RELATIVE RANKING OF SUPPLY CHAINS USING GREY RELATIONAL ANALYSIS

In this application, more than one performance can be evaluated for each supply chain (team). A good supply chain can be identified based on the several performance measures. This application has the feature to rank the supply chains based on several performance measures. Grey Relational Analysis is used for this purpose. The ranking is provided at the end of the game based on the teams involved in a play. This application also allows ranking of supply chains involved in different games. A game contains several teams and at a time a game is only possible. Once a game is over the administrator can set the next game.

Grey Relational Analysis (GRA) is used to solve multi-attribute decision making problems (Fung 2003, Kuo et al. 2008). Initially, the performance of each alternative is translated into a comparability sequence in GRA. According to the comparability sequences, a reference sequence called an ideal target sequence is defined. In the next step, a grey relational coefficient between the reference sequence and the comparability sequence of every alternative is calculated. Finally, a grey relational grade, between the reference sequence and every comparability sequence is calculated based on the grey relational coefficients. The comparability sequence which has the highest grey relational grade between the reference sequence and itself is the best choice and the alternative of that comparability sequence is the best alternative.

GRA from the Supply Chain Role Play Game (SCRPG) software:

In this software for grey relational analysis the alternatives can be selected as a number of games (consist of more number of teams), attributes are Total cost of Supply chain, fill rate of Retailer, bullwhip effect (i.e. variance of orders of factory/variance of orders of customer demand) for the lost sales environment and Total cost of Supply chain, bull whip effect for the case of backorder environment.

Steps for extracting the results from SCRPG:

Open the admin functions page, the following screen shot will appear. (*For ranking the supply chains, the settings in VMI-based SCRPG are same as in SCRPG V4 and hence the screenshot shown below are from SCRPG V4.*)

Fig.1. Screen shot of Admin Functions

Click on the Grey Relation Analysis between saved games link under the admin functions, the following screen shot will appear. Select the lost sales or backorder and proceed.

Fig.2. Screen shot of GRA to choose business environment

It will ask for the grey relational parameters as Zeta value, weight for Bullwhip effect, weight for supply chain cost, weight for fill rate. The Zeta value should be between 0 and 1. The sum of weights for the Bullwhip effect, supply chain cost and fill rate should be 1(give it as a decimal values). The screen shot of grey relational parameters window is given in Figure.3.

Fig.3. Screen shot of grey relation parameters

After submitting the grey relation parameters, select the game from the list to evaluate grey relation. The screen shot of select the game to evaluate Grey Relation is given in Figure.4.

Fig.4. Screen shot of select the game to evaluate Grey Relation

After clicking the submit button it shows the result of Grey Relation Analysis result, consist of rank, grey relation grade, team number and game name. The screen shot result window is given in Figure.5.

Rank	Supply Chain Cost	Bullwhip Effect	Fill Rate	Grey Relation Grade	Team Number	Game Name
1	0.285091	0.327582	0.334000	0.946673	6	posLostSales27-4
2	0.247027	0.326808	0.316536	0.890372	2	posLostSales27-4
3	0.305713	0.333000	0.189922	0.828634	7	posLostSales27-4
4	0.333000	0.331208	0.136423	0.800630	3	posLostSales27-4
5	0.203005	0.329185	0.245838	0.778028	4	posLostSales27-4
6	0.241541	0.328527	0.116139	0.686208	1	posLostSales27-4
7	0.111000	0.111000	0.111333	0.333333	5	posLostSales27-4

Fig.5. Screen shot of GRA results window

Various steps in the GRA method are given below.

Step 1: Grey relational generating

This process converts all performance values of each alternative into a comparability sequence. This process is analogous to normalization. After this process, all performance values are in [0, 1]. If there are u alternatives and v attributes or criteria, then i^{th} alternative can be expressed as $A_i = \{e_{i1}, e_{i2}, e_{i3}, \ldots, e_{iv}\}$. Then, the comparability sequence for i^{th} alternative can be expressed as $C_i = \{f_{i1}, f_{i2}, f_{i3}, \ldots, f_{iv}\}$and this sequence can be obtained using the equation 1 or 2 or 3 based on the attribute type.

Equation 1 is used if the attribute is the smaller the better type, equation 2 is used if the attribute is the larger the better and the equation 3 is used if the attribute is closer to the e_j^* is the better.

$$f_{ij} = \frac{\max(e_{ij}, \forall i) - e_{ij}}{\max(e_{ij}, \forall i) - \min(e_{ij}, \forall i)}, \quad \forall i, \forall j \quad \ldots \quad (1)$$

$$f_{ij} = \frac{e_{ij} - \min(e_{ij}, \forall i)}{\max(e_{ij}, \forall i) - \min(e_{ij}, \forall i)}, \quad \forall i, \forall j \quad \ldots \quad (2)$$

$$f_{ij} = 1 - \frac{\left|e_{ij} - e_j^*\right|}{\max\left\{\max(e_{ij}, \forall i) - e_j^*, e_j^* - \min(e_{ij}, \forall i)\right\}}, \quad \forall i, \forall j \quad \ldots \quad (3)$$

where,

e_{ij} Value of j^{th} attribute of i^{th} alternative

f_{ij} Grey relational generating value for j^{th} attribute of i^{th} alternative

e_j^* Preferred value for attribute j

Alternatives (i) considered as game number, attributes (j) are supply chain cost (SC Cost), fill rate, bullwhip effect (BWE).

Table 1: Input performance measures (e_{ij}):

Game no. (Alternatives)	Performance measures (Attributes)		
	SC Cost	BWE	Fill rate
1	13586	27.30136	0.813
2	12960	12.29064	0.945
3	5844	5.2238	0.844
4	18937	8.44888	0.923
5	46737	1046.88	0.804
6	9280	11.03472	0.949
7	7669	2.39688	0.894

Since SC Cost, BWE smaller is the better, so that Equation (1) can be used for comparability sequence, and fill rate maximum is the better, Equation (2) can be used.

For example in the Table 1 for the SC Cost the maximum value is 46737, minimum value is 5844 and comparability sequence can be calculated for the first alternative f_{11} is (46737 – 13586)/(46737 – 5844) = 0.810677. For the fill rate maximum value is 0.949, minimum value 0.804 and comparability sequence can be calculated for the first alternative f_{13} is (0.813– 0.804)/ (0.949-0.804) = 0.062069. All the values for Table 1 are given in the Table 2 below.

Step 2: Define the reference sequence

After the grey relational generating procedure, all the performance values of each alternative i.e., f_{ij} will be between 0 and 1. If f_{ij} is equal to 1 or closer to 1 than any other alternative, then the alternative i is the best choice for the attribute j. The alternative which has all of its f_{ij} values equal to 1, or closer to 1 is the best choice. So, the reference sequence, $C_{0,}$ can be set as $\{ f_{01}, f_{02}, f_{03}, \dots , f_{0v}\} = \{1,1,1,\dots, 1\}$.

Reference sequence is also given in Table 2.

Table 2: Grey relational generating values (Comparability Sequence (f_{ij})):

Alternatives Game no.	Performance measures (attributes)		
	SC Cost	BWE	Fill rate
1	0.810676644	0.976156168	0.062068966
2	0.825984887	0.990527602	0.972413793
3	1	0.997293475	0.275862069
4	0.679822953	0.994205746	0.820689655
5	0	0	0
6	0.915975839	0.991730034	1
7	0.955371335	1	0.620689655
Reference sequence (C_0)	1.00000	1.00000	1.00000

Step 3: Calculating the grey relational coefficient

The grey relational coefficient measures the closeness of f_{ij} of comparability sequence, C_i, with f_{0j} of reference sequence C_0. If the grey relational coefficient is larger, then f_{ij} and f_{0j} are closer to each other. The grey relational coefficient is calculated using equation 4.

$$\gamma(f_{oj}, f_{ij}) = \frac{\Delta_{\min} + \zeta\,\Delta_{\max}}{\Delta_{ij} + \zeta\,\Delta_{\max}}, \qquad \forall i, \forall j \qquad \ldots \qquad (4)$$

where,

$\gamma(f_{oj}, f_{ij})$ is the grey relational coefficient between f_{oj} and f_{ij}

$\Delta_{ij} = | f_{0j} - f_{ij} |$

$\Delta_{\min} = \min(\Delta_{ij}$, for all $i)$, for all j

$\Delta_{\max} = \max(\Delta_{ij}$, for all $i)$, for all j

ζ is a distinguishing coefficient and its value varies from 0 to 1. The purpose of this coefficient is to expand or compress the range of grey relational coefficient. As per Kuo et al. (2008) study, the rank for an alternative does not change with the value of this distinguishing coefficient. In the present research, its value is taken as 0.5.

The grey relational coefficient between reference sequence and comparability sequence is calculated using equation 4. The value of Δ_{ij}, $\Delta_{\min}$ and $\Delta_{\max}$ for each alternative is calculated and are given in Table 3. These values are required to calculate relational coefficient between reference sequence and comparability sequence. The results of grey relational coefficient $\gamma(f_{oj}, f_{ij})$ are given in Table 4.

Table 3: The value of Δ_{ij}, Δ_{min} and Δ_{max} for each alternative

	Performance measures (attributes)		
Game no. (Alternatives)	SC Cost	BWE	Fill rate
	Δ_{ij}	Δ_{ij}	Δ_{ij}
1	0.189323356	0.023843832	0.937931034
2	0.174015113	0.009472398	0.027586207
3	0	0.002706525	0.724137931
4	0.320177047	0.005794254	0.179310345
5	1	1	1
6	0.084024161	0.008269966	0
7	0.044628665	0	0.379310345
Reference sequence (R_0)	1.00000	1.00000	1.00000
Δ_{min}	0	0	0
Δ_{max}	1	1	1

In the above table Δ_{11} is calculated as $| f_{01} - f_{ij} |$, i.e. | 1 - 0.810676644 | = 0.189323356, Δ_{min} for first attribute is minimum of (Δ_{11} to Δ_{71}), i.e. 0 and Δ_{max} for first attribute is maximum of (Δ_{11} to Δ_{71}), i.e. 1 and it is calculated for all attributes.

Table 4: Results of grey relational coefficient:

Game no. (Alternatives)	Performance measures (Attributes)		
	SC Cost	BWE	Fill rate
1	0.72534899	0.954482938	0.347721823
2	0.741823129	0.981407436	0.947712418
3	1	0.994616093	0.408450704
4	0.609624473	0.988544248	0.736040609
5	0.333333333	0.333333333	0.333333333
6	0.856128965	0.983729186	1
7	0.918056709	1	0.568627451

For example in Table 4 the grey relation coefficient of SC cost for alternative 1 is calculated as $\gamma(f_{o1}, f_{11})$ = (0+(0.5)(1))/(0.189323356++(0.5)(1))= 0.72534899.

Step 4: Calculation of grey relational grade

The grey relational grade represents the degree of similarity (Fung 2003) or level of correlation (Kuo et al. 2008) between the reference and the comparability sequence. The alternative whose comparability sequence gets the highest grade is the best choice. Grey relational grade between C_0 and C_i, $\Psi_{(C_o,C_i)}$ is calculated using equation 5.

$$\Psi_{(C_o,C_i)} = \sum_{j=1}^{v} w_j \gamma(f_{0j}, f_{ij}), \qquad \forall i \qquad \ldots \qquad (5)$$

where,

w_j is the weight of attribute j and its value is based on the decision maker judgment. In the present study equal weight is given to all attributes.

The grey relational grade between reference sequence and the comparability sequence is calculated using equation 5, and are given in Table 5. In the present study, it is assumed that all the performance measures are equally important. So, weight for each attribute is the same and it is equal to 0.3333 (1/3). Ranks are assigned to each alternative which is having high grey relational grade value and is also given in Table 5.

Table 5: Results of grey relational grade:

Game no. (Alternatives)	Performance measures (Attributes)			Grey relational grade	Rank
	SC Cost	BWE	Fill rate		
1	0.241541214	0.317842818	0.116139089	0.675523121	6
2	0.247027102	0.326808676	0.316535948	0.890371726	2
3	0.333	0.331207159	0.136422535	0.800629694	4
4	0.203004949	0.329185235	0.245837563	0.778027747	5
5	0.111	0.111	0.111333333	0.333333333	7
6	0.285090945	0.327581819	0.334	0.946672764	1
7	0.305712884	0.333	0.189921569	0.828634453	3

For example in Table 5 SC cost for alternative 1 is calculated as (0.333)*(0.72534899) = 0.241541214, BWE for alternative 1 is calculated as (0.333)*(0.954482938) = 0.317842818 and Fill rate for alternative 1 is calculated as (0.334)*(0.347721823) = 0.116139089. The grey relation grade is sum of SC cost, BWE and Fill rate, i.e. (0.241541214) + (0.317842818) + (0.116139089) = 0.675523121. It is calculated for all the alternatives and having the higher value of grey relation grade is given as rank 1. In the Table 5 the value of grey relation grade for team 6 is high, rank is given as 1. The same result is shown in Figure 5, which is the screen shot from the software.

References

Fung, C. P. (2003). Manufacturing process optimization for wear property of fiber-reinforced polybutylene terephthalate composites with grey relational analysis. *Wear*, 254, 298–306.

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