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AN INTEGRATED DEMATEL-ANP-VIKOR APPROACH FOR FOOD DISTRIBUTION CENTER SITE SELECTION: A CASE STUDY OF GEORGIA*

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ABSTRACT
Purpose - Distrution center location selection is a long-term strategic decision. In this study, it is aimed to present an approach for food distribution center location in Tbilisi, Georgia.
Methodology - The proposed integrated approach includes three stages. In the first stage, the relationships between the criteria were determined by DEMATEL. Then, the criteria were weighted by ANP. In the last stage, the most suitable food distribution center was chosen by VIKOR.
Findings - According to results of the study, transportation is the most important criterion, and Gori is the most suitable food distribution center alternative.

Keywords: ANP, DEMATEL, distribution center location, Georgia, VIKOR.
JEL Codes: C44, L66, M11

1. INTRODUCTION

In the distribution center location selection, delivery of the products to the retailer in optimal time and at the least cost has a great importance (Uyanik, 2016). Distribution centers can be expressed as custom-defined areas that are close to transportation points (Kuo, 2011) and located near or easily accessible to markets and border gates (Kuo, 2011). They enable well-organized storage and distribution of the products depending on their type and durability (Demirtas, 2014). They also shouldn't affect the environment and city layout negatively (Uyanik, 2016) and provide a logistical contribution to the located country by presenting the features of a working and employment system in accordance with the social and political infrastructure of the country (Chen, 2001).

Distribution centers, which have many examples in the world, are tried to be formed in accordance with the social, economic, geographical and other characteristics of the country they are located in. Georgia has always been a country that needs to be developed in terms of logistics. Georgia, as a geopolitical location, is the region where Central Asian countries reach the sea,

* This paper is extended form of the study presented in 7. National Logistics and Supply Chain Congress

which is a crossing point between Asia and Europe, and is a country on the historic Silk Road. It also has Baku-Tbilisi-Kars railway system and a 1612 km long railway system that is currently being transported to Azerbaijan and Armenia, providing transportation for neighboring countries (Titvinidze, 2010).

Emerged from the collapsing Soviet Union as an independent state with its unique position on the newly formed geopolitical map, Georgia creates an important air corridor (URL-1). Due to this location, Georgia is a very important resource (gas, oil) transfer area, and it is a critical region for the transport of energy from the Caspian Sea (Aliyev, 2010). Moreover, the agricultural sector is one of the most important economic activities in Georgia. Due to the scarcely usage of unnatural additives, agricultural products are produced and sold in their natural form. There is a need for areas where distribution can be planned correctly in order to use Georgia's this advantage in food products more effectively. In this context, it is aimed to present an integrated approach in which the most suitable food distribution center can be determined in Tbilisi, which is one of the most intense commercial areas of Georgia. Food distribution center selection is a decision problem which should be evaluated together with qualitative and quantitative factors. Therefore, a three-stage approach with Multi-Criteria Decision Making (MCDM) techniques is presented in this study. Firstly, the relationships between the criteria were determined by DEMATEL. Secondly, the criteria that may be effective in the selection of food distribution center are weighted by ANP. Thirdly, location selection is made by VIKOR.

The structure of the paper is organized as follows. In literature review section, the related studies on distribution centers and the methods used in those studies are provided. In the third section, the methods are explained, and in the fourth section the application steps and findings are given. The study is finalized with the conclusion section in which the results are interpreted and future recommendations are included.

2. LITERATURE REVIEW

The studies on distribution and logistics centers have been summarized in terms of their methods as follows:

i) Mathematical model; Taniguchi et al., (1999) used queuing theory and nonlinear programming to determine the optimal size and location of public logistics terminals. Nozick and Turnquist (2001) have utilized a two-stage inventory model for selecting appropriate distribution center location. Ross and Droge (2002) compared logistics centers efficiencies by Data Envelopment Analysis (DEA). Avittathur et al., (2005) determined a distribution center location by a nonlinear mixed integer programming model. Ambrosino and Scutella (2005) evaluated the problem of a distribution network design by mathematical programming with the criteria of transport, storage, inventory costs. Baohua and Shiwei (2009) developed a stochastic optimization model for logistics center location selection. Xing et al. (2011) aimed to determine the optimal distribution center location by integer programming model.

ii) MCDM Techniques; Chen (2001) evaluated distribution center location by Multi Criteria Decision Making (MCDM) methods. Farahani and Asgari (2007) investigated the optimal location of warehouse and distribution centers that can be used in the military system by MCDM techniques. Ballis and Mavrotas (2007) selected the appropriate logistics center location by PROMETHEE. Bamyaci and Tanyas (2008) used AHP and Simple Additive Weighting (SAW) to select optimal site of logistics centers in Istanbul. Erkayman et al. (2011) evaluated the alternatives of logistics center location in the Eastern Anatolia region of Turkey by TOPSIS. Eryuruk et al. (2011) sought the optimal location of textile logistics center in the Marmara Region by AHP. Gorgulu (2012) suggested a model for optimal logistics village in Konya by AHP. Regmi and Hanaoka (2013) ranked logistics center location alternatives by AHP. Onder and Yildirim (2014) combined AHP and VIKOR methodologies for evaluating optimal logistics village location. Zak and Weglinski (2014) identified the optimal logistics center site in Poland by Electre III. Stevic et al. (2015) determined optimal location of the logistics center in Bosnia and Herzegovina by AHP. Ozceylan et al. (2016) developed a model that combines Geographic Information Systems, ANP and TOPSIS to selection best alternative of logistics center in Ankara. Peker et al. (2016) proposed a model which is named ANP-BOCR (Benefits, Opportunities, Costs and Risk) to select the appropriate logistics center location in Trabzon.

iii) Fuzzy Logic; Chen and Qu (2006) decided an optimal logistics center location by Fuzzy AHP and Delphi Method with the criteria of environmental effect, transportation status, and public enterprise. Wang and Liu (2007) carried out the logistics center location selection using the Fuzzy AHP and TOPSIS. Ghoseiri and Lessan (2008) first evaluated the criteria through natural resource, economic benefit, social benefit, transportation and development potential; then determined the potential locations of distribution centers by fuzzy AHP and ELECTRE. Li et al. (2010) examined the optimal location of a logistics center by Axiomatic Fuzzy Set clustering and TOPSIS. Dheena and Mohanraj (2011) proposed an integrated model, a combination of Fuzzy DEMATEL and AHP. Liu et al., (2011) presented a comprehensive methodology by utilizing Rough Clusters Method and Fuzzy logic for the selection of optimal distribution center location. Awasti et al., (2011) investigated an urban distribution center location problem by fuzzy TOPSIS.

iv) Heuristic-Meta-Heuristic methods; Yang et al., (2007) utilized Tabu Search, Genetic Algorithm and fuzzy simulation algorithm to determine optimal distribution center location. Ji and Huailin (2009) chose appropriate distribution center location by Genetic Algorithm and AHP. Kayikci (2010) used Fuzzy AHP and Artificial Neural Networks to determine optimal intermodal freight logistics center location. Tomic et al. (2014) concentrated a model which integrates AHP and heuristic algorithm to select of a suitable logistics center location.

v) Qualitative methods; Elgun and Elitas (2011) analyzed the optimal location of freight villages in terms of local, national and international transport and trade by Delphi Method.

The literature review indicates that no study on food distribution center site selection has been conducted by integrating DEMATEL-ANP-VIKOR methods. For this reason, optimal distribution center location selection procedure is presented using these methods. In addition, there is no study on distribution centers in Georgia. In this context, a case study designed for the city of Tbilisi in Georgia. The results of the study show that the proposed approach can be used in the selection of the distribution center.

3. METHODS

3.1. DEMATEL Method

The DEMATEL method was developed in 1972 by the Battelle Memorial Institute of the Geneva Research Center (Gabus and Fontela, 1972). It is a MCDM method and used in the solution of complex problem groups (Shieh et al., 2010). It categorizes the criteria as cause group and effect group (Sheng et al., 2018). Cause group criteria are the ones that have an impact on the other criteria. Effect group criteria are influenced by others (Shieh et al., 2010). DEMATEL is used to determine the relationship between the criteria in this study. The steps of the DEMATEL method can be expressed as follows (Tzeng and Huang 2011; Sheng et al., 2018):

1. Establishment of the initial direct - relation matrix (Z): Z is a nxn matrix obtained by pairwise comparisons scale. This scale was designed as four levels: No influence (0), low influence (1), medium influence (2), high influence (3) and very high influence (4). This matrix is constructed by averages of the evaluations.

2. Formation of the normalized direct-relation matrix (X): The Direct Relationship Matrix (X), calculated by Eq. (1) and Eq. (2), is created by dividing each element of the Direct Relationship matrix by the line or column with the smallest value (k).

$$X = k \times Z \qquad (1)$$

$$k = \text{Min}\left(\frac{1}{max\sum_{j=1}^{n}|z_{ij}|}, \frac{1}{max\sum_{i=1}^{n}|z_{ij}|}\right) \qquad i,j = 1,2,3,\ldots,n \qquad (2)$$

3. Creation of total effect matrix (T): Total effect M matrix T is obtained by using equation (3). I represents the Unit Matrix.

$$T = X + X^2 + X^3 + X^4 + \ldots + X^m = X \cdot (I - X)^{-1} \qquad (m \rightarrow \infty) \text{ iken} \qquad (3)$$

4. Determining the vector D and R: The sum of the i. row shows the total effect of the i. criteria on other criteria and is symbolized as d_i. The sum of the j. column shows the total impact of the criteria by other criteria and is symbolized as rj.

$$D = [d_i]_{nx1} = [\sum_{j=1}^{n} t_{ij}]_{nx1} \qquad (4)$$

$$R = [r_j]_{nx1} = [\sum_{i=1}^{n} t_{ij}]_{1xn} \qquad (5)$$

(D) and (R) are calculated by the Eqs (4) and (5). The highest (D+R) value means that it has a high relationship with other factors/criteria and have an important role. If the value of the criteria (D-R) is positive, it has a significant effect on other criteria and is of greater importance and is referred to as the cause group. The negative criteria (D-R) are more influential than the others and these criteria are called the effect group.

5. Set a Thereshold value to draw Influential relation map (IRM): In order to simplify the total impact matrix, avoid the complexity of minor effects, it is necessary to assign a threshold value (α) by the decision-makers or the experts. Determination of the appropriate threshold (α) is extremely critical. If the threshold (α) is detected too high, the impact will not appear on the IRM or if it is found to be too low, the number of criteria in the IRM increases and the map becomes too complex. Threshold (α) is calculated by finding the average of the T-matrix (Chiu et al., 2006; Liou et al., 2007), where N represents the sum of the elements in the T matrix is obtained by Eq. (6).

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}}{N} \qquad (6)$$

3.2. Analytical Network Process

The Analytic Network process (ANP), introduced by Saaty, allows to reach more effective and realistic solutions in complex decision making problems compared to the Analytic Hierarchy Process (AHP) method (Saaty, 2008). It enables decision makers taking into considering the dependence between the criteria of the hierarchy. The method consists of the following steps (Jharkharia and Shankar, 2007; Saaty, 2008):

1. Construct the model: The decision problem is defined by determining the criteria, sub-criteria and alternatives.

2. *Creation of the relationship matrix and the network model:* Decision makers complete all pairwise comparisons using 1-9 scale suggested by Saaty.

3. Creation of unweighted and weighted matrix: Pairwise comparisons matrix formed from the relationship matrix; all of these paired comparisons are shown in the unweighted matrix. The weighted matrix is then formed by multiplying the criteria weights with the sub-criteria weights.

4. Creation of supermatrix: All the row values of the weighted matrix are formed by taking the power from the degree (2n + 1) until they converge. At this point; the calculation of the consistency ratio is very important when comparing the criteria. The consistency ratio (CR) is obtained by Eqs. (7), (8) (9). The random index (RI) can be shown in Table 1. If CR is lower than 0.10, the evaluations are considered as consistency. Otherwise, the decision matrix should be rearranged.

$$\lambda_{max} = \frac{\sum_{n=1}^{n} E_1}{n} \qquad (7)$$

Consistency Index (CI) = (λ_{max}-n) / (n-1) (8)

Consistency Ratio (CR = CI / RI) = Consistency Index / Random Index (9)

Table 1: Random Index

N	1	2	3	4	5	6	7	8	9	10
Random Index	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

(Saaty, 1990)

3.3. VIKOR Method

The VIKOR method, which is one of the new MCDM methods, is based on the creation of a solution within the scope of alternatives and criteria and this solution is the closest to the ideal solution (Chu et al., 2007). It was developed by Opricovic for the first time in 1998 (Yildiz and Deveci, 2013). The closest compromise solution is obtained from evaluated alternatives. (Opricovic and Tzeng, 2007). The application steps of the VIKOR method are shown as follows (Opricovic and Tzeng, 2004; Chen and Wang, 2009):

1. Choosing the best and worst values: The best (f_j *) and the worst (f_j^-) values for each criterion are determined. Eq. (10) and (11) are used for benefit and cost criteria set respectively.

f_i*= max x_i , f_i^- = min x_{ij} (10)

f_i*= min x_{ij} , f_i^- = max x_{ij} (11)

2. Determining normalized matrix: The normalized decision matrix is denoted by R, and the normalized value of the each criterion is indicated by the r_{ij} obtained using Eq. (12).

r_{ij} = (f_i * -x_{ij}) / (f_i * -f_i^-) (12)

3: Determining weighted normalize matrix: The normalized decision matrix is weighted by Eq.(13).

$$t_{ij} = W \times r_{ij} \quad (13)$$

4. Determination of S_i and R_i values: In weighted normalize matrix, S_i and R_i values are calculated by Eq. (14) and (15).

$$S_i = \sum_{j=1}^{n} tij \quad (14)$$

$$R_i = \max t_{ij} \quad (15)$$

5. Calculation of Q_i values: Qi values are calculated by Eq (16), (17) and (18) respectively for i = 1,2,3, ... n.

$$Q_i = [v.(S_i - S^*)/(S—S^*)]+[(1-v).(R_i - R^*)/(R—R^*)] \quad (16)$$

S_i and R_i values;

$$S^* = \min S_i,\ S^- = \max S_i \quad (17)$$

$$R^* = \min R_i,\ R^- = \max R_i \quad (18)$$

6. Ranking the alternatives: Alternatives are ranked in ascending order according to their Q_i values.

7. Achieving the ideal outcome and conditions: To test the accuracy of the rank, it is necessary to be checked whether the alternative which has a minimum Q value satisfies the conditions of advantage and acceptable stability.

Condition 1- Acceptable Advantage: It can be calculated by (Eq. 19).

$$Q(A_2) - Q(A_1) \geq DQ \quad DQ = 1/m, \quad (19)$$

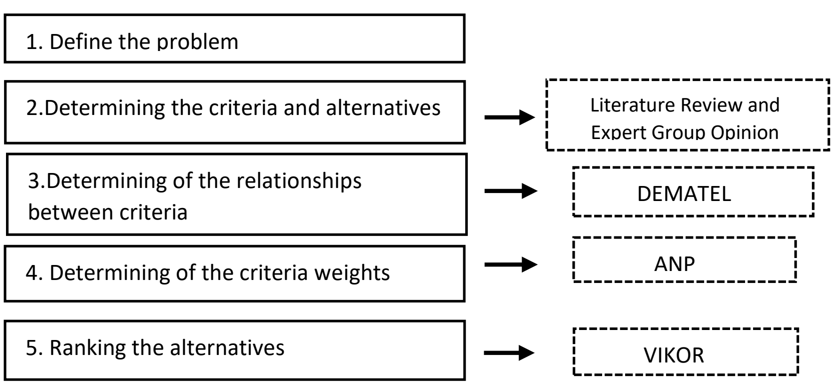
where $Q(A_2)$ is the second alternative in the ranking list and m is the number of alternatives.

Condition 2- Acceptable Stability in Decision Making: When the Q_i values are ranked from small to large, the alternative A_1 is the best alternative and has a minimum value. In addition, the S and R values are ranked from small to large, alternative A_1 is the best alternative has the minimum value both S and R values. These are the rankings and consensus common solutions made with S, R and Q values.

4. APPLICATION

In this study, an integrated approach which combines DEMATEL-ANP-VIKOR is proposed. The application stages of it are shown in Figure 1.

Figure 1: Application Steps of the Proposed Approach



4.1. Define the Problem

The decision problem of this study is to select the suitable location of food distribution center in Tbilisi, which is the most important city in Georgia.

4.2. Determining the Criteria and Alternatives

Based on an extensive literature review and the expert group's opinion, the criteria are determined as shown in Table 2. The experts group is 11 people who consist of Public Institutions and Organizations Managers (2), Logistics Service Providers Managers (2), Manufacturing Firms Managers (2), Non-Governmental Organizations Managers (2) and Academician (3).

After, three alternatives are determined based on expert group's opinion, which are *Gori, Marneuli* and *Rustavi. Gori* is an agricultural district. It is located on the Tbilisi-Batumi highway, and about 80 km to Tbilisi. It is located at the crossroads of the Georgia, Turkey, Russia, Azerbaijan, and Armenia borders. It has an important geopolitical location from a logistics point of view. *Gori,* which also has a railway network, is also 300 km to the port of Batumi that is one of the important ports of the Black Sea, and 250 km to the Port of Poti (URL 2). *Marneuli* is located about 45 km to Tbilisi, It is an agricultural district and a commercially developing city. In Marneuli, there is no railway network and it is located 20 km to the Azerbaijani border on the east side and approximately 140 km to the Armenian border in the South (URL 2) *Rustavi* is located between Tbilisi and Georgia-Azerbaijan border, and it is 25 km to Tbilisi. It is known as the industrial district of the Caucasus. The distance of the area to the border with Azerbaijan is about 85 km. It does not have a railway network (URL 2).

Table 2: Food Distribution Center Location Selection Criteria

Main Criteria	Sub-Criteria	References
COST (C_1)	Installation Cost (C_{11})	(Imren,2011)
	Transportation Costs (C_{12})	(Onel,2014)
	Operating Costs (C_{13})	(Janjevic et al., 2016; Kuo, 2011).
LOCATION (C_2)	Distance to Transport Points (C_{21})	(Pinar,1989; Kuo, 2011)
	Distance to Markets (C_{22})	**(** Kuo, 2011)
	Distance to Border Gates (C_{23})	**(** Kuo, 2011)
	Hinterland (C_{24})	**(** Kuo, 2011)
SERVICE (C)	Storage Convenience (C_{31})	(Omurbek and Simsek, 2014)
	Operational Service Level (C_{32})	**(** Kuo, 2011)
	Transfer Convenience (C_{33})	(Zhu, et al., 2014)
POLICY (C_4)	Government Policy (C_{41})	(Onel,2014)
	Geopolitical Position of the Country (C_{42})	Expert Group
	Infrastructure Statement (C_{43})	(Onel,2014)
	Economic Policy (C_{44})	Chen ,2001
SOCIAL (C_5)	Community Perspective (C_{51})	(Serdar, 2008)
	Environmental Impact (C_{52})	(Imren, 2011)
	Traffic Impact (C_{53})	(Bamyaci and Tanyas, 2008)
	Impact on Regional Development (C_{54})	(Janjevic et al., 2016)

4.3. Determining of the Relationships Between Criteria

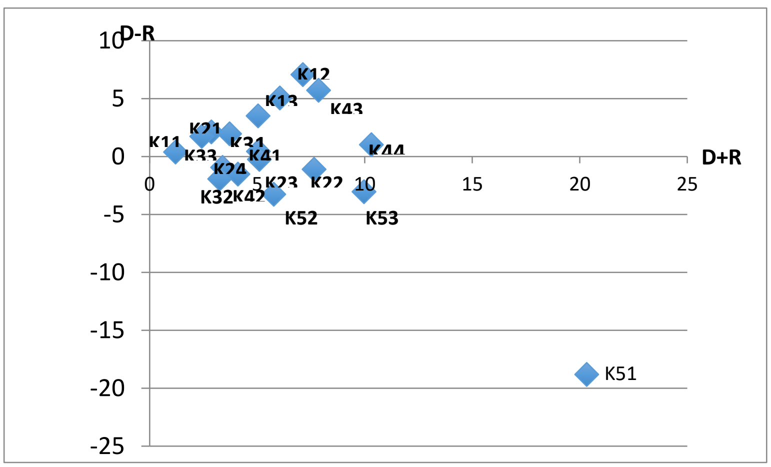
Following the above-mentioned steps of DEMATEL, (D + R) and (D-R) values are determined and presented in Table 3.

Table 3: D + R / D-R Values of Sub-Criteria

Sub-Criteria	D+R	D-R	Sub-Criteria	D+R	D-R
C_{11}	1.21	0.40	C_{41}	5.10	-0.25
C_{12}	7.13	7.09	C_{42}	4.11	-1.51
C_{13}	6.05	5.07	C_{43}	7.86	5.73
C_{21}	2.87	2.14	C_{44}	10.31	1.04
C_{22}	7.65	-1.10	C_{51}	20.33	-18.81
C_{23}	5.05	0.45	C_{52}	5.77	-3.26
C_{24}	3.39	-0.93	C_{53}	9.97	-3.02
C_{31}	3.72	1.98	C_{54}	5.05	3.51
C_{32}	3.26	-1.93			
C_{33}	2.43	1.75			

Community Perspective (C_{51}), *Economic Policy (C_{44})* and *Traffic Impact (C_{53})* are the most important criteria according to D+R *values.* In addition, the values of the criteria (D-R) are determined. *Transportation Cost (C_{12}), Infrastructure (C_{43})* and *Operating Cost* (C_{13}) are obtained by positive. It means these criteria have great importance on the other criteria. *Community Perspective (C_{51})* is the most affected criterion with a negative (D-R) value. Then, the Influential Relation Map (IRM) which is formed by D+R and D-R values is shown in Figure 3.

Figure 3: Influential Relation Map



4.4. Determining of the Criteria Weights

Following the determination of the relations between the criteria, the main criteria and sub-criteria weights by the ANP are determined as in Table 4. As can be seen in Table 6, *Cost (C_1)* is the most important criterion and *Social (C_5)* is the least one. it can be emphasized that *Transportation Cost (C_{12})* has the highest importance level while *Traffic Impact (C_{53})* has the least importance.

Table 4: Main Criteria and Sub-Criteria Weights

Criteria and Weights	Sub-Criteria	Weights (W)	Criteria and Weights	Sub-Criteria	Weights (W)
	C_{11}	0.02		C_{41}	0.10
C_1=0.48	C_{12}	0.20		C_{42}	0.07
	C_{13}	0.09	C_4=0.10	C_{43}	0.18
	C_{21}	0.03		C_{44}	0.11
	C_{22}	0.06		C_{51}	0.005
C_2=0.31	C_{23}	0.04		C_{52}	0.03
	C_{24}	0.01	C_5=0.05	C_{53}	0.003
	C_{31}	0.02		C_{54}	0.06
C_3=0.07	C_{32}	0.01			
	C_{33}	0.03			

4.5. Ranking the Alternatives

In VIKOR results, *Gori* is the most suitable food distribution center (v=0,5). This is followed by *Rustavi* and *Marnuli* respectively. According to different v values, the Q_i scores of the alternatives are presented in Table 5. Accordingly, the ranking results have not changed. Therefore, it can be said that the integrated approach is robust.

Table 5: Q_i values of alternatives

Alternatives	v=0.00	v=0.25	v=0.50	v=0.75	v=1.00
Gori	0	0	0	0	0
Rustavi	0.43	0.45	0.47	0.49	0.41
Marnouli	1	1	1	1	1

5. CONCLUSION

Georgia is an important part of the intensive logistics traffic in the Caucasus. However, due to the country's inadequate infrastructure and recent war shortages, it has remained incomplete in terms of logistics. Likewise, this is also the case with the most densely populated and developed city, Tbilisi. The primitive conditions of the distribution of food products that are at the forefront in the import and export rankings, especially in Tbilisi and its surroundings, indicate the necessity of food distribution center. In the literature, it is determined that there are a lot of logistics distribution center location selection studies, but there is no study on distribution center or similar subjects in the context of Georgia. In this respect, the study contributes to the current literature.

Food distribution center selection is a decision problem which should be evaluated together with qualitative and quantitative factors. For this purpose, a three-stage model is used in this study. In the first stage, the DEMATEL is used to determine the relationships between the criteria. ANP is utilized to weight the criteria in the second stage. In the last stage, the most suitable food distribution center in Tbilisi is determined by VIKOR. The integrated use of DEMATEL-ANP-VIKOR methods is another contribution to the literature in the selection of distribution center. According to the results of the study, the *Cost* is the most important criterion. When the literature is reviewed, Uyanik (2016) and Peker et al. (2016) determined the cost criteria in the highest weight in parallel with this study. According to the results of VIKOR, the most suitable food distribution center is in *Gori*, and it is also selected for different v values. Therefore, it can be concluded that the integrated approach is robust. In obtaining this result, the fact that Gori is almost of equal distance from the borders of Russia, Turkey, Azerbaijan and Armenia; only 80 km to Tbilisi; 250 km to Poti Port and 300 km to Batumi Port; and has a railway system.

The results may change if the criteria and decision makers differ. This situation can be thought as one of major constraint of the study. The study, which is limited to Tbilisi and its environs, can be extended to all of Georgia in the future. Moreover, the methods such as TOPSIS, ELECTRE, fuzzy TOPSIS and Fuzzy ELECTRE can be used for the distribution center site selection for Georgia, and the results can be compared with this study.

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