17.

Table 1
Quantitative data expressed in Grey intervals

Supplier	Price (P)		Quality (Q)		Delivery Performance (DP)		Distance (D)		Supply Variety (SV)	
1	80	120	100	100	80	100	224.1	273.9	1.8	2.2
2	80	120	99.69	99.89	70	90	578.7	707.3	11.7	14.3
3	80	120	100	100	80	100	642.6	785.4	2.7	3.3
4	80	120	100	100	80	100	1628.1	1989.9	2.7	3.3
5	80	120	99.73	99.93	70	90	214.2	261.8	21.6	26.4
6	80	120	96.49	96.69	70	100	216.9	265.1	25.2	30.8
7	80	120	100	100	80	95	1263.6	1544.4	0.9	1.1
8	80	120	100	100	96	98	885.6	1082.4	21.6	26.4
9	80	120	99.88	99.93	80	100	576.9	705.1	9.9	12.1
10	80	120	97.44	97.64	100	100	529.2	646.8	47.7	58.3
11	80	120	99.925	99.975	90	100	216.9	265.1	9	11
12	80	120	99.75	99.95	96	100	510.3	623.7	6.3	7.7
13	80	120	99.97	99.97	80	100	510.3	623.7	17.1	20.9
14	80	120	91.87	91.91	80	100	870.3	1063.7	10.8	13.2
15	60	100	99.98	100	90	100	571.5	698.5	29.7	36.3
16	80	120	100	100	90	100	715.5	874.5	1.8	2.2
17	60	100	99.98	100	90	100	620.1	757.9	30.6	37.4
18	80	120	99.26	99.46	80	90	821.7	1004.3	8.1	9.9

A closer look at the values of attributes and their importance for suppliers 10 and 17 reveals that supplier 17 is superior than supplier 10 with respect to attributes price and quality and these two are the most important attributes as per the weights given by Rao (2007).

Table 2
E_i, F_i and P_i values for example 1

Supplier	$\overline{E_i}$	$\overline{\overline{E_i}}$	E_i	$\overline{F_i}$	$\overline{\overline{F_i}}$	F_i	P_i	Rank
1	0.2131	0.3858	0.2994	0.1361	0.1727	0.1544	0.2666	9
2	0.4731	0.4850	0.4790	0.2590	0.2590	0.2590	0.5174	17
3	0.2246	0.3972	0.3109	0.1361	0.1727	0.1544	0.2748	11
4	0.2551	0.4278	0.3414	0.1361	0.1727	0.1544	0.2965	12
5	0.4429	0.4547	0.4488	0.2590	0.2590	0.2590	0.4959	15
6	0.3714	0.6413	0.5063	0.1976	0.2590	0.2283	0.5007	16
7	0.3763	0.4195	0.3979	0.1361	0.1727	0.1544	0.3367	13
8	0.2523	0.2350	0.2437	0.1361	0.1361	0.1361	0.2054	4
9	0.2147	0.3903	0.3025	0.1361	0.1727	0.1544	0.2688	10
10	0.2867	0.2979	0.2923	0.1409	0.1521	0.1465	0.2523	7
11	0.2023	0.2916	0.2470	0.1361	0.1361	0.1361	0.2078	5
12	0.2174	0.2638	0.2492	0.1361	0.1361	0.1361	0.2033	3
13	0.1982	0.3709	0.3277	0.1361	0.1727	0.1544	0.2560	8
14	0.7010	0.8736	0.8305	0.4829	0.4829	0.4829	1.0000	18
15	0.0411	0.1287	0.1065	0.0274	0.0863	0.0582	0.0009	2
16	0.2283	0.3147	0.2931	0.1361	0.1361	0.1361	0.2252	6
17	0.0411	0.1287	0.1065	0.0286	0.0863	0.0575	0.0000	1
18	0.5259	0.4512	0.4535	0.2590	0.1727	0.2158	0.4735	14

Liu (2000) also suggested that supplier alternatives 17, 1, 10, 12, 15 are the only efficient suppliers, so proposing supplier 17 as the best choice is justified. While calculating P_i values, the value of v is usually taken as 0.5 (Rao, 2008), but actually its value lies between 0 and 1. Table 3 shows the compromise rankings of the alternative suppliers for two extreme values of $v = 0.1$ and $v = 0.9$.

Table 3
Ranking of suppliers for example 1 for different values of v

Supplier	P_i ($v = 0.9$)	Rank	P_i ($v = 0.1$)	Rank
1	0.2977	9	0.2356	9
2	0.5524	15	0.4825	17
3	0.3124	11	0.2373	11
4	0.3515	12	0.2416	12
5	0.5137	14	0.4782	16
6	0.5801	17	0.4214	15
7	0.4238	13	0.2496	13
8	0.2219	4	0.1890	4
9	0.3016	10	0.2361	10
10	0.2867	8	0.2179	7
11	0.2262	5	0.1895	5
12	0.2180	3	0.1885	3
13	0.2786	7	0.2335	8
14	1.0000	18	1.0000	18
15	0.0002	2	0.0016	2
16	0.2576	6	0.1929	6
17	0.0000	1	0.0000	1
18	0.5544	16	0.3925	14

In both these cases, the best choice of supplier (supplier alternative 17) does not change, although the ranking of the alternative supplier changes slightly, which suggest that VIKOR-G method can be successfully applied for dealing with complex supplier selection problems. Fig. 1 compares the ranking performance of the proposed VIKOR-G method with respect to TOPSIS method proposed by Rao (2008).

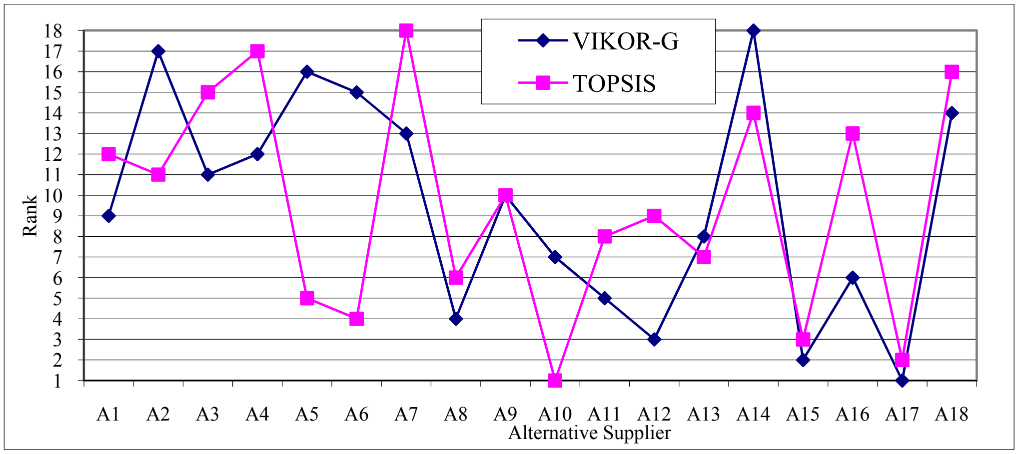

Fig. 1. Comparative rankings of alternative suppliers for example 1

7. Illustrative example 2

The second example (Lin et al., 2007) deals with the selection of the most appropriate subcontractor for an engineering corporation to demonstrate the potentiality, feasibility and applicability of the proposed method. The performance of each subcontractor was evaluated on the basis of four criteria, i.e. Reliability (RA), Schedule-control ability (SA), Management ability (MA), and Labor quality (LQ). The reliability of subcontractors is evaluated by their reputation, records and financial condition. The schedule-control ability is measured by subcontractors' efficiency and mobilization. Management ability (MA) is assessed by the quality, safety, and environmental management level of each subcontractor. Labor quality (LQ) is evaluated by the workers' skill level, coordination and cooperation of subcontractors. So all the four criteria are beneficial in nature where higher values are desirable. Four suppliers namely S_1, S_2, S_3, and S_4 were considered as the alternatives. Thus, the MCDM problem consists of 4 alternative suppliers and 4 supplier selection criteria, as shown in Table 4.

Table 4
Quantitative data expressed in Grey intervals (Lin et al., 2007)

Supplier	RA		SA		MA		LQ	
1	80	120	100	100	80	100	224.1	273.9
2	80	120	99.69	99.89	70	90	578.7	707.3
3	80	120	100	100	80	100	642.6	785.4
4	80	120	100	100	80	100	1628.1	1989.9

At first, the best and the worst values of all the criteria are identified. Lin et al. (2007) determined the weights of the considered criteria, as w_{RA}= 0.2,w_{SA}= 0.25, w_{MA}= 0.20 and w_{LQ}= 0.20. These criteria weights are used here for all the analysis. Now, the values of E_i and F_i are calculated using Eqs. (3), (4), (5) and (6) respectively, as given in Table 5. Table 5 also exhibits the values of "supplier selection index" P_i for v = 0.5 and the compromise ranking list of the considered alternative suppliers. The candidate suppliers are arranged in ascending order, according to the values of the "supplier selection index" P_i. The best choice of supplier is supplier 3. Supplier 1 is the second choice and the last choice is supplier 4. Using the method as proposed by Lin et al. (2007), a ranking of the alternative suppliers obtained as 3-1-2-4, whereas, using the proposed VIKOR-G method, the compromise ranking of suppliers is 3-1-2-4, which exactly corroborates with that of Lin et al. (2007).

Table 5
E_i, F_i and P_i values for example 2

Supplier	$\overline{E_i}$	$\overline{\overline{E_i}}$	E_i	$\overline{F_i}$	$\overline{\overline{F_i}}$	F_i	P_i	Rank
1	0.4000	0.7000	0.5500	0.2000	0.2000	0.2	0.6346	2
2	0.4500	0.4000	0.4250	0.3500	0.1750	0.2625	0.6426	3
3	0.0000	0.1000	0.0500	0.0000	0.1000	0.05	0.0000	1
4	0.7000	0.7000	0.7000	0.3500	0.3500	0.35	1.0000	4

Table 6 shows the compromise rankings of the alternative suppliers for two extreme values of v = 0.1 and v = 0.9. In both these cases, the best choice of supplier (supplier alternative 15) does not change, although the ranking of the alternative supplier may change slightly. Fig. 2 compares the ranking performance of the proposed method with respect to Lin et al. (2007).

Table 6
Ranking of suppliers for example 2 for different values of v

Supplier	P_i ($v = 0.9$)	Rank	P_i ($v = 0.1$)	Rank
1	0.7423	3	0.5269	2
2	0.5901	2	0.6952	3
3	0.0000	1	0.0000	1
4	1.0000	4	1.0000	4

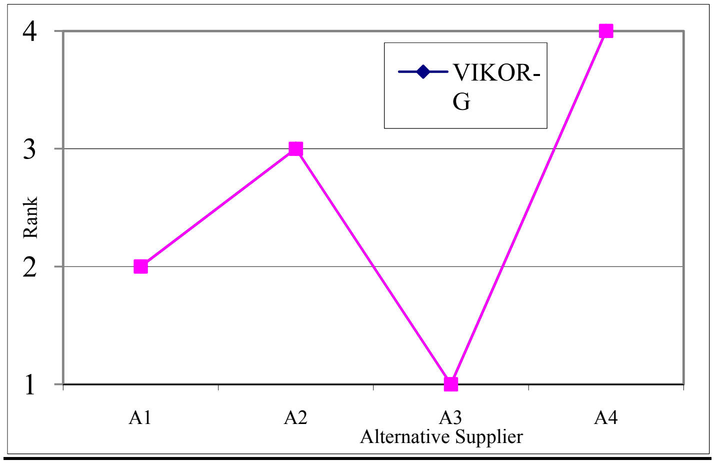

Fig. 2 Comparative rankings of alternative suppliers for example 2

8. Conclusions

Owing to the increasing complexity in decision making, the uncertainty of evaluation increases. In real time manufacturing environment, the decision maker may not always be able to give precise evaluations to the alternatives on every criterion. However, they can give an approximate range of evaluation based on their knowledge and cognition. Under this situation, it becomes necessary to develop such decision making models which can easily handle the uncertain information. In this paper, the concept Grey Interval Number integrated has been used with the Compromise Ranking Method VIKOR, to propose a decision making framework and a "Grey supplier selection index" which can effectively handle the uncertain information and rank the alternative suppliers. The two cited examples demonstrate the potentiality, applicability and simplicity of the proposed VIKOR-G method in solving supplier selection decision-making problems, involving uncertain and qualitative as well as quantitative criteria. The proposed method can incorporate the decision maker's preferences regarding the relative importance of different criteria. The measures of the quantitative and qualitative criteria and their relative importance are used together to rank the alternatives under uncertain environment, providing a better evaluation of the alternatives. The VIKOR-G method can make a compromise ranking among the alternatives. The results derived using the proposed VIKOR-G method show an excellent correlation with those obtained by the past researchers, which specifically prove the global applicability of these two methods while solving such type of complex supplier selection problems. The proposed VIKOR-G method can also be used for any type of decision-making problem, involving any number of quantitative and qualitative criteria and any number of alternatives under uncertain and incomplete environment.

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