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WAREHOUSE SITE SELECTION IN RETAIL SECTOR: AN APPLICATION OF AHP (ANALYTICAL HIERARCHY PROCESS) AND VIKOR METHODS

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ABSTRACT: *In a globalized world, it is very important to determine where the warehouse would be located in order to reduce the production and supply chain costs of the firms. There are many methods used in warehouse selection. Analytic Hierarchy Process (AHP), VIKOR, Analytic Network Process (ANP), TOPSIS, Fuzzy TOPSIS, Fuzzy AHP is often used in multi criterion decision making (MCDM) techniques. Within the scope of this study, a warehouse location selection application for a retail firm is implemented. Since the AHP and VIKOR techniques are used in the retail sector very little in the Turkish literature, the study shows originality. The choice of four warehouse locations (Bolu, Düzce, Kocaeli, and Sakarya) of the firm is determined according to the six criteria obtained in the literature. In the research, a combination approach of AHP and VIKOR methods are used as AHP method used for weighting the determined criteria and VIKOR used for sorting the alternatives regarding the criterion values obtained from AHP.The AHP is analyzed by Super Decision 2.7 and Expert Choice.11 program is used for VIKOR application. According to the results of AHP-VIKOR methods, the most suitable locations are determined as Bolu, Düzce, Kocaeli, and Sakarya respectively. The study results are shared with the firm authorities.*

KEYWORDS:*AHP, multi-criteria decision making, VIKOR, Warehouse site selection*

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I. INTRODUCTION

Reducing the logistics costs of firms and keeping them at the optimum level are important for supply chain management. The general purpose of logistics is to deliver the raw materials, semi-finished products and auxiliaries when needed, at the lowest cost, under appropriate conditions. Warehousing, an important branch of your logistics, is crucial to well-organize logistics activities.The decision of where to place the warehouse is one of the important decisions affecting the total supply chain. Therefore, there are a lot of criteria to be considered when choosing the storage location. The criteria that are generally required in selecting the warehouse location are infrastructure, socio-economic structure, transportation, service level, market situation and technology.There are many methods used in warehouse selection. These are methods such as mathematical methods, heuristic methods, financial methods, simulation, and multi-criteria decision-making techniques such as Analytic Hierarchy Process (AHP), VIKOR, Analytic Network Process (ANP), TOPSIS, Fuzzy TOPSIS, and Fuzzy AHP. Considering the recent studies in the literature, there are many different approaches in the selection of warehouse location, and it is seen that multi-criteria decision making and mixed approaches have been put forward (Aktepe and Ersöz, 2014: 3).As can be understood from the studies in the literature, it has been argued that the choice of warehouse location is a multi-criteria decision-making problem. For this reason, we prefer to use the AHP and VIKOR method to determine the storage location selection.

II. LITERATURE REVIEW

The problem of the warehouse location selection is subject to many applications from the manufacturing enterprises to the service enterprises. Since this study covers the selection of warehouse location for a retailer operating in the service sector, the literature review is restricted to studies related only to service sector.
Some of the researched studied on service sector is given Table 1.

Table 1. Selected Papers Studied on Service Sector

Authors	Application Area
Tengilimoğlu (2001)	Hospital

Tzeng et al. (2002)	Restaurant
Padilla (2002)	Library
Cheng et al. (2005)	Shopping center
Birsel and Cerit (2009)	Logistics operation
Xu et al. (2009)	Distribution center
Çınar (2010)	Bank branch
Çatay (2011)	Fire station
Köksal and Emirza (2011)	Street stores and shopping centers
Çiçekdağı and Kırış (2012)	Disaster station collection center
Arık and others. (2012) and Timor (2002)	Site selection for a retail firm

Sivitanidou (1996) examined the factors affecting rent on the warehouse in Los Angeles. Sivitanidou's survey shows that the physical properties of the structures of the deposits and the location of the warehouse are influenced by the transportation infrastructure and the labor market.Canadian Urban Institute conducted a study in 2000 to identify the needs of businesses providing warehousing services. The location selection factors of the enterprises included in this study include general location factors, closeness to the airline, proximity to highways, proximity to similar businesses, proximity to customers, proximity to suppliers, meeting existing building needs, suitable area for new construction, competitive rent / land costs, other location requirements.In a research conducted by Warffemius (2007) Amsterdam Schiphol Airport, the factors that are effective in selecting the warehouse location are the number of cities, warehouse types (private warehouse, general warehouse, operator's own warehouse etc.), warehouse main European distribution centers, value added, warehouse sector, number of employees, warehouse size and investment capital for warehouse.Ashrafzadeh et al. (2012) used the fuzzy AHP method of MCDM methods in an industrial operation in white goods sector in Iran, in the process of deciding to build a new warehouse. Arslan(2017) ranked suppliers in the supplier selection of bakery products companies by using AHP-VIKOR method to provide optimum benefits for their suppliers. The results of the analysis were shared with the relevant business managers.

Some of the warehouse location selection criteria, particularly required for retailers, are listed in Table 2 (Çaka, 2012: 29-31).

Table 2: Some Criteria used in Literature for Selection of Warehouse

	Criteria	**Resources**
1	Total cost	(Ashrafzadeh et al., 2012), (Alberto, 2000), (MacCarthy and Atthirawong, 2003)
2	Operational Cost	(Ashrafzadeh et al., 2012), (Alberto, 2000), (MacCarthy and Atthirawong, 2003)
3	Investment Cost	(Ashrafzadeh et al., 2012), (Alberto, 2000), (MacCarthy and Atthirawong, 2003)
4	Physical Properties of Warehouse	(Colson and Dorigo, 2004)
5	Warehouse Location	(Alberto, 2000), (Ashrafzadeh et al., 2012), (MacCarthy and Atthirawong, 2003)
6	Proximity to major transport destinations and markets	(Colson and Dorigo, 2004), (Ashrafzadeh et al., 2012), (Alberto, 2000), (MacCarthy and Atthirawong, 2003)
7	Environmental factors	(Ashrafzadeh et al., 2012), (Alberto, 2000), (MacCarthy and Atthirawong, 2003)
8	Capacity	(Colson and Dorigo, 2004)

Source: Çaka, E. (2012). Tedarik Zinciri Yönetiminde CHOQUET İntegral Yöntemi İle Depo Yeri Seçimi. Istanbul Technical University, Institute of Science and Technology, Department of Industrial Engineering, Master Thesis.

III. METHOD

The purpose of this study is to determine the most suitable warehouse location for a retailer in the four different cities (Düzce, Bolu, Sakarya, Kocaeli) of the Eastern Marmara Division, Turkey.In the research the approach used for warehouse location selection is a combination of AHP and VIKOR methods. Before starting application, giving a general explanation of the AHP and VIKOR methods would be beneficial.

3.1. AHP (Analytic Hierarchy Process) Method

AHP is a multi-criteria decision-making technique that takes problems in a hierarchical structure and relies on the dual comparison. With this method, it is possible to combine qualitative and quantitative factors in decision making process with groups and individuals (Saaty, 1980).

Complex problems can be made clear by determining the hierarchical relationships of the components that make up the problem. In AHP, problems must be represented in a hierarchical structure to form a hierarchy that includes the whole of the basic items needed to handle the problem in the hierarchy to be created. Once the hierarchy, target and decision alternatives are identified, it is determined which criteria to consider evaluating these alternatives.For this purpose, all main criteria and sub criteria are formed (Aksoy et al., 2015: 6). In order to determine the criteria formed in the hierarchy, a questionnaire study is conducted and the opinions of experts are used (Dağdeviren et al., 2004: 132).Figure 1 shows a three-level Analytic Hierarchy Model.

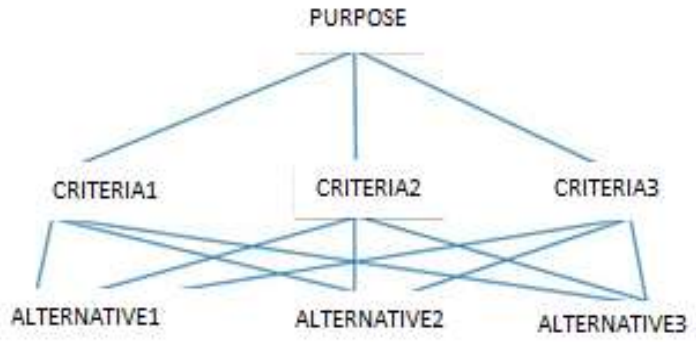

Figure 1. Three-Level Analytic Hierarchy Model

After the hierarchy is created, it is required to make binary decision matrices and make a comparison between decision makers. It is checked whether these comparisons provide a consistency test. After binary comparisons are made, relative weights are calculated from binary comparison matrices (Aslan, 2005: 5). The refenced scale that is used for pairwise comparisons is given Table 3.

Table3. The Fundamental Scale for Pairwise Comparisons

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

3.2. VIKOR (ViseKriterijumskaOptimicacijai KompromisnoResenje) Method

The VIKOR method is used to bring a sort sequence based on the ideal alternate proximity measure of all alternatives. It is a method of determining a consensus ranking and achieving a compromise resolution under specified weights. The selection of the most suitable is determined by determining the order of the alternatives under contradictory criteria. The VIKOR method takes a multi-criterion ranking index based on the ideal solution approximation and provides a solution to the problems with conflicting criteria and helps to reach the decision makers (Ertuğrul and Karakaşoğlu, 2009).

The steps of the VIKOR Method are as follows.

First, the best alternative (i) (Equation 1) and worst alternative (i) (Equation 2) are found for a criterion (j).

$$bji=\max(bj) \quad j=1, 2,\ldots,m \ (1) \text{ and}$$

$$bji=\max(\ ) bj \quad j=1, 2,\ldots,m \ (2)$$

Then, for each alternative (i), the values of S (Equation 3) and R (Equation 4) are calculated.

$$Si = \sum_{j=1}^{m} wj(bj^{+} - bji)/(bj^{+} - bj^{-}) \; i = 1,2,\ldots,n \ (3)$$

$$Ri = max[(wj.(bj^{+} - bji)/(bj^{+} - bj^{-}))i = 1,2,\dots,n(4)$$

In the third step, the Q values for each alternative (i) are calculated (Equation 5).

$$Qi = v(Si - S^{+})/(S^{-} - S^{+}) + (1 - v)(Ri - R^{+})/(R^{-} - R^{+}) = 1,2,\dots,n(5)$$

In Equation 5, S ^ + and R ^ + represent the smallest S and R values among the n alternatives, and S ^ - and R ^ - represent the largest S and R among the n alternatives. Solving is achieved by sorting by S, R and Q values. Where v represents the maximum group benefit weight; It is between 0 and 1. If the median v is greater than 0.5 then the median v is equal to 0.5 and there is a full consensus. In the last step there is an acceptable advantage (Equation 6) and acceptable stability conditions. If these two conditions are met, the alternative with the minimum Q value is determined as the best.

$$Q(i'') - Q(i') \geq 1/(n-1) \quad (6)$$

Here, i "represents the second alternative and i represents the first alternative. After this condition the second condition is checked. Accordingly, i 'must be at least 1 in the order of Si or Ri. If condition 2 is not satisfied, then i 'and i' 'are the compromise solution, and if condition 1 is not satisfied, the conditional alternatives determined by Equation 7 are considered the compromise solution.

$$Q(i(m)) - Q(i') < 1/(n-1) \quad (7)$$

3.3. Framework of Application

First of all, the opinions of experts about the criteria that would be formed for warehouse location selection were asked. Once the ideas are taken, the main criteria have been determined, decision-making groups will be established, and information will be given about the methods and digital techniques they can use in the research. At the same time, alternative cities were determined for warehouse location selection. Once the cities identified, the process of setting evaluation criteria will be passed. The AHP method will be used for weighting the determined criteria. According to the criterion values obtained, sorting will be done using VIKOR method. In order to improve the activities of the retail operation, the application steps of the survey to determine which city can be established among the four alternatives determined at the location of 1 warehouse are as follows.

3.4. Application Steps

Identifying the Problem: The problem is determining the most suitable warehouse location among the available alternatives for the firm and helping the firmto make correct decision. In the study, 3 different provinces will be evaluated according to the determined criteria.

Establishing a working group: A decision-making group consisting of experts who have experience in warehouse location has been established.

Determination of Alternatives: Four cities, Sakarya, Düzce and Bolu,Kocaeli ,identified as East Marmara Region are selected for the warehouse location subject to the study.

Determination of Main Criteria: When determining the criteria for warehouse location, relevant literature has been searched and appropriate studies have been used. In addition to these, the opinions of the experts have been taken on the selection of the storage location and the criteria have been given the final form as shown in Table 4.

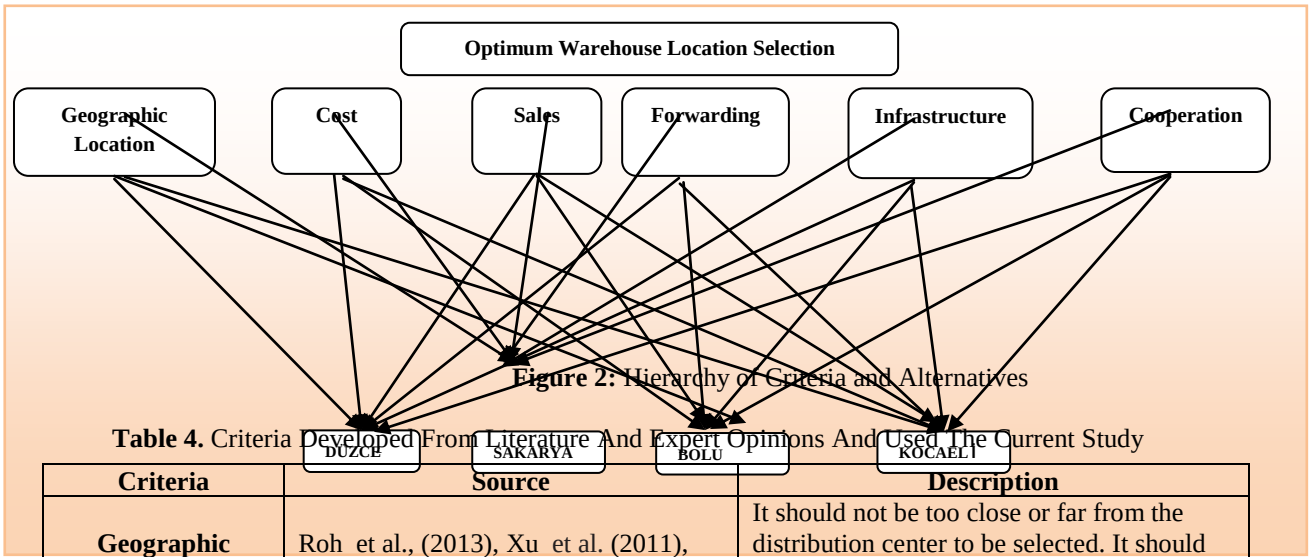

Figure 2: Hierarchy of Criteria and Alternatives

Table 4. Criteria Developed From Literature And Expert Opinions And Used The Current Study

Criteria	Source	Description
Geographic Location	Roh et al., (2013), Xu et al. (2011), Expert Opinions	It should not be too close or far from the distribution center to be selected. It should be at the most convenient distance to the city center.

	Awasti et al., (2011)	the proximity of the location of the distribution center to the location of the destination should be taken into consideration so that the transportation can be carried out in a short time and at a lower cost.
Cost	Ashrafzadeh et al., (2012)	Cost of material, human resource and service provision
	Chou et al., (2008), Expert Opinions	
Sales	Expert Opinions	Total sales of product
Forwarding	Ashrafzadeh et al., . (2012), Alberto (2000), Expert Opinions	Moving items one place to another.
Infrastructure	Crecente et al., (2012)	Size of the evaluated area
	Üreten (2006), Expert Opinions	The distribution center to be selected is influenced by the workforce diversity of the place.
	Urtasun and Gutierrez (2006),Chou et al., (2008), Expert Opinions	The proximity to the main roads where the installation will be located and the diversity of transportation services
Cooperation	Expert Opinions; Roh et al., (2013)	The government criterion must be considered in terms of financial assistance and incentives for the location of the distribution center to be selected.
	Crecente et al., (2012), Expert Opinions	Restrictions such as zoning permit status and building height based on legal regulations

IV. APPLICATION OF THE PROBLEM OF WAREHOUSE SITE SELECTION FOR THE RETAIL FIRM

4.1. Transfer of AHP and VIKOR Processes to Related Computer Programs

The study has been started in a retail firm in April, 2017. The firm is planned to determine optimum location of warehouese among Düzce, Bolu, Sakarya and Kocaeli ,where the warehouse is served in Düzce currently. The Criteria and optimum alternatives have been determined with the help of 3 specialists of the firm in each cities and each of them has been interviewed to form the criteria first. Combining both expert opinion and literature we constructed the criteria shown Table 3. After that, it is started to help the firmon optimum warehouse location by using Multi Criteria Decision Making (MCDM) methods. The weight of the criteria was determined by the AHP (Analytical Hierarchy Process) method when the data of the above-mentioned decision problem was evaluated. When the AHP method was analyzed, Super Decision 2.7 was used as the program. After determining the criterion weights, the alternatives are ranked according to their priority by applying the VIKOR method. Expert Choice.11 program was used for VIKOR application.

4.2. Description of Problem

As clearly stated previous sections, the choice of the most suitable suppliers for retailers is a challenging decision problem. The solution of such decision problems also includes the beneficial results of making correct and on-the-spot decisions about the efficient use of the retail sector in the selection of suppliers with the MCDM methods. The warehouse location of the company where the application was made is now in Düzce. But the company has a suspicion that this warehouse location is optimum. For this reason, the company wants to determine which one of the four provinces, Düzce, Bolu, Kocaeli, Sakarya, which are the supplier of the firm, is the optimum location within the framework of determined criteria. For this purpose, analyzes have been performed with ÇKKV methods. In this respect, the best supplier choice constitutes the goal of work and is included in the objective part of the decision analysis model.

4.3. Description of Criteria

After the problem has been defined in each dimention, more than one criterion that is effective in the warehouse location selection decision is defined in Super Decision (SD) and Expert Choice programs. Accordingly, the criteria are six, including Infrastructure, Cooperation, Location, Cost, Sales and Shipment.

4.4. Description of Alternatives

Once the criteria have been transferred to the relevant interfaces of the programs, four alternative locations have been identified where the most suitable warehouse location selection decision for the operation can be made. Alternative places determined for the study are Düzce, Bolu, Sakarya and Kocaeli.

4.5. Creating the Decision Analysis Structure

The most important stage of the MCDM process is the phase of the creation of a hierarchical model. In this phase, a hierarchical decision analysis model was established for the criteria determined in the second stage and for the alternatives in the third stage, starting from the goal determined in the first stage. This model is shown in Figure 3.

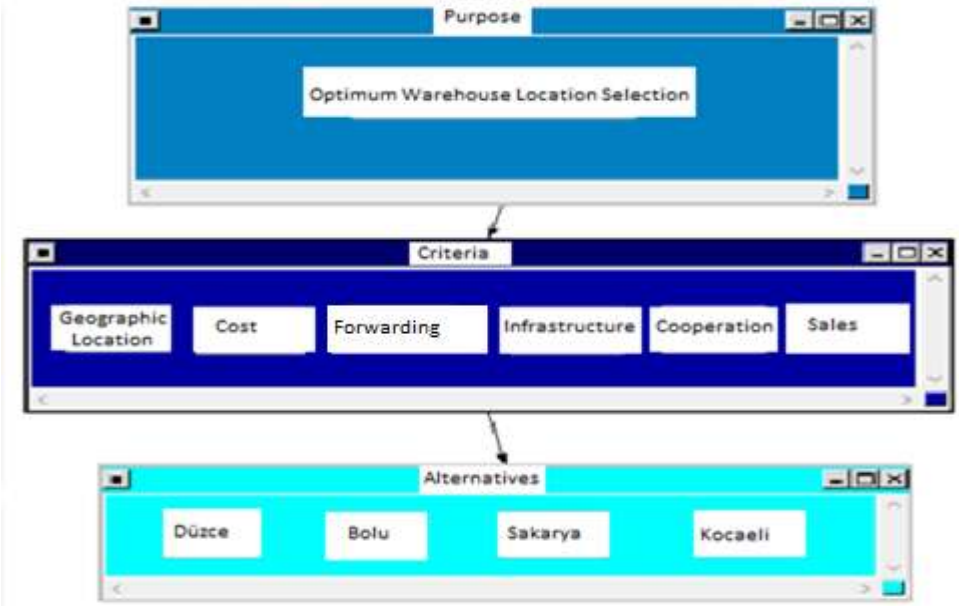

Figure 3. Model of Decision Analysis of Warehouse Location Selection

Evaluation of both qualitative and quantitative factors that are required for the study revealed the use of MCDM method requirements. It has been concluded that it is more appropriate to use AHP and VIKOR approaches in decision analysis methods in order to reduce the error risk in the decision stage.

4.6. Pairwise comparison of Criteria

At this stage, the criteria and alternatives at each level within the hierarchical structure of the model are mutually compared with each other. Thus, binary benchmarking matrices of all criteria and alternatives are established. In each of these matrices, each criterion is compared to itself, and there is a continuous 1 value on the diagonal of the comparison matrix expressed in Table 5.

Table5. Pairwise Comparison of Criteria and Weights

	Infrastructure	**Cooperation**	**Location**	**Cost**	**Sales**	**Forwarding**	**Weight**	**Consistency ratio**
Infrastructure	1	2	0.167	0.143	0.143	1	0.046	0.0707<0,1 Matrix is consistent
Cooperation	0.5	1	0.111	0.143	0.143	0.143	0.027	
Location	6	9	1	1	2	7	0.326	
Cost	7	7	1	1	1	6	0.275	
Sales	7	7	0.5	1	1	7	0.259	
Forwarding	1	7	0.143	0.167	0.143	1	0.067	

The weight of each criterion is determined by the comparison matrix of the criteria expressed in Table 5 and it is understood that the value of 0.0707 which is the result of the calculations that the evaluator has made the evaluation for the criteria is smaller than 0.1 value.

4.7. Calculation of Total Priorities for Criteria and Alternatives

In order to determine the weights of criteria and alternatives, a decision matrix containing priority values needs to be established.

Tablo 6. Decision Matrix

	Infrastructure	Cooperation	Location	Cost	Sales	Forwarding
Düzce	0.40787	0.66667	0.30804	0.26213	0.32922	0.32983
Bolu	0.42178	0.08611	0.50932	0.54131	0.47275	0.43990
Sakarya	0.5556	0.09167	0.06409	0.04519	0.05486	0.04990
Kocaeli	0.11480	0.15556	0.11855	0.15207	0.14317	0.18037

The values of the criteria for each alternative are expressed by the decision matrix shown in Table 6. For example, it is understood that the value of the Düzce alternative is 0.40787 according to the Infrastructure Criteria.

4.8. VIKOR Method and Steps

The steps of the VIKOR method are in fact similar to the AHP method until the determination of the decision matrix. For this reason, in the studies in which the AHP-VIKOR methods are used together in the literature, evaluation analysis is applied together to the decision matrix stage.

Table 7. Best (f *) and Worst (f -) Values for Each Criteria

Criteria	f_i^*	f_i^-
Infrastructure	0.42178	0.05556
Cooperation	0.66667	0.08611
Location	0.50932	0.06409
Cost	0.54131	0.04519
Sales	0.47275	0.05486
Forwarding	0.43990	0.04990

In Table 7, the best and worst values of each criterion are determined according to the values in the decision matrix and presented.

Table 8. Ranking Results of Suppliers by VIKOR Method

	Sj	Rj	Qj	Evaluation according to Sj	Evaluation according to Rj	Evaluation according to Qj
Düzce	0.4115	0.1547	0.4111	Bolu	Bolu	Bolu
Bolu	0.0270	0.0270	0	Düzce	Düzce	Düzce
Sakarya	0.9997	0.3260	1	Kocaeli	Kocaeli	Kocaeli
Kocaeli	0.8055	0.2861	0.8333	Sakarya	Sakarya	Sakarya

In Table 8, Sj, Rj, and Qj calculated according to the VIKOR method are ranked according to their alternative suppliers' priorities.

4.9. Acceptability Test Results and Comments by VIKOR Method

Acceptable Advantage Condition: $Q(A^{II}) - Q(A^{I}) \geq .DQ$
Since $0.4111 - 0 \geq 0.333$ is obtained, an acceptable advantage condition is provided..

Acceptable Stabilization Condition: In order to achieve this condition, the same priority order must occur in at least two of the sequences according to Sj, Rj and Qj. When Table 8 is examined, the acceptable stability condition is provided since all three orders according to Sj, Rj and Qj have the same ranking priorities.The acceptability test according to the VIKOR method is audited according to whether the above conditions are met. These conditions seem to have been met. For this reason, there is no need to try different compromise methods.

4.10. Findings and Comments

Regarding warehouse location selection data of the firm, programs have been run since the application was transferred to the Super Decision 2.7 and Expert Choice.11 programs. First, the decision matrix values given in Table 6 are calculated based on the comparison matrix and the consistency analysis, which include the mutual comparison of the criteria expressed in Table 5. Taking these values into consideration, the best and worst values for each criterion in the VIKOR method steps are expressed in Table 7. Sj, Rj and Qj values are calculated for the best and worst criterion values respectively, and the order of alternatives according to these values is given in Table 8. According to the findings of this study, when alternative warehouse locations were sorted according to the AHP-VIKOR method, the most suitable locations were determined as Bolu, Düzce, Kocaeli, and Sakarya respectively.

V. CONCLUSION

In today's business world, Firms consider their costs to gain competitive advantage in the sector. They try to increase their profitability by reducing their operating costs, and they gain a competitive advantage by being financially stronger. Cost reduction is required, cost analysis should be done and appropriate decisions must be made by making the right choices and appropriate methods in the direction of this analysis. One way to reduce costs is to optimize warehouse location selection. Determining the optimum warehouse location provides many benefits such as reaching on time to customer, reduction of costs (land, transportation, etc.), taxation, labour force and closeness to raw materials. In this study, it has been aimed to determine the optimum warehouse location of a retail firm among four cities, Düzce, Bolu, Sakarya, Kocaeli, in eastern Marmara Region. Criteria and optimum alternatives have been determined by 3 expert of the firm in each cities and experts has been interviewed to form the criteria first. Afterwards, data were obtained through questionnaires and the four alternatives were sorted by AHP and VIKOR methods. According to the results of the research, Bolu, Düzce, Kocaeli, and Sakarya sequences have been determined as optimum, respecitively. This result indicates that the firm does not located in optimum places, wihich is Düzce, currently. Due to AHP and VIKOR techniques are rarely used in the retail sector in the Turkish literature, the study shows originality. One of the limitations of the study is that number of consulted experts might be more than twelve.

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