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Research Article

Grey Target Decision Method for a Variable Target Centre Based on the Decision Maker's Preferences

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In multiattribute grey target decision making, the decision maker (DM) may have certain preferences for some attributes. The impacts of two types of DM's preferences for some attribute values on alternatives were studied. To deal with the attribute preferences of a DM, a generalised grey target decision method was presented. The proposed method required that the index values of all alternatives were not normalised. The target centre index values can be obtained by substituting DM's preference values for some of the original target centre index values as determined by the alternatives themselves. Following this, the proposed generalised method was used to calculate the target centre distances. A case study showed that this method of handling DM's preferences for some attributes was effective.

1. Introduction

In multiattribute decision making, the relative optimality of one parameter can be obtained using a grey target decision method by comparison with feasible alternatives without recourse to other standard modes. The grey target decision method has been widely used in many fields since it was proposed by Deng [1]. Over the past few years, many scholars have made progress in this area. Chen and Xie tested the incontinency problem of Deng's grey transformation by simulation [2]. Dang et al. improved the calculation operators of the grey target decision method [3, 4]. Some scholars also studied its weight determination [5–7]. The grey target decision method for mixed attributes has also been studied [8–14]. Furthermore, some other theories and methods were introduced to the grey target decision method [13–16] which enrich its potential. However, the consideration of the DM's preferences was seldom studied apart from a limited contribution by Zhu and Hipel [6, 16]. This work expanded the target centre as determined by the alternatives themselves to some indices of the target centre replaced by the DM's preferences. There are two types of preferences: some attribute values were expected to reach their desired levels; however, some other attribute values were regarded as excellent only if they reached some specified values without acquiring the optimal solution. This work assessed the effects of a variable target centre determined partially by the DM's preferences over the available alternatives and presented a new generalised grey target decision method to deal with this problem.

The remainder of this paper is organised as follows: Section 2 introduces the concepts, Section 3 discusses the proposed method, Section 4 presents a case study, and Section 5 is the conclusion.

2. Preliminaries

Definition 1. Let $S = \{S_1, S_2, \ldots, S_n\}$ be an alternative set, let $A = \{A_1, A_2, \ldots, A_m\}$ be an attribute set, and let S_{ij} $(i = 1, 2, \ldots, n, j = 1, 2, \ldots, m)$ be the measure of alternative S_i under attribute A_j, and $J^+$and J^- are benefit type attribute, and cost type attribute, sets, respectively: these form the basic elements of multiattribute decision making.

Remark 2. Based on the theory of grey target decision making, however the method differed from the classical version (the generalised grey target method). Compared to the traditional model, the generalised grey target method had two differences: no need to normalise the index values S_{ij} ($i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$) and the difference in the target centre distance calculation.

Definition 3. Let $C^a = (C_1^a, C_2^a, \dots, C_m^a)$ be the target centre determined by the alternative measure S_{ij} ($i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$), where C_j^a satisfies

$$C_j^a = \begin{cases} \max\left\{S_{ij}\right\}, S_{ij} \in J^+ \\ \min\left\{S_{ij}\right\}, S_{ij} \in J^- \end{cases} \quad i = 1, 2, \dots, n, \ j = 1, 2, \dots, m. \tag{1}$$

Definition 4. Let C_k^{de} ($k \in \{1, 2, \dots, m\}$) be the DM's desirable preference value, such that the DM's preference value is better than or equal to the optimal index value of alternatives under attribute A_j, which satisfies

$$C_k^{\text{de}} \geq \max\left\{S_{ij}\right\}, \quad S_{ij} \in J^+, \ i = 1, 2, \dots, n, \ j = 1, 2, \dots, m, \tag{2}$$

or

$$C_k^{\text{de}} \leq \min\left\{S_{ij}\right\}, \quad S_{ij} \in J^-, \ i = 1, 2, \dots, n, \ j = 1, 2, \dots, m. \tag{3}$$

Definition 5. Let C_k^{ds} ($k \in \{1, 2, \dots, m\}$) be the DM's selection preference value, such that some index value is regarded as excellent only when it is better than or equal to the value C_k^{ds} given by the DM under attribute A_j, which satisfies

$$\min\left\{S_{ij}\right\} < C_k^{\text{ds}} < \max\left\{S_{ij}\right\}, \quad i = 1, 2, \dots, n, \ j = 1, 2, \dots, m. \tag{4}$$

Definition 6. Suppose that the target centre $C^a = (C_1^a, C_2^a, \dots, C_m^a)$ is decided by S_{ij} ($i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$) and DM's preference value under attribute A_k ($k \in \{1, 2, \dots, m\}$) is C_k^d ($k \in \{1, 2, \dots, m\}$). Then the target centre, determined partially by preference values, becomes $C^0 = (C_1^0, C_2^0, \dots, C_m^0)$, the elements of which are as follows:

$$C_j^0 = \begin{cases} C_j^a, & j = 1, 2, \dots, m, \ j \neq k \\ C_k^d, & k \in \{1, 2, \dots, m\}, \ j = k. \end{cases} \tag{5}$$

3. Grey Target Decision Making Method for Variable Target Centre

3.1. The Impacts of Variable Target Centre on Alternatives. Desirable preferences and selection preferences are two types of attribute preferences for the DM. Different DM's attribute preferences may cause different impacts on alternatives with respect to any grey target decision model. Figure 1 shows the impact of desirable attribute preference on the alternatives.

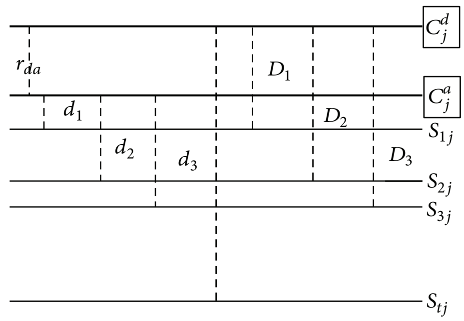

FIGURE 1: The impact of desirable attribute preference on the alternative.

In Figure 1, suppose that S_{ij} which belongs to the benefit type attribute set is the index value under attribute A_j, and S_{tj} is the worst value. Let C_j^a and C_j^d be the target centre indices under attribute A_j, as determined by feasible alternatives and DM's preferences, respectively. Suppose that d_1, d_2, and d_3 are the distances of index values S_{1j}, S_{2j}, and S_{3j} to C_j^a, respectively, and D_1, D_2, and D_3 are the distances of index values S_{1j}, S_{2j}, and S_{3j} to C_j^d, respectively, while r_{da} is the difference between C_j^d and C_j^a. Obviously, the target centre index C_j^d, determined by the desirable attribute preference value, expanded the distances from d_1, d_2, and d_3 to D_1, D_2, and D_3, respectively. Figure 2 shows the impact of selection attribute preference on alternatives (the meaning of the parameters in Figure 2 matches that in Figure 1). The target centre index value determined by DM's selection preference is inferior to that of the alternatives, which changes the distances of S_{1j}, S_{2j}, and S_{3j} to C_j^a to the distances of S_{1j}, S_{2j}, and S_{3j} to C_j^d, such that d_1, d_2, and d_3 changed to D_1, D_2, and D_3, respectively. It can be seen from Figure 2 that C_j^d was actually inferior to S_{1j} and S_{2j}, so there was no meaning attributable to either D_1 or D_2. From the perspective of a cluster of indices, the distances of S_{1j} and S_{2j} to C_j^d can be regarded as excellent indices with target centre distances of zero. Only D_3 denoted the real target centre distances, but its value is less than d_3 and the reduced value is r_{da} which is the difference between C_j^a and C_j^d.

The impacts of target centre determined by different preferences over the alternatives are discussed as follows: assume that S_{ij} ($i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$) is the measure of alternative S_i under attribute A_j and $S_{i_0 j}$ and $S_{(i_0+1)j}$ are any two index values. Let d_{i_0} and d_{i_0+1} be the distances of $S_{i_0 j}$ and $S_{(i_0+1)j}$ to C_j^a, respectively; then set $d_{i_0} < d_{i_0+1}$ without affecting the conclusions so that under attribute A_j the distances of $S_{i_0 j}$ and $S_{(i_0+1)j}$ to C_j^d are D_{i_0} and D_{i_0+1}, respectively: the difference between C_j^d and C_j^a is r_{da}. For comparison, the target centre distances of all indices under some attribute must be normalised. The linear method is used to normalise these target centre distances using (12). The following equations are the difference between the two

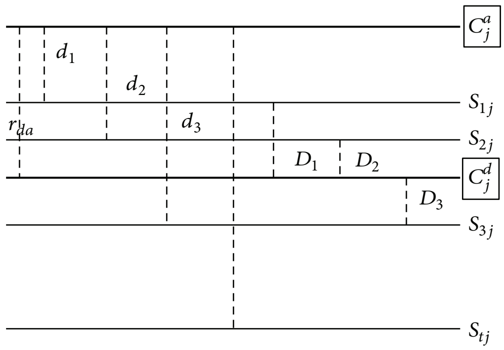

FIGURE 2: The impact of selection attribute preference on the alternative.

alternatives' target centre distances under some attribute for different target centres:

$$\Delta Z_a = \frac{d_{i_0+1}}{\sum_{i=1}^{n} d_i} - \frac{d_{i_0}}{\sum_{i=1}^{n} d_i} = \frac{d_{i_0+1} - d_{i_0}}{\sum_{i=1}^{n} d_i}, \tag{6}$$

where d_i is the distance of S_{ij} to C_j^a; namely, $d_i = |C_j^a - S_{ij}|$:

$$\Delta Z_d = \frac{D_{i_0+1}}{\sum_{i=1}^{n} D_i} - \frac{D_{i_0}}{\sum_{i=1}^{n} D_i} = \frac{D_{i_0+1} - D_{i_0}}{\sum_{i=1}^{n} D_i}, \tag{7}$$

where D_i is the distance of S_{ij} to C_j^d, which can be calculated by (11).

The target centre C_j^a determined by alternatives and the target centre C_j^d determined by DM's preference value have the following relationship:

$$r_{da} = C_j^d - C_j^a. \tag{8}$$

So (7) can be rewritten as

$$\begin{aligned}\Delta Z_d &= \frac{r_{da} + d_{i_0+1}}{\sum_{i=1}^{n} (r_{da} + d_i)} \\ &\quad - \frac{r_{da} + d_{i_0}}{\sum_{i=1}^{n} (r_{da} + d_i)} = \frac{d_{i_0+1} - d_{i_0}}{n r_{da} + \sum_{i=1}^{n} d_i}.\end{aligned} \tag{9}$$

Compared with (5) and (2), the conclusions may be drawn as follows.

(1) If $r_{da} > 0$, which is the DM's desirable preference, then $\Delta Z_d < \Delta Z_a$ means the difference of the two alternatives' target centre distances decreased, which implied that the target centre, as determined by desirable preference, can reduce the difference in index values for each alternative.

(2) If $r_{da} < 0$, which is the DM's selection preference, then $\Delta Z_d > \Delta Z_a$ means the difference of the two alternatives' target centre distances increased, which implied that the target centre, as determined by selection preference, can enlarge the difference in index values for each alternative. However, note that some indices' target centre distances were zero when they were superior to the target centre index implying an indifference to the value of these indices. Therefore, the target centre index, as determined by selection preference, had the potential to act as a "rewarding good and punishing bad" function.

This discussion was based on benefit-type indices; however, the same conclusions may be drawn from consideration of cost-type indices.

3.2. Variable Target Centre Determination. To obtain the target centre combined with the DM's preferences, the target centre, as decided by alternatives, must first be determined. The final target centre was determined by substituting some preference values for the predetermined target centre index values. Note that the predetermined target centre originated from the nonnormalised index matrix. The target centre combined with DM's preferences can be obtained using (1) and (5).

3.3. Target Centre Distance Calculation. In grey target decision making, the optimal alternative is determined by the minimum of all integrated target centre distances. The target centre determined only by the DM's desirable preferences is easy to deal with; however, the target centre combined with the DM's selection preferences may be more complicated. Some index values may be superior to the target centre index values determined by selection preferences, so their index target centre distances were zero, as were all those regarded as excellent values. A new generalised grey target method will be used to solve this problem.

Suppose that the target centre determined by S_{ij} ($i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$) was $C^a = (C_1^a, C_2^a, \ldots, C_m^a)$, so the target centre combined with the DM's preferences can be calculated according to the following steps.

(1) The new index measure I_{ij} can be obtained from S_{ij} ($i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$) compared with the target centre index C_j^0 ($j = 1, 2, \ldots, m$) under attribute A_j ($j = 1, 2, \ldots, m$):

$$I_{ij} = \begin{cases} S_{ij}, & \text{if } \left(S_{ij} < C_j^0,\ S_{ij} \in J^+\right) \text{ or } \left(S_{ij} > C_j^0,\ S_{ij} \in J^-\right) \\ C_j^0, & \text{if } \left(S_{ij} \geq C_j^0,\ S_{ij} \in J^+\right) \text{ or } \left(S_{ij} \leq C_j^0,\ S_{ij} \in J^-\right). \end{cases} \tag{10}$$

(2) Calculate the distance of index value I_{ij} ($i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$) to the target centre index value C_j^0 ($j = 1, 2, \ldots, m$) under attribute A_j ($j = 1, 2, \ldots, m$), using the Hamming distance:

$$r_{ij} = \left|C_j^0 - I_{ij}\right|, \quad i = 1, 2, \ldots, n,\ j = 1, 2, \ldots, m. \tag{11}$$

(3) Normalise the index target centre distances of all alternatives for comparability, and the linear normalised method was then used to retain the indices' own characteristics:

$$z_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}, \quad i = 1, \ldots, n;\ j = 1, \ldots, m. \tag{12}$$

(4) Having obtained the weight ω_j under attribute A_j $(j = 1, 2, \ldots, m)$, the integrated target centre distances for all alternatives can then be calculated using (13):

$$w_i = \omega_j z_{ij}, \quad i = 1, \ldots, n,\ j = 1, \ldots, m. \tag{13}$$

3.4. Weight Determination. The attribute weights can be determined by: subjective method, objective method, or comprehensive method. There are many articles contributing to weight determination: the interested reader is referred to the relevant literature [2–4, 10, 12].

3.5. Algorithm of Grey Target Decision Making Method Based on the DM's Preferences

(1) Give the DM's attribute preferences.

(2) Calculate the original target centre for nonnormalised alternatives' matrix of index values.

(3) Achieve the target centre combined with the DM's attribute preferences.

(4) Deal with the index values of all alternatives by the final target centre.

(5) Calculate the distances of all index values to their target centre index values.

(6) Determine the weights of all attributes.

(7) Integrate all of the normalised target centre distances under all attributes for all alternatives, and rank the alternatives according to their integrated target centre distances in ascending order.

4. Case Study

4.1. Background and Data. To evaluate ten coal mines' comprehensive safety performances, eight indices including seam dip (°), methane emission rate (m^3/t), water inflow (m^3/h), spontaneous combustion period (month), ventilating structures qualification rate (%), equivalent orifice (m^2), mortality *per* million tons (person/10^6 t), and accident economic loss (10^5 Yuan) [17] are denoted by A_1 to A_{10}, and alternatives are denoted by S_1 to S_{10}. The data are shown in Table 1, the benefit-type attributes are A_4 to A_6, and the others are cost-type attributes. The DM's attribute preferences are A_2, A_5, A_6, and A_7 with their values set to 0, 95, 2.0, and 0.2, respectively.

4.2. Decision Making Process

(1) Calculate the target centre determined by alternatives.

The original target centre $C^a = (10, 3.7, 120, 12, 100, 3.6, 0, 300)$ is obtained using (1).

(2) Determine the target centre combined with the DM's preferences.

The final target centre $C^0 = (10, 0, 120, 12, 95, 2.0, 0.2, 300)$ combined with the DM's preferences can be determined using (5).

(3) Deal with the index matrix based on target centre C^0.

Use (10) and the original index matrix can be converted to a new index matrix based on target centre C^0: the results are shown in Table 2.

(4) Calculate all index target centre distances.

Using (11), all index target centre distances can be calculated as listed in Table 3.

(5) Normalise all index target centre distances.

All index target centre distances can be normalised using (12) with the results shown in Table 4.

(6) Integrate the normalised index target centre distances.

Given $\omega = (0.06, 0.15, 0.03, 0.08, 0.12, 0.13, 0.27, 0.14)$, the integrated target centre distances $w = (0.043051, 0.110387, 0.140379, 0.064991, 0.082207, 0.015661, 0.189271, 0.146908, 0.124351, 0.186678)$ can be obtained by (13). So the alternatives, in rank order, were $S_6 \succ S_1 \succ S_4 \succ S_5 \succ S_2 \succ S_9 \succ S_8 \succ S_3 \succ S_{10} \succ S_7$.

Given $\omega = (0.06, 0.15, 0.03, 0.08, 0.12, 0.13, 0.27, 0.14)$ without considering the preferences, then $w = (0.055198, 0.094923, 0.147292, 0.049522, 0.091520, 0.020273, 0.166158, 0.173715, 0.119444, 0.076746)$ can be obtained by (13). So the alternatives in rank order were $S_6 \succ S_4 \succ S_1 \succ S_{10} \succ S_5 \succ S_2 \succ S_9 \succ S_3 \succ S_7 \succ S_8$.

4.3. Discussion. The results, considering the attribute preferences of A_2, A_5, A_6, and A_7 with values 0, 95, 2.0, and 0.2, respectively, and the results without considering attribute preferences are shown in Table 5.

As seen in Table 5, the integrated target centre distances and alternative ranking would change when considering the DM's preferences. With respect to the ranking of the alternatives, most of them changed except for S_3 and S_6. Alternative S_{10} changed its ranking from fourth to ninth when not considering preferences and considering preferences: the magnitude of this change indicated that the DM's attributes influenced the decision making with regard to the available alternatives.

5. Conclusions

This research proposed a grey target decision method with a variable target centre considering DM's desirable preferences and selection preferences. The study indicated that the target centre determined by desirable preferences could reduce the difference between index values for each alternative, which resulted in indicial clustering. However, the target centre, as determined by selection preference, had the potential to act in a "rewarding good and punishing bad" role. When some index values were superior to the target centre index, these indices were rewarded as excellent values; when some index values were inferior to the target centre index, these indices were punished with a larger difference therefrom. A case study illustrated that the generalised grey target decision method could effectively solve the problem for a target centre determined partially by the DM's preferences.

Table 1: Safety data from coal mines.

S_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	21	6	220	12	92	1.8	0.18	381
S_2	16	3.7	200	6	90	1.4	0.712	564
S_3	26	9.2	180	10	88	2.7	1.34	1051.6
S_4	10	4	260	8	94	1.2	0	442.5
S_5	30	8.2	350	10	96	3.6	0.641	788
S_6	19	5	130	12	100	2.4	0	300
S_7	17	9.6	400	6	86	1.3	1.23	964.7
S_8	40	14	600	6	95	2.1	1.12	885.6
S_9	12	12.8	120	10	91	1.5	0.872	839.3
S_{10}	14	5.8	155	12	89	1.7	0.426	617.2

Table 2: Index values processed based on final target centre.

S_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	21	6	220	12	92	1.8	0.2	381
S_2	16	3.7	200	6	90	1.4	0.712	564
S_3	26	9.2	180	10	88	2.0	1.34	1051.6
S_4	10	4	260	8	94	1.2	0.2	442.5
S_5	30	8.2	350	10	95	2.0	0.641	788
S_6	19	5	130	12	95	2.0	0.2	300
S_7	17	9.6	400	6	86	1.3	1.23	964.7
S_8	40	14	600	6	95	2.0	1.12	885.6
S_9	12	12.8	120	10	91	1.5	0.872	839.3
S_{10}	14	5.8	155	12	89	1.7	0.426	617.2

Table 3: All index target centre distances.

r_{ij}	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
r_{1j}	11	6	100	0	3	0.2	0	81
r_{2j}	6	3.7	80	6	5	0.6	0.512	264
r_{3j}	16	9.2	60	2	7	0	1.14	751.6
r_{4j}	0	4	140	4	1	0.8	0	142.5
r_{5j}	20	8.2	230	2	0	0	0.441	488
r_{6j}	9	5	10	0	0	0	0	0
r_{7j}	7	9.6	280	6	9	0.7	1.03	664.7
r_{8j}	30	14	480	6	0	0	0.92	585.6
r_{9j}	2	12.8	0	2	4	0.5	0.672	539.3
r_{10j}	4	5.8	35	0	6	0.3	0.226	317.2

Table 4: Normalised index target centre distances.

Z_{ij}	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
Z_{1j}	0.104762	0.076628	0.070671	0	0.085714	0.064516	0	0.021127
Z_{2j}	0.057143	0.047254	0.056537	0.214286	0.142857	0.193548	0.103623	0.068859
Z_{3j}	0.152381	0.117497	0.042403	0.071429	0.2	0	0.230723	0.196041
Z_{4j}	0	0.051086	0.09894	0.142857	0.028571	0.258065	0	0.037168
Z_{5j}	0.190476	0.104725	0.162544	0.071429	0	0	0.089253	0.127286
Z_{6j}	0.085714	0.063857	0.007076	0	0	0	0	0
Z_{7j}	0.066667	0.122605	0.19788	0.214286	0.257143	0.225806	0.20846	0.173374
Z_{8j}	0.285714	0.178799	0.339233	0.214286	0	0	0.186197	0.152743
Z_{9j}	0.019048	0.163474	0	0.071429	0.114286	0.16129	0.136005	0.140666
Z_{10j}	0.038095	0.074074	0.024735	0	0.171429	0.96774	0.04574	0.082736

Table 5: Alternatives ranked either with, or without, consideration of preferences.

S_i	Z_{ij} (no preferences)	Ranking (no preferences)	Z_{ij} (preferences)	Ranking (preferences)	Ranking changes
S_1	0.055198	3	0.043051	2	−1
S_2	0.094923	6	0.110387	5	−1
S_3	0.147292	8	0.140379	8	0
S_4	0.049522	2	0.064991	3	+1
S_5	0.091520	5	0.082207	4	−1
S_6	0.020273	1	0.015661	1	0
S_7	0.166158	9	0.189271	10	+1
S_8	0.173715	10	0.146908	7	−3
S_9	0.119444	7	0.124351	6	−1
S_{10}	0.076746	4	0.186678	9	+5

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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