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A COPRAS-F base multi-criteria group decision making approach for site selection of wind farm

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CHRONICLE

Article history:
Received July 28, 2012
Accepted November 27, 2012
Available online
December 1 2012

Keywords:
MCDM
Fuzzy MCDM
Multi Criteria Group Decision making (MCGDM)
COPRAS-F
Wind Farm Location

ABSTRACT

Today global warming is on the rise and the natural resources are getting consumed at a faster rate. Power consumption has increased many folds to cater the human need. Thus renewable energy resources are the only option available at this juncture. Wind energy is one of the renewable energy. Location selection for wind farm takes an important role on power generation. However, the location selection is a complex multicriteria problem due to the criteria factors which are conflicting in nature as well as uncertain. The process becomes more complex when a group of decision makers are involved in decision making. In the present study, a COPRAS (COmplex PRoportional ASsessment) based multi-criteria decision-making (MCDM) methodology is done under fuzzy environment with the help of multiple decision makers. More specifically, this study is aimed to focus the applicability of COPRAS-F as a strategic decision making tools to handle the group decision-making problems.

1. Introduction

To prevent the increasing rate of carbon dioxide percentage in atmosphere one should opt for renewable energy resources. Renewable energy is the energy obtained from inconsumable sources of energy occurring in the natural environment. Wind energy is one such nonconventional energy (Tiwari & Ghosal 2005). Wind is air in motion relative to the surface of the earth. The primary cause of air motion is uneven heating of the earth due to solar radiation. The air is not heated directly. Solar radiation is first absorbed by the earth’s surface and is then transferred into the overlying atmosphere. Since the surface of the earth is not homogeneous (land, water, desert, forest, etc.), the amount of energy that is absorbed varies both in space and time. This creates differences in atmospheric temperature, density, and pressure, which create forces, that displace the air from one place to another (Frost & Aspliden 2009). The wind turbine captures the wind’s kinetic energy in a rotor consisting of two or more blades coupled with an electrical generator. The turbine is mounted on a tall tower to capture the energy. A number of wind turbines are installed at one site to build a wind farm of the desired power generation capacity. The actual power extracted by the rotor blades is the difference between the upstream and downstream wind powers (Patel, 2006).

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doi: 10.5267/j.dsl.2012.11.001

Multiple Criteria Decision Making (MCDM) is the process of selecting an optimal solution from a set of available alternatives for satisfying a set of objectives. MCDM is applied to analyze complex real life problems that are conflicting in nature the different alternatives (i.e., strategy, policy, scenario etc.) on various criteria for possible selection of the best/suitable alternative(s). From the last decade MCDM has grown leaps and bounds in business sectors, industries, agriculture, rural and urban area development, sustainable development, forestry management, finance, defense and as well as in sports. The MCDM problems may be classified as classical MCDM and fuzzy MCDM i.e. FMCDM problems. In classical MCDM decision makers make decision under certainty on the basis of objective criteria. Where the criteria values and weights cannot be assign definitely, there fuzzy set theory is introduced to model the problem of uncertainty in decision making and such problem is known as fuzzy multiple criteria decision making (Dey et al. 2012).

The researchers for solving MCDM problems have developed various techniques. In this present paper Fuzzy COmplex PRoportional ASsessment (COPRAS - F) is applied under group decision making to select the feasible location for wind farm from a set of alternatives. Development of a wind farm not only requires location of high wind speed sites to maximize energy production but also should consider some other criteria like; land elevation, quality of air, availability and cost of land along with the technical, commercial and environmental issues. The objective of the present paper is to select the suitable location for the wind farm taking into account the considerable criteria using extended COPRAS-F under group decision-making.

From the literature review, it is reviled that many researchers have enlightened over the various methods concerned with MCDM problems like, Churchman & Ackoff (1954) and MacCrimon (1968), presented SAW (Simple Additive Weighting), Srinivasan and Shocker (1973) presented LINMAP (Linear Programming Techniques for Multidimensional Analysis of Preference), Hwang and Yoon (1981) developed TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), Roy (1991) developed ELECTRE (Elimination and Choice Translating Reality), Brauers and Zavadskas (2006) presented MOORA (Multi-Objective Optimization on basis of Ratio Analysis), Zavadskas and Turskis (2010) presented ARAS (Additive Ratio ASsessment). Zavadskas and Kaklauskas (1996) introduced COPRAS (COmplex PRoportional ASsessment) which is one of the well known MCDM method, that helps to choose the best alternative among a pool of feasible alternatives. This technique is employed by various researchers to solve the decision making problems. Kaklauskas et al. (2006) applied COPRAS method to select low-e windows in retrofit of public buildings and to select a retrofit contractor. Zagorskas (2007) applied COPRAS with the geographical information system for the purpose of an efficient calculation of parameters and visualisation of city compactness. Banaitiene et al. (2008) used COPRAS to evaluate the life cycle of buildings. Chatterjee et al. (2011) explored the applicability and capability of COPRAS method for materials selection.

Zadeh (1965) introduced Fuzzy logic which can take into account the uncertainty and solve the problems where there are no sharp boundaries and precise values. Zavadskas and Antucheviciene (2007) applied fuzzyfied COPRAS method to analyze the regeneration alternatives of derelict buildings in rural areas at Lithuania. Antucheviciene et al. (2011) compared fuzzy COPRAS, TOPSIS and VIKOR methods with respect to ranking of redevelopment of derelict buildings. Yazdani et al, (2011) used the fuzzy COPRAS (COPRAS-F) to provide a risk analysis framework with the aim to overcome limitations of the classical approach to build a more secure, safer, and more resilient critical infrastructures in order to develop, implement and control. Chen, (2000) applied TOPSIS for group decision-making under fuzzy environment to select a system analysis engineer for a software company. Moradi et al, (2011) used VIKOR under fuzzy circumstance group decision making process for vendor selection of car parts in Iran. In their view the nature of vendor selection is a complex MCDM problem including both quantitative and qualitative factors. It may be conflicting and uncertain in nature. The process becomes more complex when a group of decision makers (DMs) take decisions. Baležentis et al. (2012) used fuzzy MULTIMOORA with linguistic reasoning and group decision-making (MULTIMOORA-FG) by aggregating the subjective assessments of the decision-makers to perform a more robust personnel selection. Awasthi et al (2011) used Fuzzy TOPSIS to solve the facility location selection problem applying group decision-making.

In the present paper, on the basis of concepts of the above literature review, FMCDM problems are mainly discussed, and the proposed method is based on the incorporated efficient fuzzy model for solving decision-making problems with multi-decision makers. It will efficiently grasp the uncertainty existing in the available information. In this paper COPRAS-F is suggested for decision making in order to solve the problem. COPRAS method helps to accurately evaluate and validate the calculation results mathematically. However, the awareness of its properties allows us to show the benefits of the method's application, to predict the influence of minimizing criteria values on the final result (estimate), to check the calculations and to take into account possible instability of estimates yielded by the method due to the specific character of the actual data (Podvezko 2011).

Finally, in this study an example of selection of the suitable location for the wind farm is illustrated. The remainder of this paper is organized as follows. Section 2 introduces the technique, fuzzy COPRAS approach under group decision making model. In Section 3, an illustrative example of location selection for the wind farm applying the method from Section 2. Section 4 contains the result and discussion. Finally, conclusions are presented in Section 4.

2. Fuzzy COPRAS approach under group decision making

2.1 Multiple Criteria Group Decision Making (MCGDM)

Decision making is a dynamic process concerns with choosing a suitable course of action to achieve the goal. Basically it is the process of selecting a feasible alternative from a set of alternatives. When the alternative has only one criterion, its state of nature is predictable which makes decision making less complicated. This is known as decision making under certainty. Uncertainty arises when there is no data available for criterion to solve the problem.

1. MCDM is defined, as the study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process. The MCDM is a model to analysis several conflicting criteria scientifically and rationally. Hwang and Yoon (1981) broadly categorized MCDM into two types, i.e., multi-attribute decision-making (MADM) and multi-objective decision-making (MODM). MADM concerns with selection of the feasible alternative from a set of alternatives based on prioritized attributes of the alternatives and MODM concerns with optimization of an alternative or alternatives on the based on preferences of objectives. Nowadays Group Decision Making (GDM) problems takes an important role in decision making in real world. In MCGDM a committee of decision makers is formed to aim the ranking of all the alternatives more rationally by aggregating the judgment or evaluation by virtue of their respective knowledge, experience and preference for a decision space i.e., a finite set of alternatives (Liang and Pang 2012).

2.1. Fuzzy set theory

Sometimes vague judgments of decision maker(s) makes it difficult to measure exact numerical value, so the crisp data are inadequate to model real-life situations. Uses of linguistic assessments of weights of the criteria in the problem are more realistic approach instead of numerical values. Decision matrix can be converted into a fuzzy decision matrix and a weighted normalized fuzzy decision matrix after the decision makers' fuzzy ratings have been completed. In a universe of discourse X, a fuzzy set $\tilde{d}$ is characterized by a membership function $\mu_{\tilde{d}}(x)$, i.e., degree of membership of x in $\tilde{d}$ which maps each element x in X to a real number in the interval [0, 1]. A triangular fuzzy number (TFN), $\tilde{d}$ can be defined as a triplet (d_1, d_2, d_3) and the membership function is defined (Dubois & Prade 1978, Keufmann & Gupta 1991) as shown by Eq.(1).

$$\mu_{\tilde{d}}(x) = \begin{cases} 0, & x \le d_1 \\ \dfrac{x-d_1}{d_2-d_1}, & \mathrm{d}_1 \le x \le d_2 \\ \dfrac{d_3-x}{d_3-d_2}, & \mathrm{d}_2 \le x \le d_3 \\ 0, & x > \mathrm{d}_3 \end{cases} \tag{1}$$

The above equation can also be depicted in Fig. 1. The conversion technique of fuzzy number into non-fuzzy number, i.e., crisp value is known as defuzzyfication. There are many types of defuzzyfication techniques available, like, Centroid of area, Bisector of area, Mean of maximum , Smallest of maximum, Largest of maximum techniques (Naaz et al. 2011), 'α-cut' technique etc. In this paper 'centroid of area' technique for determining Best Non-fuzzy Performance (BNP) value is applied.

$$BNP = \frac{[(d_3-d_1)-(d_2-d_1)]}{3} + d_1 \tag{2}$$

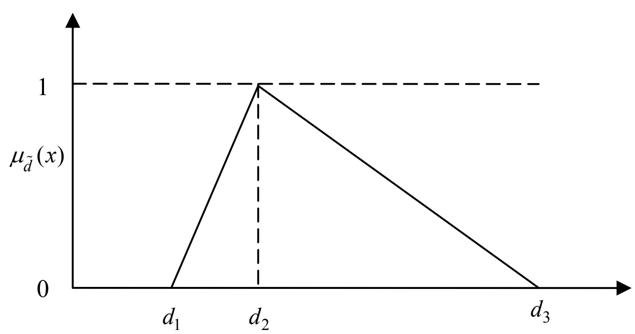

Fig. 1. Membership function of a triangular fuzzy number

2.2.COPRAS-F under Group Decision Making

The COPRAS is one of the well known MCDM methods, which select the best alternative among a lot of feasible alternatives by determining a solution with direct and proportional ratio to the best solution to the ratio with the ideal-worst solution. In classical COPRAS, the criteria weights and the alternatives ratings are taken into account as crisp numerical data. However, in reality the crisp data are insufficient to handle the problems of decision making under uncertainty and on the other hand exact crisp data are not easily available. These make the decision-making problems erroneous and inaccurate. COPRAS-F is applicable where criteria weights and alternative ratings are given by linguistic terms that are addressed using fuzzy numbers (triangular or trapezoidal). The steps for solving the problems are depicted (Yazdani et al 2011, Baležentis et al. 2012) as follows:

Step-1: Initialization of decision-making: Generation of feasible alternatives (*m*), Determination of the evaluation criteria (*n*), Selecting a group of decision makers (*k*).

Step-2: Choosing the linguistic ratings for criteria and alternatives: The importance weights of various criteria and alternatives are considered as linguistic variables. These linguistic variables can be expressed in positive triangular fuzzy numbers as Tables 1 and 2.

Table 1
Linguistic terms for criteria

Linguistic terms	Fuzzy number
Very High (VH)	(0.9,1.0,1.0)
High (H)	(0.7,0.9,1.0)
Moderate High (MH)	(0.5,0.7,0.9)
Moderate (M)	(0.3,0.5,0.7)
Moderate Low (ML)	(0.1,0.3,0.5)
Low (L)	(0.0,0.1,0.3)
Very Low (VL)	(0.0,0.0,0.1)

Table 2
Linguistic terms for alternative

Linguistic terms	Fuzzy number
Very Good (VG)	(0.9,1.0,1.0)
Good (G)	(0.7,0.9,1.0)
Medium Good (MG)	(0.5,0.7,0.9)
Medium (M)	(0.3,0.5,0.7)
Medium Poor (MP)	(0.1,0.3,0.5)
Poor (P)	(0.0,0.1,0.3)
Very Poor (VP)	(0.0,0.0,0.1)

Step-3: Formation of the decision matrix: The fuzzy group decision matrix is formed as in Eq. (3)

$$\text{Alternatives} \qquad \text{Criteria} \rightarrow$$

$$\tilde{D} = \begin{bmatrix} & \downarrow & C_1 & & C_j & & C_n \\ DM^1 & \begin{matrix} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} & \multicolumn{5}{c}{\begin{bmatrix} \tilde{d}^1_{11} & \cdots & \tilde{d}^1_{1j} & \cdots & \tilde{d}^1_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^1_{i1} & \cdots & \tilde{d}^1_{ij} & \cdots & \tilde{d}^1_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^1_{m1} & \cdots & \tilde{d}^1_{mj} & \cdots & \tilde{d}^1_{mn} \end{bmatrix}} \\ DM^2 & \begin{matrix} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} & \multicolumn{5}{c}{\begin{bmatrix} \tilde{d}^2_{11} & \cdots & \tilde{d}^2_{1j} & \cdots & \tilde{d}^2_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^2_{i1} & \cdots & \tilde{d}^2_{ij} & \cdots & \tilde{d}^2_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^2_{m1} & \cdots & \tilde{d}^2_{mj} & \cdots & \tilde{d}^2_{mn} \end{bmatrix}} \\ & & \vdots & & \vdots & & \vdots \\ DM^k & \begin{matrix} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} & \multicolumn{5}{c}{\begin{bmatrix} \tilde{d}^k_{11} & \cdots & \tilde{d}^k_{1j} & \cdots & \tilde{d}^k_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^k_{i1} & \cdots & \tilde{d}^k_{ij} & \cdots & \tilde{d}^k_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ \tilde{d}^k_{i1} & \cdots & \tilde{d}^k_{ij} & \cdots & \tilde{d}^k_{mn} \end{bmatrix}} \end{bmatrix} \tag{3}$$

where, $\tilde{d}^k_{ij} = d^k_{ij_1}, d^k_{ij_2}, d^k_{ij_3}$. Then applying fuzzy weighted averaging (FWA) operator the responses of the decision makers are aggregated (Xu & Da, 2003). Let $\tilde{q}_k$ be the fuzzy coefficient of significance for the k^{th} decision maker. If k is homogeneous then, $\tilde{q}_k = (1/k, 1/k, 1/k)$. Hence, the aggregated fuzzy decision matrix using the Eq. (4) will be as follows:

$$\tilde{D} = [\tilde{d}_{ij1}, \tilde{d}_{ij2}, \tilde{d}_{ij3}], \text{ where } \tilde{d}_{ij} = \frac{\sum_{k=1}^{k} \tilde{q}_k \tilde{d}^k_{ij}}{\sum_{k=1}^{k} \tilde{q}_k} \tag{4}$$

Step-3: Defuzzifying the fuzzy decision matrix:

Defuzzification of the fuzzy decision matrix into crisp values by using the Eq. (2).

Step-4: Normalization of defuzzified decision matrix $(\overline{D})$:

The objective of normalization is to obtain comparable scales of criteria values. The normalization of criteria values is not compulsory, but it may be required sometimes. In order to avoid the difficulties caused by different dimensions of the criteria values, the ratio to the optimal value is used. The normalized criteria values are determined either on the interval [0 to 1] or the interval [0 to ∞] (Zavadskas & Turskis, 2008).The normalized value $\bar{d}_{ij}$ is calculated using the Eq. (5);

$$\bar{d}_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^{m} d_{ij}}} \qquad (1 \le i \le m, \quad 1 \le j \le n) \tag{5}$$

Step-5: Computation of the criteria weight:
Defuzzify the fuzzy weight of each criterion (w_1, w_2, w_3) into crisp values (w_j) by using the Eq. (6).

$$w_j = \frac{[(w_3 - w_1) - (w_2 - w_1)]}{3} + w_1 \tag{6}$$

Compute of the Weight q_j of j^{th} criterion is as follow.

$$q_j = \frac{w_j}{\sum_{j=i}^{n} w_j} \tag{7}$$

Step-6: Formation of the Weighted Normalized Decision Matrix $(\hat{D})$**:** The weighted normalized decision value $(\hat{d})$ is calculated using Eq. (8).

$$\hat{d}_{ij} = \bar{d}_{ij} \times q_j \qquad (1 \le i \le m, \quad 1 \le j \le n) \tag{8}$$

Step-7: Calculation of the sums of weighted normalized criteria values (P_i) for each alternative whose higher values are more preferable using Eq. (9)

$$P_i = \sum_{j=1}^{l} \hat{d}_{ij} \tag{9}$$

Where l is the number of criteria value, which must to be maximized.

Step-8: Calculation of the sums of weighted normalized criteria values (R_i) for each alternative whose lower values are more preferable using Eq. (10)

$$R_i = \sum_{j=l}^{m} \hat{d}_{ij} \tag{10}$$

Where (m-l) is the number of criteria values, which should be minimized.

Step-9: Calculation of the minimal value of R_i i.e. $R_{\min}$

Step-10: Calculation of the relative weight of each alternative (Q_i), using Eq. (11),

$$Q_i = P_i + \frac{R_{\min} \sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \frac{R_{\min}}{R_i}} \tag{11}$$

$$Q_i = P_i + \frac{\sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \frac{1}{R_i}} \tag{12}$$

$$Q_i = P_i + \frac{1}{\frac{R_i}{\sum_{i=1}^{n} R_i} \sum_{i=1}^{n} \frac{1}{R_i}} \tag{13}$$

$$Q_i = P_i + \frac{1}{\overline{R_i} \sum_{i=1}^{n} \frac{1}{R_i}} \tag{14}$$

Where, $\overline{R_i}$ = Normalized value of R_i (Podvezko 2011).

$$\overline{R_i} = \frac{R_i}{\sum_{i=1}^{n} R_i} \tag{15}$$

Step-11: Calculation of the optimality criterion (*K*), i.e., maximum of Q_i, i.e., $(Q_{\max})$

Step-12: Ranking the alternatives in descending order of optimality criterion (*K*). Then, the alternative with the highest score is selected as the preferred (best) one.

Step-13: Calculation of the utility degree N_i of each alternative, using Eq. (16) showing, as a percentage, to compare the alternative is better or worse than other alternatives.

$$N_i = \frac{Q_i}{Q_{\max}} \times 100\% \tag{16}$$

3. Case study: Location selection for wind farm

In order to setup a wind farm location selection plays a significant role. The best location is selected from all of the feasible alternatives. A decision-making committee is formed consisting of four members viz. DM 1, DM 2, DM 3 and DM 4. After initial screening the committee considers four alternative wind farm locations viz. L1, L2, L3 and L4. The committee considers fifteen selection criteria and subcriteria as listed in Table -3. The criteria weight is calculated using Eq. (6) and (7). The Result is tabulated in Table 3.

Table 3
Different criteria and their linguistic terms

Criteria	Symbol	Linguistic terms	Fuzzy number (w_1,w_2,w_3)	q_j
Average wind speed	C1	VH	0.9, 1.0, 1.0	0.1007
Average air density	C_2	VH	0.9, 1.0, 1.0	0.1007
Land elevation	C_3	MH	0.5, 0.7, 0.9	0.0729
Accessibility to the proposed site	C_4	M	0.3, 0.5, 0.7	0.0521
Distance from national grid	C_5	MH	0.5, 0.7, 0.9	0.0729
Distance from nearest locality	C_6	M	0.3, 0.5, 0.7	0.0521
Distance from nearest woodland	C_7	ML	0, 0.1, 0.3	0.0139
Distance from nearest city	C_8	M	0.3, 0.5, 0.7	0.0521
Availability of land	C_9	MH	0.5, 0.7, 0.9	0.0729
Cost of Land	C_{10}	MH	0.5, 0.7, 0.9	0.0729
Availability of labour	C_{11}	ML	0.1, 0.3, 0.5	0.0313
Geological and meteorological characteristics	C_{12}	M	0.3, 0.5, 0.7	0.0521
Seismic zone	C_{12a}	M	0.3, 0.5, 0.7	0.0140
Cyclone prone area	C_{12b}	H	0.7, 0.9, 1.0	0.0242
Lighting prone area	C_{12c}	M	0.3, 0.5, 0.7	0.0140
Proposed grid connection cost	C_{13}	H	0.7, 0.9, 1.0	0.0903
Proposed operation & maintenance cost	C_{14}	MH	0.5, 0.7, 0.9	0.0729
Proposed payback period	C_{15}	H	0.7, 0.9, 1.0	0.0903

Each of the decision makers evaluated every location according to the fifteen criteria in linguistic terms as tabulated in Table 4.

Table 4
Evaluation of different locations

		C1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12} C_{12a}	C_{12b}	C_{12c}	C_{13}	C_{14}	C_{15}
		(+)	(+)	(+)	(-)	(-)	(+)	(+)	(-)	(+)	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(+)
DM 1	L 1	G	M	M	G	G	P	G	P	G	G	VP	MG	P	G	G	G	M
	L 2	M	L	MG	VG	M	P	MP	G	G	G	G	P	G	G	G	M	M
	L 3	MG	MP	G	G	MG	MP	MG	VG	MG	VG	P	M	MP	MG	G	MG	G
	L 4	G	M	MP	MG	M	MP	VG	VG	VG	P	MP	P	P	P	P	G	MP
DM 2	L 1	G	G	P	G	VG	MP	G	G	MG	M	G	G	P	G	G	M	M
	L 2	M	M	MG	M	MG	P	M	MP	G	MG	M	P	G	MG	M	M	M
	L 3	M	MG	G	MG	G	MG	P	P	MG	G	G	M	MP	MG	MG	MG	G
	L 4	MG	M	MP	MG	MG	MG	VG	P	VG	VP	MG	MP	VP	P	P	MP	M
DM 3	L 1	G	G	P	G	G	P	G	G	G	M	M	G	P	MG	G	M	M
	L 2	M	M	M	M	MG	VP	M	G	G	M	M	P	G	G	G	M	M
	L 3	M	M	G	VG	G	MP	MP	P	MG	G	G	M	MP	M	MG	MG	G
	L 4	MG	M	MP	VG	MG	M	VG	P	VG	VP	MG	MP	P	P	P	MG	MP
DM 4	L 1	M	MG	M	G	VG	VP	VH	MG	G	M	M	G	P	HG	VG	G	M
	L 2	MP	MP	MG	VG	G	VP	G	MG	G	M	G	P	G	G	G	M	MG
	L 3	MP	M	VG	MG	VG	M	MG	H	M	H	MG	M	MP	MG	M	MG	G
	L 4	M	MG	M	M	G	G	VG	VG	VG	VP	MG	MP	VP	P	P	G	MG

The maximizing criteria are denoted by (+) sign and the minimizing criteria are denoted by (-) sign.

Now using Eqs. (4), (5), (8), (9), (10), (12) and (16) we get the final result as tabulated in Table-5.

Table 5
Final Result

Locations	P_i	R_i	Q_i	Rank	N_i
L1	0.133	0.135	0.281	2	82.42
L2	0.118	0.154	0.249	4	72.92
L3	0.149	0.161	0.273	3	80.76
L4	0.135	0.096	0.344	1	100.00

4. Discussion

Using COPRAS, an initial assessment of the feasibility of the location for wind farm has been conducted. The analysis compared four alternative locations based on fifteen weighted decision criteria. Based on the judgment of four decision makers a ranking of the priorities of the location is compiled (Table 5): priority 1 = L4, priority 2 = L1, priority 3 = L3, priority 4 = L2. Therefore, the area that best satisfies for wind farm is L4. From Eq. (14), the concept of the method COPRAS is unambiguously distinct, that the value of the i-th alternative Q_i is directly proportional to the effect of maximizing criteria (P_i) and inversely proportional to the sum of the weighted normalized values of minimizing criteria (R_i) (Podvezko 2011). It has been observed that the maximizing criteria (P_i) of L3 is high but still its ranks 3^{rd} in the list, this is because its R_i value is highest which eventually lowers the overall Q_i value.

5. Conclusions

Proper selection of location for wind farm has a significant impact on power generation. In this present paper a group decision-making (GDM) problem is highlighted. To solve the complexity and uncertainty arising due to various conflicting criteria and independent views of four decision makers of the proposed model, COPRAS method is used, based on linguistic parameters and the fuzzy set theory. In order to take major decisions, like site selection for plant installation, supply chain management, etc. decision of a group of decision makers is more accurate and authentic than that of individual's decision. The problem is analyzed by aggregating the decision of committee members. A case study is presented in order to demonstrate the practicality and effectiveness of the methodology, where the location L4 is ranked first. In future there is a scope to solve the problem initially by individuals and then ranked the results by voting. This problem will set a benchmark for the power generating industries to utilize their resources for better customer satisfaction.

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