Loss Severity Evaluation Using Grey Relational Analysis: A Case Study of Natural Disasters in Taiwan

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Abstract: Taiwan is affected by three primary types of natural disasters: typhoons, earthquakes, and floods. Natural disasters in Taiwan can cause human casualties and loss of housing. Therefore, a method for evaluating the severity of losses caused by natural disasters would be beneficial for disaster management institutes in Taiwan when developing further supply chain management (SCM) strategies. To evaluate loss severity resulted from natural disasters in Taiwan, this study adopted grey relational analysis (GRA) to develop a method for evaluating the severity of losses caused by typhoons, earthquakes, and floods based on four indicators: human casualties, loss of housing, disaster relief personnel, and disaster relief equipment. According to the study results, the proposed GRA method is appropriate for evaluating the severity of losses caused by typhoons, earthquakes, and floods. The proposed GRA method is effective for evaluating the severity of loss resulting from natural disasters in Taiwan, which can serve as a reference for disaster management institutes to develop supply strategies in the future.

Keywords: Grey Relation Analysis (GRA), Losses Caused by Natural Disasters (LCND), Supply Chain Management (SCM).

1. INTRODUCTION

Natural disasters in Taiwan lead to human casualties and substantial loss of housing and property, requiring the mobilization of considerable human resources and equipment to implement disaster relief efforts. An effective method for evaluating the severity of loss caused by natural disasters in Taiwan can serve as a reference for disaster management institutes developing future supply chain management (SCM) strategies. Therefore, the evaluation of the severity of losses caused by natural disasters in Taiwan is an essential topic. In this study, grey relational analysis (GRA) was employed to evaluate and compare the severity of loss caused by typhoons, earthquakes, and floods. The research data were obtained from Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) [1], and the National Fire Agency, Ministry of the Interior, Executive Yuan, R.O.C. (Taiwan) [2]. The results of this study can serve as a reference for disaster management institutes in establishing goals and developing supply chain management (SCM) strategies.

2. MATERIALS AND METHODS

GRA theory was proposed by Deng [3], and it has been widely applied in various topics. Shao and Li [4] applied the GRA to evaluate the heavy metal pollution. Chen [5] used the GRA to understand the employee training quality. Geum et al. [6] used the GRA to analyze the service failure diagnosis. Xiao et al. [7] utilized the GRA to know about the website service quality. Tseng [8] has applied the GRA to understand the environmental knowledge management. Kung and Wen [9] adopted the GRA to analyze the financial performance. Golmohammadi and Mahour [10] applied the GRA to know about the evaluation and selection of suppliers. Lee and Lin [11] adopted the GRA to know about the evaluation of energy performance of office buildings. Zhang [12] applied the GRA to understand the venture capital investment. Adopting the procedures proposed by Wen et al. [13], this study used GRA to evaluate the severity of loss resulting from natural disasters in Taiwan.

2.1. Grey Relation Analysis

The original data of the indicators for evaluating the severity of losses caused by natural disasters (i.e., typhoons, floods, and earthquakes) satisfy comparability requirements. Consequently, this study used the original data to conduct GRA and established a reference sequence and a comparison sequence.

Using the equation 1, the size of the difference sequences of the evaluation indicators can be calculated.

\[ \Delta Q_i(k) = |G_0(k) - G_i(k)| \]

Eq. (1)
Then, the maximal and minimal difference sequences of the evaluation indicators were calculated. The obtained Z value weight was 0.5.

The grey relational coefficient of the evaluation indicators can be calculated using the following equation 2.
\[ Y(Gi(k), Gj(k)) = (\Delta \text{min} + Z \Delta \text{max}) / (\Delta \text{i}(k) + Z \Delta \text{max}) \]  
Eq.(2)

The grey relational grades of the indicators for evaluating the severity of loss caused by typhoons, floods, and earthquakes were calculated. The grey relational orders of the aforementioned indicators were sorted.

3. RESULTS

After determining the severity of loss caused by natural disasters in Taiwan, Table 1 was compiled. Table 1 shows the 2011-2013 data for evaluating the severity of loss caused by typhoons, floods, and earthquakes. According to the database of the Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) [1], and the National Fire Agency, Ministry of the Interior, Executive Yuan, R.O.C. (Taiwan) [2], human casualties, loss of housing, disaster relief personnel, and disaster relief equipment are the primary indicators [1, 2] for evaluating the severity of loss resulting from natural disasters.

The framework developed by Wen et al. [13] was adopted to calculate the severity of loss caused by natural disasters in Taiwan in 2011. The evaluation results are presented below. Subsequently, the same calculation was performed for 2012-2013, also according to Wen et al. [13]. Table 2 shows the evaluation results. The software used in this study was obtained from the CD in the publication by Wen et al. [13].

Step 1: The original data of the indicators for evaluating the losses caused by natural disasters (i.e., typhoons, floods, and earthquakes) satisfy comparability requirements. Therefore, the original data were used to conduct the GRA.

Reference sequence 0.4, 2.2, 9,791.6, 1,693.2

Comparison sequence 0.4, 2.2, 9,791.6, 1,693.2

<table>
<thead>
<tr>
<th>Year 2011</th>
<th>Typhoons</th>
<th>Floods</th>
<th>Earthquakes</th>
<th>Year 2012</th>
<th>Typhoons</th>
<th>Floods</th>
<th>Earthquakes</th>
<th>Year 2013</th>
<th>Typhoons</th>
<th>Floods</th>
<th>Earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Casualties (Persons)</td>
<td></td>
<td></td>
<td></td>
<td>Casualties (Persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1.73</td>
<td>0</td>
<td></td>
<td>28.6</td>
<td>0</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of Housing</td>
<td>2.2</td>
<td>0</td>
<td>0</td>
<td>Loss of Housing</td>
<td>20.57</td>
<td>0.18</td>
<td>0</td>
<td>Loss of Housing</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Disaster relief personnel (Number of Personnel)</td>
<td>9791.6</td>
<td>281.4</td>
<td>0</td>
<td>Disaster relief personnel (Number of Personnel)</td>
<td>21144.85</td>
<td>2504.45</td>
<td>0</td>
<td>Disaster relief personnel (Number of Personnel)</td>
<td>21506.16</td>
<td>1731</td>
</tr>
<tr>
<td></td>
<td>Disaster relief equipment</td>
<td>1693.20</td>
<td>9</td>
<td>0</td>
<td>Disaster relief equipment</td>
<td>7154.85</td>
<td>925</td>
<td>0</td>
<td>Disaster relief equipment</td>
<td>7920.33</td>
<td>410</td>
</tr>
</tbody>
</table>

Source: Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) [1], and the National Fire Agency, Ministry of the Interior, Executive Yuan, R.O.C. (Taiwan) [2].

Step 2: The formula \[ \Delta Q_i (k) = |G_i(k) - G_j(k)| \] was used to calculate the sizes of the different sequences of the indicators for evaluating the losses caused by natural disasters. The calculation results are presented as follows.

\[ \Delta Q_1 = (0.0, 0.0, 0.0, 0.0) \]

\[ \Delta Q_2 = (0.4, 2.2, 9,510.2, 1,684.2) \]

\[ \Delta Q_3 = (0.4, 2.2, 9,791.6, 1,693.2) \]

Step 3: The maximal and minimal difference sequences of the evaluation indicators were calculated.

Maximal difference: 9,791.6

Minimal difference: 0.0

Step 4: The obtained Z value = 0.5000.

Step 5: Using the formula
\[ Y(Gi(k), Gj(k)) = (\Delta \text{min} + Z \Delta \text{max}) / (\Delta \text{i}(k) + Z \Delta \text{max}) \]  
the grey relational coefficients of the evaluation indicators were calculated. The results are presented as follows.

\[ Y(Gd(1), Gd(1)) = 1.0000, Y(Gd(2), Gd(2)) = 1.0000, Y(Gd(3), Gd(3)) = 1.0000, Y(Gd(4), Gd(4)) = 1.0000, Y(Gd(1), Gd(1)) = 0.9999, Y(Gd(2), Gd(2)) = 0.9996, Y(Gd(3), Gd(3)) = 0.3398, Y(Gd(4), Gd(4)) = 0.7440, \]

\[ Y(Gd(1), Gd(1)) = 0.9999, Y(Gd(2), Gd(2)) = 0.9996, Y(Gd(3), Gd(3)) = 0.3333, Y(Gd(4), Gd(4)) = 0.7430 \]

Step 6: The grey relational grades were calculated for the indicators for evaluating the severity of loss caused by typhoons, floods, and earthquakes. Given an equal weight value \( \beta = 1/4 \), the following grades were obtained:

\[ Y(G_0, G_1) = 1.0000 \]  (typhoons), \( Y(G_0, G_2) = 0.7708 \)  (floods), and \( Y(G_0, G_3) = 0.7690 \)  (earthquakes).

Step 7: The grey relational orders of the indicators for evaluating the severity of loss caused by typhoons, floods, and earthquakes were sorted from the highest to the lowest value:
The findings of this study indicate that typhoons caused the most serious losses in Taiwan, followed by floods, and then earthquakes. The severity of loss caused by natural disasters shows that typhoons indeed cause the most substantial damage. Moreover, the data of human casualties, loss of housing, disaster relief personnel, and disaster relief equipment demonstrate that the severity of loss caused by typhoons is extremely high.

The results of this study can assist disaster management institutes in identifying problems that lead to severe losses by providing comparable evaluation results based on the three primary natural disasters affecting Taiwan, thereby serving as a reference for disaster management institutes to improve their supply chain management (SCM) strategies.

**CONFLICT OF INTEREST**

The authors confirm that this article content has no conflict of interest.

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Declared none.

**REFERENCES**


