# Use of Grey Relational Analysis in Solving Multiple Attribute Decision-Making Problem: A Case Study of Warehouse Location Selection

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**Abstract:** Optimum location of distribution warehouse is an important partial task of optimization of logistics system. The efficient and effective movement of goods from raw material site to processing facilities, component fabrication plants, finished good assembly plants, distribution centers and warehouse, retailers and customers is critical in today's turbulent business environment. The selection of the warehouse location is one of the most important, strategic and long-term decision in the optimization of logistic systems. Warehouse location is influenced by many quantitative and qualitative factors. The main factors taken into account in this paper are unit price, stock holding capacity, average distance to main suppliers, movement flexibility. This paper addresses the problem of selecting the most appropriate warehouse location for a manufacturing organization. Here three multiple criteria decision making techniques VIKOR, TOPSIS, Gray Theory (GRA) are used to facilitate decision making in the selection of a warehouse. The model proposed in this paper determines the most appropriate warehouse location alternative through maximization of objectives. A case study of manufacturing company is presented to illustrate these three multiple criteria decision making techniques for the selection of warehouse facility.

**Keywords:** Multi criteria decision making; warehouse location selection; VIKOR, TOPSIS, GRA

## 1 INTRODUCTION

Warehouses are a key aspect of modern supply chains and play a vital role in the success, or failure of businesses today [1]. Warehouses are utilized by manufacturers, importers, exporters, retailers, transport businesses, etc. The location theory was first introduced by Weber (1989) who considered [2].

The problem of locating a single warehouse in order to minimize the total travel distance between the warehouse and a set of spatially distributed customers. The selection of a warehouse location among alternative locations is a multi-criteria decision making problem including both quantitative and qualitative criteria. Such decisions are of great importance to companies because they are costly and difficult to reverse, and entail a long term commitment. They also have an impact on operating costs and revenues. For instance, a poor choice of location might result in excessive transportation costs, a shortage of qualified labour, loss of competitive advantage or some similar condition that would be detrimental to operations.

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The general procedure for making location decision usually consists of the following steps:

- Decide on the criteria that will be used to evaluate location of alternatives
- Identify the criteria that are important
- Develop location alternative
- Evaluate the alternatives and make the selection

Multi-criteria decision making techniques can be defined as the evaluation of the alternatives for the purpose of selection or ranking, using a number of quantitative or qualitative criteria that have different measurement units.

## 2 PROBLEM DESCRIPTION

An efficient strategic investment decision is required for the selection of a warehouse location for maximum business profitability. In a business model, one of the important decision making process of the logistic administrators is decision for the location of the distribution centre. After a lot of research a business model with four different alternative warehouses are specified. For the warehouse location, the evaluation criteria based on cost, capacity and customer related to the prospect of sector and business is covered.

*(a) Unit price (UP):* it is one of the most important factors in determining the storage of goods in warehouse. If the unit price is less the probability of choosing that location over others increases.

*(b) Stock holding capacity (SHC):* this should not be very high which will cause wastage or extra space nor should it be very small. The capacity should be somewhat in the middle level to satisfy these criteria for the decision maker.

*(c) Average distance to shops (ADS):* If the presentation period of goods is reduced, it provides an important advantage in competition for the retail sector businesses. The main aim of a decision maker should always be to choose such a location which will provide the company a good access to the shops is less it will be in the advantage of the company.

*(d) Average distance to main suppliers (ADMS):* Minimization in these criteria provides to produce less presentation time and logistics transportation cost.

*(e) Movement flexibility (MF):* The movement flexibility is decided by the evaluation of architectural and layout factors of the warehouse location which tells about the total storage space in the ware house and other conformity factors. Thus alternative warehouse locations are evaluated based on 0-4 scale (really bad, bad, average, good and really good).

So the beneficial attributes (higher is better) is movement flexibility and the non-beneficial attributes are unit price, average distance to shops and average distance to main suppliers, stockholding capacity must be somewhat to desired capacity Table 2 shows all the attributes pertaining to different criteria. The importance weights of criteria in the decision problem are calculated by AHP method, {WUP, WSHC, WADS, WADM, WMF} = (0.309701, 0.123977, 0.123977, 0.309701, and 0.132645).

Table 1. Weighting matrix of attributes for ware house selection

| Alternatives | Unit Price (UP) ($/m2) | Stock holding capacity (SHC) | Average distance to shops (ADS) | Average distance to main suppliers (ADMS) | Movement flexibility (MF) |
|---|---|---|---|---|---|
| UP | 1 | 3 | 3 | 1 | 2 |
| SHC | 1/3 | 1 | 1 | 1/3 | 2/3 |
| ADS | 1/3 | 1 | 1 | 1/3 | 2/3 |
| ADM | 1 | 3 | 3 | 1 | 2 |
| MF | 1/2 | 3/2 | 3/2 | ½ | 1 |

Table 2. Objective data of attributes for warehouse selection

| Alternatives | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 17 | 10 | 12 | 14 | 3 |
| B | 40 | 12 | 8 | 10 | 1 |
| C | 18 | 15 | 15 | 12 | 2 |
| D | 16 | 18 | 16 | 13 | 4 |

## 3 EVOLUTION OF VIKOR TECHNIQUE TO SOLVE THE PROBLEM

Multi criteria decision making (MCDM) is one of the most prevalent methods for resolving conflict management issues (Deng & Chan, 2011). MCDM deals with decision and planning problems by consideration of multiple criteria and the importance of each (Haleh & Hamidi, 2011). Among the many MCDM methods, VIKOR is a compromise ranking method to optimize the multi-response process (Opricovic, 1998). It uses a multi criteria ranking index derived by comparing the closeness of each criterion to the ideal alternative. The core concept of VIKOR is the focus on ranking and selecting from a set of alternatives in the presence of conflicting criteria (Opricovic, 2011). In VIKOR, ranking index is derived by considering both the maximum group utility and minimum individual regret of the opponent (Liou, Tsai, Lin, & Tzeng, 2011).

VIKOR denotes the various n alternatives as $a_1, a_2, \ldots\ldots, a_n$. for an alternative $a_i$ , the merit of the $j^{th}$ aspect is represented by $f_{ij}$ that is $f_{ij}$ is the value of the $j^{th}$ criterion function for the alternative $a_i$ , n being the number of criteria. The VIKOR procedure is divided into the following six steps:

1. Firstly Objective values of warehouse selection given in Table 2 are normalized to accommodate with the different units and this method follows linear normalization. UP, ADS, ADMS, are non-beneficial and lower values are desirable. SHC and MF are beneficial and higher values are desirable. It is normalized as shown in Table 3. As 16/17=0.9412 for $f_{11}$, and 3/4=0.75 for $f_{15}$.

Table 3. Normalized value of data

| Alternative | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 0.9412 | 0.5555 | 0.6667 | 0.7142 | 0.75 |
| B | 0.4000 | 0.6667 | 1 | 1 | 0.25 |
| C | 0.8889 | 0.8333 | 0.5333 | 0.8333 | 0.5 |
| D | 1 | 1 | 0.5 | 0.7692 | 1 |

Table 4. Best $f_j^*$ and worst $f_j^-$ values

| | UP | SHC | ADM | ADMS | MF |
|---|---|---|---|---|---|
| $f_j^*$ | 1 | 1 | 1 | 1 | 1 |
| $f_j^-$ | 0.4 | 0.5555 | 0.5 | 0.7142 | 0.25 |

Table 5. Value of $\left[\frac{w_i(f_j^*-f_{ij})}{f_j^*-f_j^-}\right]$

| Alternative | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 0.0304 | 0.1240 | 0.0826 | 0.3097 | 0.0442 |
| B | 0.3097 | 0.0930 | 0 | 0 | 0.1326 |
| C | 0.0573 | 0.0465 | 0.1157 | 0.1806 | 0.0884 |
| D | 0 | 0 | 0.1240 | 0.2501 | 0 |

Table 6. Value of $S_i$, $R_i$ and $Q_i$

| Alternative | $S_i$ | $R_i$ | $Q_i$ | Rank |
|---|---|---|---|---|
| A | 0.5909 | 0.3097 | 1 | 4 |
| B | 0.5353 | 0.3097 | 0.8718 | 3 |
| C | 0.4885 | 0.1806 | 0.2638 | 1 |
| D | 0.3741 | 0.2301 | 0.2691 | 2 |

2. Determine the best $f_j^*$ and worst $f_j^-$ all criterion functions. If the $j^{th}$ criterion function represents a merit, then

$$f_j^* = max_i f_{ij} \text{ , } f_j^- = min_i f_{ij} \quad (1)$$

As shown in Table 4 above.

3. Calculate the values of $S_i$ and $R_i$, i=1,2,3,....m, by the following relations:

$$S_i = \sum_{j=1}^{n} \frac{w_i(f_j^*-f_{ij})}{f_j^*-f_j^-} \text{ , } R_i = \max\left[\frac{w_i(f_j^*-f_{ij})}{f_j^*-f_j^-}\right] \quad (2)$$

Where $w_i$ is the weight of the $j^{th}$ criterion which expresses the relative importance of the criteria? The above values can be obtained by the following Table 5.

4. Compute the value of $Q_i$, i = 1, 2, 3... m. By the relation

$$Q_i = v\left[\frac{S_i-S^*}{S^- -S^*}\right] + (1-v)\left[\frac{R_i-R^*}{R^- -R^*}\right] \quad (3)$$

Where $S^* = min_i S_i$ , $S^- = max_i S_i$ , $R^*$=$min_i R_i$, $R^-$= $max_i R_i$ and v is the weight of the strategy of maximum group utility , whereas (1-v) is the weight of the individual regret. Taking value of v as 0.5 $Q_i$ can be calculated. Value of $S_i$, $R_i$ and $Q_i$ are given in the following Table 6.

5. Rank the alternatives, sorting by the values in decreasing order.

Hence in this manner we found that alternative C is best alternative according to VIKOR method.

## 4 EVALUATION OF PROBLEM USING TOPSIS METHOD

TOPSIS is a multi-criteria decision making methodology which determines solution alternatives from a finite set in the basis of maximizing the distance from the negative ideal point and minimizing the distance from the positive ideal point. It's practice in this case study is as follows:

1. Firstly the raw values ($X_{ij}$) are normalized ($r_{ij}$) using vector normalization that is using the following formula

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \text{ i = 1,2,3,....m} \quad (4)$$

And j =1,2,3,…n. as shown in Table 7.

Here for $r_{11} = \frac{17}{\sqrt{(17^2+40^2+18^2+16^2)}} = 0.3421$

2. Now Calculate the weighted normalized decision matrix. The weighted normalized value $v_{ij}$ is calculated as follows:

$$v_{ij} = w_{ij} \times r_{ij} \quad (5)$$

where i =1, 2,..., m and j = 1, 2, ..., n. As shown in Table 8.

Here $v_{11} = w_{UP} \times r_{11}$= 0.309701× 0.3421=0.1059

3. For every criterion ideal alternative with best performance ($S^+$) and worst performance ($S^-$) is determined if j is the benefit criteria;

$$S^+ = \{v_{1j}, v_{2j}, \dots, v_{mj}\} = \{\max v_{1j} \; for \; \forall \; j \in n\} \quad (6)$$

If j is the cost criteria;

$$S^- = \{v_{1j}, v_{2j}, \dots, v_{mj}\} = \{\min v_{1j} \; for \; \forall \; j \in n\} \quad (7)$$

For a benefit criteria $S^-$ values are determined selecting the minimum value and for a cost criteria by selecting the maximum values.

In this problem the values that shows best performed ideal alternative and worst performed values for every criteria are;

$S^+$ = (0.0997;0.0792;0.0377;0.1254;0.0968)

$S^-$ = (0.2493;0.0440;0.0755;0.1756;0.0242)

Table 7. Normalized decision matrix

| Alternative | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 0.3421 | 0.3551 | 0.4571 | 0.5673 | 0.5477 |
| B | 0.8050 | 0.4261 | 0.3047 | 0.4052 | 0.1825 |
| C | 0.3622 | 0.5326 | 0.5714 | 0.4862 | 0.3651 |
| D | 0.3220 | 0.6391 | 0.6095 | 0.5267 | 0.7302 |

Table 8. Weighted normalized decision matrix

| Alternative | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 0.1059 | 0.0440 | 0.0566 | 0.1756 | 0.0726 |
| B | 0.2493 | 0.0528 | 0.0377 | 0.1254 | 0.0242 |
| C | 0.1121 | 0.0660 | 0.0708 | 0.1505 | 0.0484 |
| D | 0.0997 | 0.0792 | 0.0755 | 0.1631 | 0.0968 |

Table 9. Value of $D_i^+$ and $D_i^-$

| Alternative | A | B | C | D |
|---|---|---|---|---|
| $D_I^+$ | 0.0688 | 0.1683 | 0.0663 | 0.0533 |
| $D_I^-$ | 0.1525 | 0.0634 | 0.1433 | 0.1704 |

Table 10. Relative closeness to the ideal solution

| Alternative | Relative closeness | Value | Rank |
|---|---|---|---|
| A | $C_1$ | 0.6891 | 3 |
| B | $C_2$ | 0.2736 | 4 |
| C | $C_3$ | 1.8610 | 1 |
| D | $C_4$ | 1.4564 | 2 |

4. Every alternative's distance to the best alternative ($D_i^+$) and worst alternative ($D_i^-$) for all criteria is calculated.

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - S_j^+\right)^2} \quad (8)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - S_j^-\right)^2} \quad (9)$$

For i = 1,2,...,m.

Using above to formulas for the warehouse location alternatives, the distance values to the positive and negative solutions can be found which are given in Table 9. As for alternative A

$$D_i^+ = [(0.1059 - 0.0997)^2 + (0.0440 - 0.0792)^2 + (0.0566 - 0.0377)^2 + (0.1756 - 0.1254)^2 + (0.0726 - 0.0968)^2]^{1/2}$$

$$D_i^- = [(0.1059 - 0.0440)^2 + (0.0440 - 0.0440)^2 + (0.0566 - 0.0755)^2 + (0.1756 - 0.1756)^2 + (0.0726 - 0.0242)^2]^{1/2}$$

5. For every alternative by dividing distance to the negative solution by the sum of distance to the positive and negative solution Ci is determined. Ci exhibit the similarity to the positive ideal solution. According to the magnitude of Ci alternatives are arranged. The bigger Ci value is selected.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \text{ for i = 1,2,...,m. And } 0 \le C_i \le 1. \quad (10)$$

Different values of Ci and the rank of alternatives is given in Table 10.

Hence according to the TOPSIS methodology we got alternative C as the best alternative.

## 5 EVALUATION OF PROBLEM USING GREY RELATIONAL ANALYSIS (GRA)

The main procedure of GRA is firstly translating the performance of all alternatives into a comparability sequence. This step is called grey relational generating. According to these sequences, a reference sequence (ideal target sequence) is defined. Then, the grey relational coefficient between all comparability sequences and the reference sequence is calculated. Finally, based on these grey relational coefficients, the grey relational grade between the reference sequence and every comparability sequences is calculated. If a comparability sequence translated from an alternative has the highest grey relational grade between the reference sequence and itself, that alternative will be the best choice.

The details of the proposed GRA procedure is presented below.

*1. Grey relational generating:* The main purpose of grey relational generating is transferring the original data into comparability sequences. Unit price (UP), average distance to shops (ADS) and average distance to main suppliers (ADM) are all smaller-the-better attributes. Stock holding capacity (SHC) is a close-to-the-desired value the better attribute (The desire value being 1). Movement flexibility (MF) is a higher-the -better attribute. The grey relational generating process adopts Equation (12) for data of performance values of unit price, average distance to shops, average distance to main suppliers, Equation (11) for data of performance values of movement flexibility, Equation (13) for data of performance values of stock holding capacity

Table 11. Results of grey relational generating

| Alternative | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| A | 0.9583 | 0.6667 | 0.5000 | 0.0000 | 0.6667 |
| B | 0.9167 | 1.0000 | 1.0000 | 1.0000 | 0.0000 |
| C | 0.0000 | 0.5000 | 0.1250 | 0.5000 | 0.3333 |
| D | 1.0000 | 0.0000 | 0.0000 | 0.2500 | 1.0000 |

Table 12. Results of grey relational coefficient

| | UP | SHC | ADS | ADMS | MF |
|---|---|---|---|---|---|
| $X_0$ | 1 | 1 | 1 | 1 | 1 |
| A | 0.9230 | 0.6000 | 0.5000 | 0.3333 | 0.6000 |
| B | 0.3333 | 1.0000 | 1.0000 | 1.0000 | 0.3333 |
| C | 0.8571 | 0.5000 | 0.3636 | 0.5000 | 0.4286 |
| D | 1.0000 | 0.3333 | 0.3333 | 0.4000 | 1.0000 |

Table 13. Results of GRA, TOPSIS and VIKOR

| Alternative | Grey relational grade | Results of GRA | Results of TOPSIS | Results of VIKOR |
|---|---|---|---|---|
| A | 0.6050 | 3 | 3 | 4 |
| B | 0.7050 | 1 | 4 | 3 |
| C | 0.5842 | 4 | 1 | 1 |
| D | 0.6489 | 2 | 2 | 2 |

where $y_j^*$ is equal to 12 (depending upon our decision). For example, in the case of unit price attribute, the maximum value is 40 for alternative B and minimum value is 16 from alternative D (from Table 2). Using Equation (12) the results of grey relational generating of alternative A is equal to (40-17)/(40-16)=0.9583. The entire results of grey relational generating are shown in Table 11.

For a MADM problem, if there are m alternatives and n attributes, the ith alternative can be expressed as

$Y_i = (Y_{i1}, Y_{i2}, .. Y_{ij}, ,..., Y_{iN}, ),$ where $Y_{ij}$, is the performance value of attribute j of alternative i. The term $Y_i$, can be translated into the comparability sequence

$X_i, = (X_{i1}, X_{i2}, ..., X_{ij}, ,..., X_{in})$ by use of one of Equations.

$$x_{ij} = \frac{y_{ij} - \min[y_{ij}, i=1,2....m]}{\max[y_{ij}, i=1,2,3...m] - \min[y_{ij}, i=1,2...m]} \quad \text{for } i = 1,2....m \text{ and } j = 1,2....n \qquad (11)$$

$$x_{ij} = \frac{\max[y_{ij}, i=1,2....m] - y_{ij}}{\max[y_{ij}, i=1,2,3...m] - \min[y_{ij}, i=1,2...m]} \quad \text{for } i = 1,2....m \text{ and } j = 1,2....n \qquad (12)$$

$$x_{ij} = \frac{|y_{ij} - y_j^*|}{\max[\max(y_{ij}\ i=1,2....,m) - y_{ij}^*, y_{ij}^* - \min(y_{ij}, i=1,2....m)]}$$

For i=1, 2, ..., m and j=1, 2,…, n (13)

Equation (11) is used for the-larger-the-better attributes, Equation (12) is used for the-smaller-the-better attributes and Equation (13) is used for the-closer-to-the-desired-value-$y_j^*$-the better.

*2. Reference sequence definition:* After the grey relational generating procedure using Equation (11), (12) or Equation (13), all performance values will be scaled into [0, 1]. For an attribute j of alternative i, if the value $x_{ij}$ which has been processed by grey relational generating procedure, is equal to 1, or nearer to 1 than the value for any other alternative, that means the performance of alternative i is the best one for the attribute j. Therefore an alternative will be the best choice if all of its performance values are closest to or equal to 1. However, this kind of alternative does not usually exist. This paper then defines the reference sequence as ($X_{01}$, $X_{02}$, ..., $X_{0j}$, ..., $X_{0n}$) = (1,1,...,1,...,1), and then aims to find the alternative whose comparability sequence is the closest to the reference sequence

*3. Grey relational coefficient calculation:* Grey relational coefficient is used for determining how close $x_{ij}$ is to $x_{0j}$. The larger the grey relational coefficient, the closer $x_{ij}$ and $x_{0j}$ are. The grey relational coefficient can be calculated by Equation (14).

$$\Upsilon(x_{0j}, x_{ij}) = \frac{\nabla_{min}+\mu\nabla_{max}}{\nabla_{ij}+\mu\nabla_{max}} \text{ for i = 1,2,….,m and j = 1,2,….,n} \quad (14)$$

in Equation (14), $(x_{0j}, x_{ij})$ is the grey relational coefficient between $x_{ij}$ and $x_{0j}$, and

$\nabla_{ij} = |x_{0j} - x_{ij}|$,

$\nabla_{min} = \min(\nabla_{ij}, i = 1,2,\dots,m; j = 1,2,\dots,n)$,

$\nabla_{max} = \max(\nabla_{ij}, i = 1,2,\dots,m; j = 1,2,\dots,n)$,

$\mu$ is the distinguishing coefficient, $\mu \in [0,1]$

The purpose of the distinguishing coefficient is to expand or compress the range of the grey relational coefficient. For example, take the case where there are three alternatives, ''a'', ''b'' and ''c''. If $\nabla_{aj}$= 0.1, $\nabla_{bj}$ =0.4 And $\nabla_{cj}$ = 0.9, its means that for attribute j, alternative ''a'' is the closest to the reference sequence. After grey relational generating using Equations (11) to (13), ∇max will be equal to 1 and ∇min will be equal to 0. Fig. 1 shows the grey relational coefficient results when different distinguishing coefficients are adopted In Fig. 1, the differences between $\Upsilon(X_{0j}, X_{aj})$, $\Upsilon(X_{0j}, X_{bj})$ and $\Upsilon(X_{0j}, X_{cj})$ always change when different distinguishing coefficients are adopted, but no matter what the distinguishing coefficient is, the rank order of $\Upsilon(X_{0j}, X_{aj})$, $\Upsilon(X_{0j}, X_{bj})$ and $\Upsilon(X_{0j}, X_{cj})$ is always the same. The distinguishing coefficient can be adjusted by the decision maker exercising judgment, and different distinguishing coefficients usually produce different results of GRA. In this paper, the distinguishing coefficient was set as 0.5 initially, while some other different distinguishing coefficients were then tested for analysis.

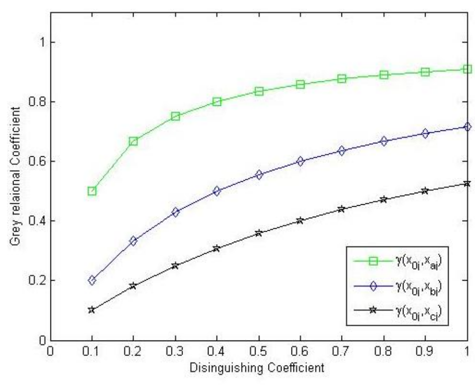


Fig. 1. The relationship between distinguishing coefficient and grey relational coefficient

In the Table 12, $X_0$ is the reference sequence. After calculating $\nabla_{ij}$, $\nabla_{max}$ and $\nabla_{min}$ all grey relational coefficient can be calculated by Equation (14). For example $\nabla_{11} = |1 - 0.9583| = 0.0417, \nabla_{max} = 1, \nabla_{min} = 0, if\ \mu = 0.5, then\ \gamma(X_{01}, X_{11}) = \frac{(0+0.5\times1)}{0.0417+0.5\times1} = 0.9230.$ the entire results for the grey relational coefficient are shown in Table 12.

*Grey relational grade calculation:* After calculating the entire grey relational coefficient $\Upsilon(X_{0j}, X_{ij})$, the grey relational grade can be then calculated using Equation (15).

$$\beta(x_0, x_i) = \sum_{j=1}^{n} w_j \Upsilon(x_{0j}, x_{ij}) \text{ for i = 1,2,…,m and j =1,2,…,n} \quad (15)$$

In Equation (5), $\beta(X_0, X_i)$ is the grey relational grade between $X_0$ and $X_i$. It represents the level of correlation between the reference sequence and the comparability sequence. $w_j$ is the weight of attribute j and usually depends on decision makers' judgment or the structure of the proposed problem. In addition, $\sum_{j=1}^{n} w_j = 1$. The grey relational grade indicates the degree of similarity between the comparability sequence and the reference sequence (Fung, 2003). As mentioned above, on each attribute, the reference sequence represents the best performance that could be achieved by any among the comparability sequences. Therefore, if a comparability sequence for an alternative gets the highest grey relational grade with the reference sequence, it means that the comparability sequence is most similar to the reference sequence, and that alternative would be the best choice.

In this case weights to all performance attributes are given as {Wup, Wshc, Wads, Wadm, Wmf}={0.309701, 0.123977, 0.123977, 0.309701, 0.132645} by using Equation(15) grey relational grade can be calculated and is shown in Table 13.

For example grey relational grade alternative A will be calculated as

$$[(0.309701 \times 0.9230) + (0.123977 \times 0.6000) + (0.123977 \times 0.5000) + (0.309701 \times 0.3333) + (0.132645 \times 0.60000)] = 0.6050$$

## 6 RESULTS AND DISCUSSION

In this paper, the author evaluated the problem by using VIKOR, TOPSIS, and GRA methodologies. When using VIKOR and TOPSIS, criteria have been evaluated parallel to two basic purposes of maximization and minimization; that has been ignored that the criteria like stock holding capacity had to define an optimum value too. At this point, Grey theory was applied to the problem of selecting warehouse location for the purpose of correcting the deficiency of VIKOR and TOPSIS methods. Results obtained are presented in Table 13, the values in the table express the preference ranking of warehouse alternatives depending on the determined method.

While VIKOR and TOPSIS are giving the same results whereas GRA is giving the different, this is due to the difference in the algorithm of methodologies. Here in GRA if we choose the different optimum values stock holding capacity criteria we may get the different results.

## 7 CONCLUSIONS

A warehouse location selection is a multi-criteria decision-making problem including both quantitative and qualitative. In step 1, the main criteria and sub-criteria for the selection of warehouse location were identified. After the main criteria and sub-criteria were determined, the hierarchy of the warehouse location selection was structured. The characteristics of objective and objective criteria are considered in the proposed model. Finally, a step by step example is illustrated to study the computational process of the MCDM model. Computationally the MCDM method is very simple and easily comprehensible which can handle large number of selection criteria. Application of this method in a wider range of selection problem in a supply chain is a direction of future research work.

## References

[1] E. Frazelle, 2002. Supply Chain Strategy: The Logistics of Supply Chain Management, McGraw-Hill, New York.

[2] W. J. Stevenson, 1993. Production/operations management, 4th ed, Richard D. Irwin Inc., Homewood.

[3] A. Chauhan and R. Vaish, 2012. Hard coating material selection using multi-criteria decision making, Materials and design, 44, pp. 240–245.

[4] T. Ozcan, N Celebi, and S. Esnaf, 2011. Comparative analysis of multi-criteria decision making methodologies and implementation of a ware house location selection problem, Expert system with application, vol. 38, pp. 9773-9779.

[5] T. Demirel, N. C. Demirel, and C. Kahraman, 2010. Multi-criteria warehouse location selection using choquet integral, Expert system with application, vol. 37, pp. 3943-3952.

[6] M. Ilangkumaran and S. Kumanan, 2012. Application of Hybrid VIKOR Model in Selection of Maintenance Strategy, Int J Inform Sys Supply Chain Manage, vol. 5, no. 2.

[7] Z. Drezner, C. Scott, and J. S. Song, 2003. The central warehouse location problem Revisited, IMA Journal of Management Mathematics, vol. 14, no. 4, pp. 321-336.

[8] C. Kahraman, U. Cebeci, and D. Ruan, 2004. Multi-attribute comparison of catering service companies using FAHP: The case of Turkey, International Journal of Production Economics, vol. 87, no. 2, pp. 171-184.

[9] T. V. Van and D. Grewal, 2005. Selecting the Location of Distribution Centre in Logistics Operations: A Conceptual Framework and Case Study, Asia Pacific Journal of Marketing and Logistics, vol. 17, pp. 3-24.

[10] Y. Y. Kuo, T. H. Yang, and G. W. Hung, 2008. The use of grey relational analysis in solving multiple attribute decision-making problems, Computers and industrial engineering, vol. 55, pp. 80-93.

[11] S. Bansal, M. Chhimwal, and A. Jayant, 2015. A Comprehensive VIKOR and TOPSIS Method For Supplier Selection In Supply Chain Management: A Case Study, Journal of Material Science and Mechanical Engineering (JMSME), vol. 2, no. 12, pp. 1-7.

[12] A. Jayant and P. Singh, 2015. Application of AHP-VIKOR Hybrid MCDM Approach for 3pl Selection: A Case Study, International Journal of Computer Applications (IJCA), vol. 125, no. 5, pp. 4-11.

[13] A. Jayant 2015. Evaluation of EOL/Used cell phones management & disposal alternatives: An ANP and balanced score

card approach, International Journal of Waste Resources (IJWR), vol. 5, no. 2.

[14] S. Bansal, M. Chhimwal, and A. Jayant, 2015. A Comprehensive VIKOR and TOPSIS Method For Supplier Selection In Supply Chain Management: A Case Study, Journal of Material Science and Mechanical Engineering (JMSME), vol. 2, no. 12, pp. 1-7.

[15] R. Bharti, V.Giri, and A. Jayant, 2015. Green Supply Chain Management Strategy Selection by Analytical Network Process (ANP) Approach: A Case Study, Journal of Material Science and Mechanical Engineering (JMSME), vol. 2, no. 12, pp. 8-13.