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Multiple Criteria Decision Model Suggestion for Determination of Technological Innovation of Logistics Firms

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Abstract. The purpose of this study is to develop a model for determination of technological innovation level of logistics firms. The suggested model is used on the ranking of logistics firms listed in 2015 Fortune 500 Turkey according to their technological innovation levels. With this purpose, the study is conducted in two phases. In this first phase, a multiple criteria decision model is developed using Delphi Method to be used in determination of technological innovation levels of logistics firms. In the second phase, the suggested model is tested using Analytical Hierarchy Process (AHP), TOPSIS, VIKOR and Bord a method in order. Study findings show that the suggested model is applicable and can be used for determination of technological innovation level of logistics firms. Additionally, according to analysis results; it is concluded that "radical innovation" is the main criterion and "big data" is the most important sub-criterion. C firm is determined as having the highest level of technological innovation level.
Keywords. Logistics, Innovation, Technological Innovation, Delphi Method, AHP, TOPSIS, VIKOR, Borda.
JEL. O31, O35, Q55.

1. Introduction

Rapid growth experienced in technology in 21th century brought the question of in which ways companies would be able to achieve competitive advantage and it is concluded in many studies that the advantage can only be achieved with innovation (Lin, 2006). With an efficient innovation management, companies may have many opportunities related to increasing revenues, decreasing costs and competitive advantage (Busse & Wallenburg, 2014). In other words, the companies which follow technological innovations and direct production methods with innovative management approach; and manage activities depending on market demand levels, establish structure and corporate policies depending on this approach can reach their targets more rapidly (Taşkın, 2014).

Costs related to logistics services which consist of almost 13% of global economy raise the necessity of innovative system designs to be able to decrease costs and manage logistics processes more efficiently in terms of both the related service takers and service providers (Sümer, 2008). As having an importance in logistics processes, success of firms which offer logistics services is highly related

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to implementing innovative methods about problem solving. (Bellingkrodt & Wallenburg, 2013).

Technology plays an important role on providing advantage of cost efficiency in addition to present location and time utility to logistics firms in terms of competitive advantage; so that with this perspective, technological innovation activities become one of the performance components which directly affect the competition power of firms which offer logistics services (Acar, 2010). Additionally, Grawe (2009) states that technological innovation subject has not been sufficiently discussed in the studied related to logistics areas.

Technological innovation problem in logistics firms is a multiple criteria decision problem which includes quantitative and qualitative factors. In this context, Peker et al. (2015) state that such model should be developed as emphasizing the lack of multiple criteria decision model which can be used on determination of technological innovation levels of logistics firms, in their study. In parallel with this suggestion, the main purpose of this study is determined to develop a multiple criteria decision model which can be used on determination of technological innovation levels of logistics firms with Delphi Method as taking ideas of stakeholders. The other purpose of this study is to test the suggested model in sample of logistics firms listed in 2015 Fortune 500 Turkey list using AnalyticalHierarchy Process (AHP), TOPSIS, VIKOR and Bordamethods.

In the following section of this study, which is consisted of totally five sections, literature review related to innovation in logistics firms is presented and in the latter section, the methods utilized in this study are presented. In the fourth section, the details related to the application are presented and in the conclusion and suggestion section, the study is concluded.

2. Literature review

Studies focusing on both logistics and innovation subjects will be presented in this section. Accordingly, in the study conducted by Kandampully (2002) which focuses on the criteria which should be taken into account in service innovation applications, the factors are determined as technology, information and relation network. Soosay& Hyland (2004) compare the innovation applications in logistics activities implemented in distribution centers in Australia and Singapore. Lin (2006), in the study where the factors affecting technological innovation application of logistics service providers in Taiwan are analyzed, using regression analysis it is determined that technological, organizational and environmental characteristics have positive effects on technological innovation. Lin (2008), in the study about logistics service providers in China, determined that technological innovation application have technological, organizational and environmental effects on the related firms therefore through this way, the performance of supply chain is increased. As a result of the applications performed by logistics firms in Taiwan Lin & Ho (2008) determined that technological, organizational and environmental phases are effective on firms' green logistics application. Wagner (2008) discussed management of innovation processes for logistics firms. In this context, innovation applications are evaluated under titles of developments in internal and external researches, capital and structure investments, information gain and education for next generations.

In their studies where Srinivas & Krishna (2009) discussed technological innovation for India logistics sector, they concluded that with reflection of technological innovation application to transportation modes, costs could be reduced. Wagner & Sutter (2012) stated that third party logistics firms gain better image in customers' mind with innovation application and they have competitive advantage as improving their relationships with customers. In their study where Yang et al. (2012) analyzed the moderator effect of innovation ability on the relationship between logistics service ability and firm performance of the firms performing maritime freight; they collected logistics service ability into four categories. These categories are logistics service credibility ability, flexibility ability, logistics value added service ability and logistics information service ability. Multiple regression analysis results showed that innovation ability, logistics service credibility ability and flexibility ability have positive effects on firm performance.

Bellingkrodt & Wallenburg (2013) stated that for logistics service providers,good relationships established with other service provider firms are effective in firms' innovation applications. De Martino et al. (2013) researched logistics innovation applications for port companies and presented a comprehensive literature research related to the subject. Gargaras & Mugiene (2013) studiedlogistics service provider firms' innovation applications in information management. Aiming to emphasis the importance of logistics innovation in transportation, Antonowicz (2014) offers transportation clusters as a logistics innovation application for the related sector. Busse &Wallenburg (2014) stated that innovation level in logistics firms are effected by factors including firms' scale, growth potential, customer loyalty and personnel innovation ability. Lee et al. (2014) tested the relationship between technological innovation and green supply chain application in production firms located in Malaysia. As a result of the analysis it was concluded that there was not an important level of positive correlation between the variables. In their studies where Shong-Iee et al. (2014) analyzed innovation competition of third party logistics service providers, they considered six factors as new value creation, external relations, job completion levels, organizational transition, multiple level service offers and supply chain performance.

In their studies Ho & Chang (2015) analyzed the relationship between innovation opportunities, service opportunities and firm performance in logistics firms. As a result of statistical analyses, it is found out that the increase in innovation opportunities and service opportunities increases firm performance. In their studies Hong et al. (2015) researched the relationship between product-service system and firm performance. As a result of study, it is concluded that technological innovation application in product and processes are effective on that product service performance are effective on firm performance. Hui-Ying &Shuang (2015) tested the relationship between technological innovation and intellectual capital in technological production firms in China. The study findings show that the internal and external social capital, as being the two phase of intellectual capital, have positive effect on technological innovation. While analyzing innovation applications in freight transportation using multiple criteria methods, Permela et al. (2015) took into account the criteria such as strategic targets and transferability of the newest applications. As developing a performance application for maritime logistics sector with innovation and technology experts using Analytical Hierarchy Process (AHP), Qu et al. (2015) determined that the criterion of "business performance" has the highest level of importance.

In general, as seen from the above mentioned studies limited number of studies have been conducted on technological innovation in logistics firms. Additionally, in their studies where Peker et al. (2015) ranked technological innovation levels of logistics firms operated in Borsa Istanbul, they only could consider the study of Germain (1996) since there is no consensus related to logistics technological innovation criterion. On the other hand, in this study, the main purpose is to develop multiple criteria decision model which can be used in determination of technological innovation levels of logistics firms as paying attention to the stakeholders of the related subject using Delphi Method. Then, ranking the logistics firms in 2015 Fortune 500 Turkey list using methods of AHP, VIKOR, TOPSIS, and Bordain order to test the suggested model is the other purpose of this study.

3. Method

Delphi, AHP, TOPSIS, VIKOR and Borda methods are considered in order, in this section.

3.1. Delphi Method

This method, which is used to get insights about a subject on which a consensus is tried to be reached, was developed by RAND Corporation in 1950s (Casifo et al., 2013; Üreten, 2013). This method is used in various areas including planning, demand evaluation, policy determination and source utilization (Ahn et al., 2014). As different than other decision making methods, a set of characteristics are used in Delphi method (Kardaras et al., 2013; Kauko & Palmroos, 2014; Jorm, 2015): (i) a decision maker is not aware of other decision makers (unawareness), (ii) till a consensus is created by experts, the statistical results of repetitive surveys are submitted to the decision makers and the chance of revising their decision is provided (controlled feedback) and (iii) the results of each Delphi survey are statistically analyzed as average, median, minimum and maximum (statistical analysis); are the main characteristics. Not having consensus about logistics technological innovation criteria in the related literature is the main reason to choose Delphi method and above mentioned characteristics are also the other reasons of utilizing this method in this study. The purpose of this is to create a consensus about logistics technological innovation criteria.

Two different methods as "Traditional Delphi Technic (as also known hard copy written version)" and "Real Gain Delphi Technic (performed in electronic environment as enabling effective use of time)" are used in order to submit the surveys to the participants and to collect data in Delphi Technic (Karacaoğlu, 2009). In our study, Real Gain Delphi Technic is preferred to reach more decision maker at the same time and to use time effectively. The decision maker group in this technic should be 5-50 people whose identities are unknown and who have information and experience in the related subject (Kabir&Hasin, 2013). In his study, Ziglio (1996) stated that expert group consisted of 10-15 people were ideal (Day&Bobeva, 2005). The application steps in this method could be listed as follows (Kabir&Hasin, 2013):

1. *Step:* Problem Determination
2. *Step:* Expert Selection
3. *Step:* Preparation and analyzing the 1st survey and submitting the result to the decision makers
4. *Step:* Preparation and analyzing the 2nd survey and submitting the result to the decision makers and requesting them to test their decisions
5. *Step*: Till gaining a consensus, repeating the 2nd and 3rd steps and gaining a consensus

3.2. Analytical Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a method which is used when relative priorities among criteria would like to be obtained (Saaty, 1986). Especially, relative measurement is preferred in case that there are many qualitative criteria influencing decision problem (Saaty 1986). This method is used to determine the priorities (weights) which are obtained through binary comparisons of criteria (Saaty, 2003). Below mentioned steps are followed in order while making decision with AHP (Saaty, 1986; Saaty, 2008; Agus et al., 2014):

- Problem determination
- Decision problem is converted to a hierarchic structure which includes purpose, criteria, sub-criteria and alternatives, in order.
- Binary comparison matrix is created. Criteria and sub-criteria are compared as binary using the scale (Table 1) developed by Saaty and binary comparison matrix (1) is created.

Table 1. *Binary Comparison Scale*

Relative priority level	Explanation (between i and j criteria)
1	Two criteria affect the purpose with same level.
3	From the two criteria, (i) is slightly more important on the purpose in comparison to (j)
5	From the two criteria, (i) is more important on the purpose in comparison to (j)
7	From the two criteria, (i) is much more important on the purpose in comparison to (j)
9	From the two criteria, (i) is definitely much more important on the purpose in comparison to (j)
2,4,6,8	Intermediate values

Setting $a_{ji=}$ $1/a_{ij}$; a binary comparison matrix is established as A= nxn.

$$A = \begin{array}{c|ccccc} & K_1 & K_2 & K_3 & \dots & K_n \\ K_1 & 1 & a_{12} & a_{13} & \dots & a_{1n} \\ K_2 & a_{21} & 1 & a_{23} & \dots & a_{2n} \\ K_3 & a_{31} & a_{32} & 1 & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ K_n & a_{n1} & a_{n2} & a_{n3} & \dots & 1 \end{array} \quad (1)$$

After normalization of binary comparison matrices (2), relative weights of criteria (3) are obtained.

$$b_j = \sum_{i=1}^{n} a_{ij} \qquad (j = 1, 2, 3, ..., n) \qquad\qquad \sum_{i=1}^{n} w_i = 1$$

$$A^* = \begin{bmatrix} 1/b_1 & a_{12}/b_2 & a_{13}/b_3 & \dots & a_{1n}/b_n \\ a_{21}/b_1 & 1/b2 & a_{23}/b_3 & \dots & a_{2n}/b_n \\ a_{31}/b_1 & a_{32}/b2 & 1/b_3 & \dots & a_{3n}/b_n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1}/b_1 & a_{n2}/b2 & a_{n3}/b_3 & \dots & 1/b_n \end{bmatrix} = \begin{bmatrix} a^*_{11} & a^*_{12} & a^*_{13} & \dots & a^*_{1n} \\ a^*_{21} & a^*_{22} & a^*_{23} & \dots & a^*_{2n} \\ a^*_{31} & a^*_{32} & a^*_{33} & \dots & a^*_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a^*_{n1} & a^*_{n2} & a^*_{n3} & \dots & a^*_{nn} \end{bmatrix} \quad (2)$$

$$w_i = \sum_{j=1}^{n} a^*_{ij} \Big/ n, \quad (i = 1, 2, 3, ..., n) \qquad\qquad W = \left(w_1, w_2, w_3, \dots, w_i, \dots, w_n\right) \quad (3)$$

Consistency of binary comparison matrices is calculated. If CR≤0,10; matrix is considered as consistent, otherwise either binary comparison matrix is not evaluated or re-compared. As λ_{max} is the maximum eigenvalue and RI is the random index;

$$CR = \frac{CI}{RI} \qquad\qquad \text{CI} = (\lambda_{\max} - n)/(n-1) \quad (4)$$

Table 2. *Random Indicators*

N	3	4	5	6	7	8	9	10
Random Indicator	0 ,58	0 ,90	1 ,12	1 ,24	1 ,32	1, 41	1, 45	1,4 9

3.3. Topsis

This method which focuses on the farthermost alternative to the negative ideal solution and the closest alternative to the positive ideal solution in the solution process of multiple criteria decision model was developed by Hwang & Yoon (1981) (Jadidi et al., 2008). Positive criteria maximizes utility value while negative solution idea minimizes utility value as maximizing cost (Venkatesh et al., 2015). In this context, the most ideal alternative is considered as the one which is the closest to the ideal solution as being the farthermost to the negative ideal solution (Opricovic & Tzeng, 2004).

Assume that a decision matrix consisted of n amount of alternatives and m amount of criteria is as $S=(s_{ij})_{nxm}$. Additionally, relative weights of criteria are $w=(w_1, w_2, w_{3\ldots}, w_{j\ldots} w_m)$ andtheir sum is equal to 1. In this situation, the application steps of TOPSIS method could be listed as follows (Opricovic & Tzeng, 2004; Shih, 2008):

Establishing normalized decision matrix.

$$k_{ij} = s_{ij} \Big/ \left(\sum_{t=1}^{n} s_{tj}^{2} \right)^{\frac{1}{2}}, \quad (i = 1, 2, 3, \ldots, n;\ j = 1, 2, 3, \ldots, m) \tag{5}$$

Calculation of weighted normalized decision matrix

$$a_{ij} = w_j k_{ij}, \quad (i = 1, 2, 3, \ldots, n;\ j = 1, 2, 3, \ldots, m) \tag{6}$$

Ideal (A^*) and negative ideal solution (A^-) are determined. Here, Icriteria which provide utility and I' criteria which provide cost.

$$A^* = \left\{ a_1^*, a_2^*, a_3^*, \ldots, a_i^*, \ldots, a_m^* \right\} = \left\{ \left(\max_i a_{ij} \,\middle|\, j \in I \right), \left(\min_i a_{ij} \,\middle|\, j \in I' \right) \right\} \tag{7}$$

$$A^- = \left\{ a_1^-, a_2^-, a_3^-, \ldots, a_i^-, \ldots, a_m^- \right\} = \left\{ \left(\min_i a_{ij} \,\middle|\, j \in I \right), \left(\max_i a_{ij} \,\middle|\, j \in I' \right) \right\} \tag{8}$$

Using n-dimension Euclid distance function, the distance of each alternative to ideal solution (E_j^*) and to negative ideal solution (E_j^-) is calculated.

$$E_i^* = \left(\sum_{j=1}^{m} \left(a_{ij} - a_j^* \right)^2 \right)^{\frac{1}{2}}, \quad i = 1, 2, 3, \ldots, n \tag{9}$$

$$E_i^- = \left(\sum_{j=1}^{m} \left(a_{ij} - a_j^- \right)^2 \right)^{\frac{1}{2}}, \quad i = 1, 2, 3, \ldots, n \tag{10}$$

The proximity to ideal solution (C_i) is calculated.

$$C_i = E_i^- \Big/ \left(E_i^* + E_i^- \right), \quad i = 1, 2, 3, \ldots, n. \tag{11}$$

According to priority levels, they are ranked (descending).

3.4. VIKOR

This method was developed for optimization of complex systems with multiple criteria and it helps decision makers to have final decisions as providing convenient solutions in problems related to select and rank the alternatives affected by criteria which conflict each other (Opricovic & Tzeng, 2004). The solution provided here is an agreeable solution (including one or more suggestion(s)) which is proximate to the ideal solution as depending on mutual exchanges of idea. In TOPSIS, which is another system focusing on the distances, the point which is closest to the ideal solution and farthermost to the negative solution is determined and the relative importance of these distances is not considered (Opricovic & Tzeng, 2007).

Assume that decision matrix consisted of n amount of alternatives and m amount of criteria as $T=(t_{ij})_{nxm}$. Additionally, relative weights of criteria are w= (w_1, $w_{2,}$ $w_{3\ldots,}w_{j\ldots}w_m$) and their sum is equal to 1. In this situation, the steps to follow in VIKOR method are as follows (Opricovic & Tzeng, 2004; Opricovic & Tzeng, 2007; Wang &Tzeng, 2012; Chiu et al., 2013; Kang & Park, 2014):

As I utility providing criteria and I' cost creating criteria; the best (t_j^*) and the worst (t_j^-) values of criteria functions are calculated.

$$t_j^* = \begin{cases} \max\limits_i t_{ij} & j \in I \\ \min\limits_i t_{ij} & j \in I' \end{cases} \quad , \quad (i=1,2,3,\ldots,n, \quad j=1,2,3,\ldots,m) \tag{12}$$

$$S_i = \sum_{j=1}^{m} w_j \left(t_j^* - t_{ij}\right) / \left(t_j^* - t_j^-\right), \tag{13}$$

$$R_i = \max_j \left[w_j \left(t_j^* - t_{ij}\right) / \left(t_j^* - t_j^-\right) \right]$$

Setting i= 1,2,3,…,n and j=1,2,3,…,n ; values of S_i and R_i are calculated.

$$S_i = \sum_{j=1}^{m} w_j \left(t_j^* - t_{ij}\right) / \left(t_j^* - t_j^-\right), \tag{14}$$

$$R_i = \max_j \left[w_j \left(t_j^* - t_{ij}\right) / \left(t_j^* - t_j^-\right) \right] \tag{15}$$

Step 3: Q_i calculated. = 1,2,3,…,n and j=1,2,3,…,n so that $S^*= \min_i S_i$, $S^- = \max_i S_i$, $R^*= \min_i R_i$, $R^- = \max_i R_i$, and v, 1-v are the maximum group utility and individual regret weights, in order;

$$Q_i = v\left(S_i - S^*\right)/\left(S^- - S^*\right) + (1-v)\left(R_i - R^*\right)/\left(R^- - R^*\right) \tag{16}$$

According to S, R and Q values, the alternatives areordered as ascending

If the below mentioned conditions are met as $A^{(i)}$ is ith alternative corresponding to $Q_{i,}$ $A^{(1)}$ is suggested as the best alternative corresponding to minimum Q_1

Condition 1 $\quad Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq 1/\left(n-1\right)$ (17)

Condition 2 $\quad A^{(1)}, A^{(2)}, A^{(3)}, \ldots, A^{(K)}$ (18)

should have the best ordering in S or R.

Compromised solution set consisted of $A^{(1)}$ and $A^{(2)}$ alternatives are suggested if condition 2 is not met or compromised solution set consisted of $A^{(1)}$, $A^{(2)}$, $A^{(3)}$,…., $A^{(k)}$ alternatives are suggested if condition 1. $A^{(k)}$ is determined for Maximum K using the equation below.

$$Q\left(A^{(K)}\right)-Q\left(A^{(1)}\right)<1/(n-1) \qquad (19)$$

3.5. BORDA Method

It is technic used in obtaining a single result as combining the related ordering in case of utilizing carious methods for alternative ordering (Momeni et al., 2011). Each of the multiple criteria decision making method ranks thealternatives and uses point as k-1 as Bordapoint in order to show k alternative number for the alternative which gains the maximum point (Pourjavad&Shirouyehzad, 2011). Likewise, Bordapoints gained in all other methods are calculated and summed so that a single point is obtained.

4. Application

Another purpose of this study, in which the main purpose is to develop a multiple criteria decision model that can be used in determination of technological innovation levels of logistics firms, is to test the suggested model in the sample of logistics firms which are listed in 2015 Fortune 500 Turkey list. In this direction, the application steps which are followed in this study are presented in Figure 1.

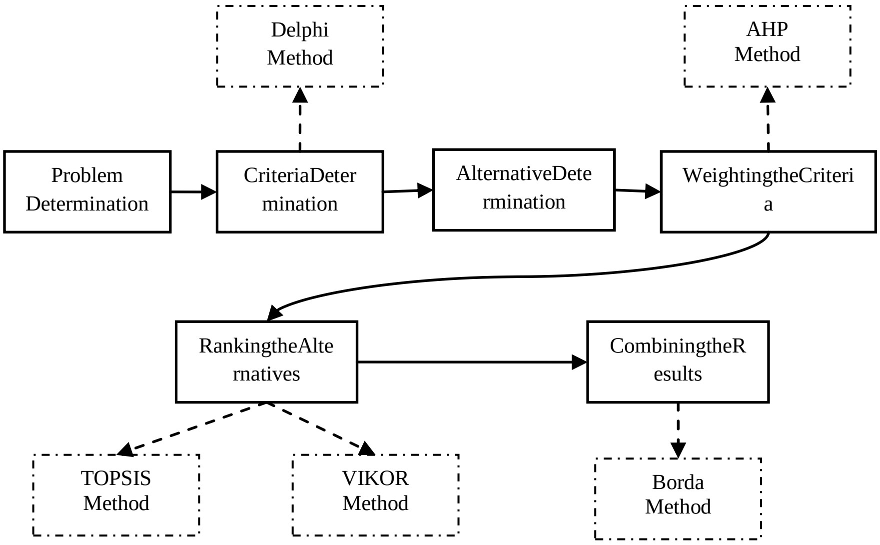

Figure 1. *Steps of Research Method*

4.1. Problem Determination

The first step of this study is to determine the decision problem which is intended to be solved. The decision problem in this study is;

i) Determination of logistics technological criteria and

ii) Determination of the logistics firm which has the highest level of technological innovation

4.2. Criteria Determination

Delphi method, which is used to get insights about a subject on which a consensus would like to be gained, is utilized in determination of the related criteria since there is no consensus about logistics technological innovation criteria and there are limited number of studies in the related literature. The application steps of this method are summarized as follows:

a) Problem *Determination:* The decision problem in this step is to determine logistics technological innovation criteria.

b) Expert Selection: The experts, whom will be selected for the application of Delphi method, should have sufficient knowledge and experience in the related subject in order to obtain accurate results. Two important factors are considered while establishing the decision maker group: i) sustaining ideal group size (10-15 people) of Delphi method and ii) the related group should have sufficient knowledge for determination of criteria.

With this direction, the decision maker group is established from 4 groups and 12 people consisting of academicians (5 people), public institution representative (1 person), logistics company executives (4 people) and manufacturing company managers (2 people). It would be beneficial to introduce decision maker group characteristics:

Academicians group is consisted of 5 academicians who work on logistics and innovation fields. The academicians work in different universities.

1 public institution representative represents Ministry of Science-Industry and Technology which has mission of developing policy, strategy and programs in the areas of science, art and technology.

4 executives from logistics companies whose technological structure has reached to higher levels over days as performing in logistics activities.

Managers of manufacturing companies which outsource majority of their activities from logistics firms.

c) Preparation and analyzing the 1st Delphi survey and submitting the result to the decision makers: The open-ended question "What are the criteria which can be used in determination of technological innovation level of a logistics firm" is asked to decision maker group in this step. The answers are statistically analyzed as average, median, minimum and maximum values, then 1st step of Delphi method is completed.

d) Preparation and analyzing the 2nd Delphi survey and submitting the result to the decision makers and requesting them to test their decisions: The information obtained as a result of the 1st step is submitted to the decision maker group and they are requested to revise their decisions depending on the related data. All of the decision makers state that the decisions they provided in the first step are not changed so that Delphi method is completed in the 2nd step and a consensus is gained. The related criteria are collected under two main criteria as radical and proportional innovation (Oke, 2007) in accordance with the change and differentiation degree caused by innovation in the framework of expert ideas. The logistics technological innovation criteria obtained in this direction are provided in Table 3.

Table 3. *Criteria which can be Used İn Determination of Logistics Technological Innovation Level*

Main Criterion	Symbol	Sub-Criterion
Radical Innovation	C_1	Communication Systems among Machines (Machine to Machine- M2M)
		Communication Systems among Vehicles(Vehicle to Vehicle- V2V)
		Cloud Technology
		Internet of Object
		Increased Reality
		Big Data
		Internet Optic
		Robots
		Gathering System with Light and Voice
		Disintegrating and Telescopic Conveyor Systems
Proportional Innovation	C_2	Electronic Data Change
		Planning System Software (e.g. ERP-MRP-DRP)
		Warehouse Management System Software
		Automatic Weight and Size Measurement Systems
		Barcode and RFID Identification Systems
		Automatic Storage Systems
		Vehicle Applications with Automatic Direction
		Demand Planning and Stock Optimization Software
		Airline-Highway-Maritime-Railway Transportation Software
		Vehicle Loading – Routing and Tracking Systems
		TMS Software (Proposal Management, Fleet Management and Documentation)
		Network Design Optimization

4.3. Alternative Determination

The third step of the research method is to determine the alternatives which will be used in solution of decision problem. In determination of the criteria, the factor that companies use or are able to use the criteria determined above is taken into consideration. In this context, alternatives are determined as the logistics firms listed in 2015 Fortune 500 Turkey list.

It would be beneficial to present some information related to alternatives. The word “logistics” is written to the company search box in Fortune 500 Turkey and 9 companies are listed. Although one of these companies has “logistics” word in its name, it is excluded from this research since it does not use the above mentioned criteria and it stated that it does not have knowledge related to those criteria. Regarding other 8 firms, it can be stated that they perform activities of “storage” and “transportation” together as being main activities of logistics management. Additionally, each of these companies are based in Istanbul and their net profits belong to 2015 vary from 300.000.000 TRY to 1.300.000.000 TRY. The firms are called as A, B, C, D, E, F, G and H in this study. Information related to these firms’ storage, distribution and transportation activities are presented in Attachment-1.

4.4. Determination of Criteria Weights

In this step of the study,binary comparison survey which includes criteria obtained in Delphi method is presented to the decision maker group and weights for main criteria and sub-criteria using formulas mentioned in AHP process are presented in Table-4 in direction of the obtained answers. At this point, it must be stated that all the results are consisted since the consistency rates in all matrices are less than 0,10.

Table 4. *Weights Belong to Main Criteria and Sub-Criteria*

Main Criteria	Weights	Sub-Criteria	Weights
Radical Innovation	0,85	Communication Systems among Machines (Machine to Machine- M2M)	0,074
		Communication Systems among Vehicles(Vehicle to Vehicle- V2V))	0,100
		Cloud Technology	0,182
		Internet of Object	0,091
		Increased Reality	0,041
		Big Data	0,222
		Internet Optic	0,041
		Robots	0,045
		Gathering System with Light and Voice	0,031
		Disintegrating and Telescopic Conveyor Systems	0,031
Proportional Innovation	0,15	Electronic Data Change	0,005
		Planning System Software (e.g. ERP-MRP-DRP)	0,016
		Warehouse Management System Software	0,017
		Automatic Weight and Size Measurement Systems	0,005
		Barcode and RFID Identification Systems	0,017
		Automatic Storage Systems	0,016
		Vehicle Applications with Automatic Direction	0,014
		Demand Planning and Stock Optimization Software	0,010
		Airway-Roadway-Maritime-Railway Transportation Software	0,008
		Vehicle Loading – Routing and Tracking Systems	0,010
		TMS Software (Proposal Management, Fleet Management and Documentation)	0,010
		Network Design Optimization	0,016
TOTAL	1,00		1,00

According to Table-4;

Radical innovation main criterion is more important than proportional innovation at a rate of 5.6.

Additionally, the most important three radical innovations are determined as “Big Data”, “Cloud Technology” and “Communication Systems among Vehicles (Vehicle to Vehicle- V2V)”.

“Gathering System with Light and Voice” and “Disintegrating and Telescopic Conveyor Systems” are radical innovation sub-criteria which have equal and the least level of importance.

In the set of proportional innovation, “Warehouse Management System Software” and “Barcode and RFID Identification Systems” are sub-criteria which have equal and the highest level of importance.

“Planning System Software”, “Automatic Storage Systems” and “Network Design Optimization”, which have equal importance, follow those criteria.

“Electronic Data Change” and “Automatic Weight and Size Measurement Systems” are proportional innovation sub-criteria which have least level of importance.

As evaluating all criteria together, “Big Data” is found as the most important sub-criterion.

4.5. Ranking the Alternatives

In this phase, in which methods of TOPSIS and VIKOR are utilized in order,a survey is created, through which all the criteria obtained in Delphi method can be evaluated for all alternatives and it is presented to the executives of 8 companies. The company executives are requested to mark their companies through 1-5 point(s) (1:minimum; 5:maximum) for each represented criterion. Through the formulas which are mentioned in the related section, they are analyzed and the results are presented in Table-5 and Table-6.

Table 5. TOPSIS Results

Alternatives	c_j	Ranking
A	0,561	2
B	0,283	4
C	0,693	1
D	0,237	7
E	0,290	3
F	0,241	5
G	0,240	6
H	0,027	8

According to Table-5; Firm C is the company which has the highest level of technological innovation level. This company is followed by A, E, B, F, G, D and H as in order.

Table 6. VIKOR Results

Alternatives	For V= (0,5) Q_i values	Ranking
A	0,385	2
B	0,613	4
C	0,000	1
D	0,679	5
E	0,581	3
F	0,684	6
G	0,696	7
H	1,000	8

In Table-6 as taking v=0,5; Firm C is found as the company which has the highest level of technological innovation level. This company is followed by A, E, B, D, F, G, and H in order. Additionally, for v=0,5 Conditions 1 and 2 are met.

4.6. Combining the Results

This phase of the model aims to combine the results obtained through methods of TOPSIS and VIKOR. For this, k-1 point is assigned to three alternatives which is given the highest point in each method “in order to show k alternative number”; as also mentioned in Borda method. Since the alternative number is 8 in this study, the logistics firm ranked as number one takes 7 as Borda value; and Borda points are given to the following firms. Hence, the firm which hasthe highest Borda point is considered as the firm which has the highest level of technological innovation level. The related calculations are presented in Table-7.

Table 7. Combined Results

Alternatives	TOPSIS Ordering	Borda Point Depending on TOPSIS Ordering	VIKOR Ordering	Borda Point Depending on VIKOR Ordering	TOTAL Borda POINT	Combined Ordering
A	2	6	2	6	12	2
B	4	4	4	4	8	4
C	1	7	1	7	14	1
D	7	1	5	3	4	6
E	3	5	3	5	10	3
F	5	3	6	2	5	5
G	6	2	7	1	3	7
H	8	0	8	0	0	8

According to Table-7; the firm C has the highest level of technological innovation. This firm is followed by A, E and B in order. On the other hand, firm H has the lowest level of technological innovation. Since firms D, F and G are ranked differently in Table 5 and Table, a necessity to combine results is arisen so that

Borda method is utilized. Using the method results are obtained as firms F, D and G ar ranked as 5., 6. and 7.respectively.

5. Conclusion

In today's world where competition has increases steadily over time.Especially manufacturing enterprises prefer supplying their logistics activities from logistics firms (3PL) in order to focus on the main activity areas, to decrease costs and to increase customer satisfaction. 3PL firms' ability to meet the demands of manufacturing enterprises depends on getting along with the advanced technology and being adaptable for innovation investments. Accordingly, the lack of a multiple criteria technological innovation decision model which can be used in order to determine the levels of logistics technological innovations of logistics firms based in Turkeyis emphasized in the study which was conducted by Peker et al. (2015). Hence, the main purpose of this study is to develop a multiple criteria decision model which can be used in determination of technological innovation levels of logistics firms. Another purpose of this study is to determine the technological innovation levels of logistics firms listed in 2015 Fortune 500 Turkey list in the framework of suggested model.

The current study conducted with these purposes is consisted of two phases. In this first phase, multiple criteria decision model is developed which can be used in determination of technological innovation levels for logistics firs with Delphi model. In the first step of the second phase, the priority levels of criteria are determined using AHP method. Findings show that radical innovation criterion is more important than proportional innovation criteria. This result also supports the findings of studies which are conducted by Germain (1996) and Peker et al. (2015). Additionally, the most important three radical innovations are determined as "Big Data", "Cloud Technology" and "Communication System among Vehicles (Vehicle to Vehicle-V2V)", in order. In the set of incrementalinnovation; "Warehouse Management System Software" and "Barcode and RFID Identification Systems" are sub-criteria that have equal and the highest level of importance. In the study which was conducted by Germain (1996), it was stated that sub-criteria of "robots", "automatic material carrying systems" and "automatic storage and unloading systems" should be considered under radical innovation main criterion. The experts, who are consulted in Delphi method for this study, state that "robots" should be considered as a sub-criterion of radical innovation and the other criteria as sub-criteria of incremental innovation. At this point, considering the modern technology, it can be said that a unique and updated classification related to logistics technological innovation criteria is utilized in this study.

In the following step of second phase, the logistics firms listed in 2015 Fortune 500 Turkey list are ranked in accordance to their technological innovation levels, based on the model developed in the previous step. In this step, methods of TOPSIS and VIKOR are used. Combined results are obtained with Borda method which is used to combine the results of two methods in order to eliminate the different results which may be created by the related methods. In the combined results, it can be said that firm C has the highest level of technological innovation. This firm is followed by A, E and B in order. On the other hand, firm H has the lowest level of technological innovation. In the review of the information obtained from the related firms (Attachment-1), it can be seen that firm C has utilized different modes of transportation in comparison to other firms. Related to storage; it can be said that all of the firms perform storage activities, and A and E firms perform more storage activities in comparison to other firms. Yet, all of the firms perform micro distribution activities, offer value added services and utilize warehouse management systems. In the evaluation of the obtained results and firm information; the result of that the increase in logistics activities of firms increases the level of their technological innovation could be obtained. The suggested model is a guidance to logistics firms' executives for their technological innovation levels. Additionally, the results show that the suggested model can be used in determination of technological innovation levels of different logistics firms as making small changes.

That the radical innovation activities used in this study may not be known and used by logistics firmscan be stated as the main limitation. In order to eliminate this limitation, joint training programs which aim to explain the logistics technological innovation criteria to the related firms and are participated by academicians, manufacturing enterprises, representatives of public institutions and logistics firms for the purpose of. Additionally, this study could be improved in the future by using different multiple criteria decision making techniques (including Grey Relational Analysis, and Electre) and fuzzy logic and the results could be compared.

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Attachment 1: Information Related to Logistics Firms

Firms	Transportation	Storage	Distribution	Custom Clearance	Insurance	Value Added Services	Information Technologies
A	• Road Transportation • Airline Transportation • Maritime Transportation • Project Cargo Transportation • Multimodal Transportation	• General (Shelf and Cast Storage) • Suspensory Storage • Full Automatic Storage • Customs Storage • Cold Storage	• Micro Distribution			• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS)
B	• Road Transportation • Airline Transportation • Maritime Transportation • Railway Transportation	• General (Shelf and Cast Storage) • Open and Close Storage • Full Automatic Storage		+		• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS)
C	• Road Transportation • Airline Transportation • Maritime Transportation • Railway Transportation • Combined Transportation • Hazardous Material Transportation • Cement, Industrial Materials, Iron and Steel Transportation	• Open and Close Storage • Special Storage	• Micro Distribution		+	• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS) • Automatic Separation System
D	• Road Transportation • Airline Transportation • Maritime Transportation • Project Cargo Transportation • Intermodal Transportation	• Open and Close Storage • Customs Storage • Storage without Customs • Special Storage	• Micro Distribution	+	+	• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS)
E	• Road Transportation • Airline Transportation • Maritime Transportation • Railway Transportation • Intermodal Transportation	• Cross-Dock and Temporary Storage • Customs Storage • Storage without Customs • National Storage • National Storage	• Micro Distribution	+	+	• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS) • Order Tracking Management • Vehicle Tracking Management • Route Optimization • Global Positioning System • RFID
F	• Road Transportation • Airline Transportation • Railway Transportation • Combined Transportation	• Storehouse • Free Storage	• Micro Distribution		+	• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS)
G	• Road Transportation • Railway Transportation	• Storehouse • Free Storage • Special Storage	• Micro Distribution			• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS) • Vehicle Tracking Management
H	• Road Transportation	• Open and Close Storage	• Micro Distribution		+	• Packing • Packaging • Labeling • Filling …	• Warehouse Management System(WMS)

+ Shows that this activity is performed by the related firm.