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Firm Selection Based on Logistics Risk Factors:
A Multiple Criteria Decision Making Approach

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ABSTRACT

Logistics firms are exposed several domestic and global risks such as variability in demand, shipment damages, earthquakes, and terrorist attacks. The purpose of this study is to provide an approach for selecting a logistics firm based on logistics risk factors according to the manufacturing firms' perspectives. An analytical network process method is utilized to determine risk factors' importance levels and VIKOR method is used to select the logistics firm. The study results show that the most important logistics risk factors are *customer* and *supplier*, and the least risky logistic firm is B. It can be concluded that the proposed model enables managers to examine potential risks influencing their logistics activities and select the logistics firm having minimum risk.

KEYWORDS

Analytic Network Process, Global Risks, Logistics Risk Factors, VIKOR

INTRODUCTION

In today's competitive business environment, companies attach more and more importance to logistics and reduction of the uncertainties in the supply chain (Vanany et al., 2009) for firm performance improvement. Such uncertainties reflect undefined tasks in logistics systems, unplanned time, and activities which include unnecessary costs and efforts and they are called as risks (Fuchs & Wohinz, 2009). Furthermore, a logistics risk is called as physical incidents implemented without planning, and it might cause obstacles on having the right products transported to the right places on the right time and the right quality, which might lead to problems in all kinds of business, information and material flow (Fuchs & Wohinz, 2009). In another definition, logistics risks for firms are stated as problems such as production hitch, stock accessibility, deterioration in products, and malfunctioning of transportation (Cavinato, 2004). When considered from this point of view, determining logistics risk factors and among those factors which should be resolved primarily; developing and applying related strategies and plans have become important. Moreover, manufacturing firms that use the services offered by logistics firms desire logistics firms to operate with the lowest risk levels (Rao & Young, 1994). As such, manufacturing firms regard insufficiencies in purchasing, logistics, and organizational structure, which will cause problems in meeting customer needs, as internal risk possibilities in their own supply chain (Zsidisin & Ellram 2003). Therefore, risks in the supply chain for manufacturing firms are related to information, material, product and money among the supply chain parties (Jüttner, 2005).

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In this framework, increasing uncertainties in today's supply and demand conditions, shortening product life cycles, complexification of international supply networks, and increasing cooperation with logistics partners cause firms to focus on supply chain risks more tightly (Christopher & Lee, 2004; Mandal, 2016). For manufacturing companies, the related developments increase importance levels of risks caused by the services offered through logistics firms. In this regard, Chopra and Sodhi (2004) showed that the success of the services offered by logistics firms are highly associated with understanding both the main risks in supply chain and companies' own internal risks, and looking for solutions. From this perspective, it can be interpreted that the success of the supply chain can exist with the aggregation of each supply chain party's success. The services offered by logistics firms must be operated on time and properly in order not to have delays in production processes, unnecessary waiting, and customer dissatisfaction; thus, logistics firm selection is very important for manufacturing firms (Dickson, 1966).

The selecting of firm based on logistics risks is a complex multiple criteria decision problem including many quantitative and qualitative criteria. The purpose of this study is to offer a multiple criteria decision-making approach to create a firm selecting by logistics risk factors. For this purpose, the logistics risk factors of the firms listed in Fortune 500 Turkey are weighted by means of Analytical Network Process (ANP) and these logistics firms are ranked by using VIKOR method based on their logistics risk factors from manufacturing firms' perspectives.

The remainder of this paper is structured as follows: Section 2 provides the literature research, section 3 introduces ANP and VIKOR methods, and section 4 presents the research model of the study, logistics risk factors' importance levels and firm selecting. Final section yields conclusions and suggestions for future studies.

LITERATURE REVIEW

Literature review is classified in two groups. Hereunder, the studies in which logistics risk factors are focused are provided firstly. Secondly, the studies in which the logistics firm selection is reviewed based on manufacturing firms are represented.

In the analysis of the related literature, it leaps to the eye that different factors are taken into consideration and many scholars provided different logistics risk classifications. Van Landeghem & Vanmaela (2002) stated that customs regulations, price changes, information delays, supplier quality and production productivity are the main sources of the uncertainty in supply chain. Jüttner et al. (2003) divided risks in supply chain into three different categories as environmental, network structure based, and organizational factors. Cavinato (2004) analyzed logistics risks under five titles as physical, financial, informational, relational, and innovative. Chopra & Sodhi (2004) analyzed risks in supply chain based on three factors; supplier, firm, and customer. Christopher & Peck (2004) stated that supply chain risks are formed from environmental, demand, supply, process and control risks. Giaglis et al. (2004) stated that logistics risks were caused by traffic problems within the cities. Giunipero & Eltantawy (2004) focused on factors; product technology level, security needs, the importance of suppliers and experience of sales. Cucchiella & Gastaldi (2006) analyzed supply chain risks under two main titles as internal based factors (capacity, customs regulations, information delays, internal organizations) and external based factors (competitors, production field, political environment, price regulations, supplier quality, stochastic cost). Gaudenzi & Borghesi (2006) separately analyzed delivery on time, order completion, order accuracy and error factors for transportation, production, order process, storage and supply process. Sheffi et al. (2006) stated that factors such as transportation capacity, transportation problems, supply delays, information problems, and demand problems pose risks. Tang (2006) emphasized the importance of operational risks (unpredicted customer demand, supply and costs) and deteriorating risks (earthquake, floats, hurricanes, terrorist attacks and economic crisis) on supply chain risk evaluation. Bogataj & Bogataj (2007) stated that supply chain risks are affected by supply, process, demand, control and environmental risks. Manuj & Mentzer (2008) studied on factors including quality, security, transportation time, expectation, and culture. Tang & Tomlin (2008) stated that supply, process, demand, intellectual property, behavioral, and political risks constitute supply chain risks. Fuchs & Wohinz (2009) used resources, errors, the characteristics of a product and relationship while ranking logistics risks. Olson & Wu (2010) focused on corporate image, responsibilities, workers' health and safety, cost reduction, public relations, customer relations, and product development factors. Blome & Schoenherr (2011) conducted a risk analysis with security, internal accuracy, external accuracy, and structural accuracy factors. Pfohl et al. (2011) evaluated logistics risks in terms of suppliers, 3 PL firms and customers. Samvedi et al. (2013) collected risks in supply chain under the titles of supply, demand, process, and environmental factors. Ho et al. (2015) summarized logistics risks in main groups of; supply, demand, production, financial, macro, informational, and transportation by an extensive literature review. Fuzzy logic, statistical methods, and mathematical techniques were used in these mentioned studies. When the risk factors used in the related studies are analyzed, it is seen that the related factors comprise numeric and non-numeric criteria which were interrelated and obtained in a complex structure. In this direction, it can be stated that the research question of the logistics risk factors evaluation could be studied as a multiple-criteria decision-making problem. Therefore, the current study contributes to the related literature by including relative weights of logistics risk criteria using ANP method.

In the analysis of primary literature in which the services offered by logistics firms are evaluated in terms of manufacturing firms, studies of Dickson (1966); Beck & Lin (1981); Weber et al. (1991); Arbel & Seidmann, (1985); Bard (1986); Zviran (1993); Ghodsypour & Brien (1998); Tam &Tummala (2001); Heizer & Render (2006) came into prominence. However, no research could be found among these studies in which logistics firms were evaluated in terms of logistics risk factors and firm selection was carried out a Multiple Criteria Decision Making (MCDM) technique. As taking into account that there is no study offers MCDM approach for firm selecting, it can be said that another contribution of this study to the literature is to use VIKOR for selecting the firm.

METHOD

In this section of the study, Analytical Network Process and VIKOR methods are presented, respectively.

Analytic Network Process

Analytic Hierarchy Process (AHP), developed by Saaty, is often used in ranking as a method for Multiple Criteria Decision Making (MCDM) problems, and it enables decision makers' experiences, information and intuition to be included in decision making in a hierarchic structure (Cheng & Li, 2004). On the other hand, as a generalized version of AHP, Analytic Network Process (ANP) enables creating mutual dependence relationships between criteria, creating feedback opportunity, and it shows this relationship in a network. With these characteristics, ANP is preferred in this study as it facilitates decision making problems to be analyzed more efficiently and reliably (Dolan, 2008; Ravasan & Mansouri, 2015).

ANP is mainly comprised of three steps (Nimiera & Saaty, 2004; Saaty & Vargas, 2006):

Step 1: Defining the Decision Problem and Establishing the Model

In this step, the purpose of the decision problem, criteria, sub-criteria, and decision makers must be defined in detail, and it should also include targets of these decision makers and possible outcomes of the decision. In short, this step is where the decision problem is defined in details and the model is formed.

Step 2: Obtaining Pair Wise Comparison Matrices and Determining Primary Vector

Main and subcriterion weights are determined as pair wise relationships which are presented in the model and seen in relationship matrix are evaluated by decision makers on the scale developed by Saaty and also used in ANP. Then, weighted super matrix is obtained including all pair wise comparisons.

$$\begin{vmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \ddots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{vmatrix} \begin{vmatrix} w_1 \\ \vdots \\ w_n \end{vmatrix} = n \begin{vmatrix} w_1 \\ \\ w_n \end{vmatrix} \quad (1)$$

Step 3: Establishing and Analyzing Super Matrix

If the total of super matrix columns is not equal to one, normalization process is carried out in order to equalize columns' total to one. Then, (2k+1) power of super matrix is taken to equalize importance degrees to a point and this matrix is called limit matrix. The priority degrees of each criterion are determined in matrix 1.

Matrix 1. Vikor

VIKOR (VIseKriterijumsaOptimizacija I KompromisnoResenje), developed by Opricovic and based on the ideal solution approximation measure, is a multiple criteria decision ranking index (Opricovic & Tzeng, 2004). It is an MCDM technique which focuses on ranking among alternatives and making a selection when there are contrasting criteria (Büyüközkan and Ruan, 2008). The purpose of the method is to rank and ultimately reach a compromise solution. Compromise solution, proposed by Yu (1973) and Zeleny (1982) for the first time, is the closest point to the ideal, and compromise refers to reaching an agreement on consensus (Vahdani et al., 2010). VIKOR is preferred in this study since it offers closer result to the ideal in ranking alternatives in MDCM problems (Opricovic and Tzeng, 2007). The 5 steps of the method are following (Opricovic & Tzeng, 2004; Opricovic & Tzeng, 2007; Lin et al., 2013):

Step 1: Establishing the best (f_i*) and the worst (f_i^-) criterion values

The best (f_i*) and the worst (f_i^-) criterion values are determined after establishing a decision matrix (i = 1, 2, …, n.).

$$f_i^* = \max_j f_{ij}$$

$$f_i^- = \min_j f_{ij} \quad (2)$$

Step 2: Calculating S_j and R_j values

S_j and R_j values are calculated for (j = 1, 2, …, J). S_j and R_j values show average and the worst group scores for alternative j.

$$S_j = \sum_{i=1}^{n} w_i \left(f_i^* - f_{ij}\right) \Big/ \left(f_i^* - f_i^-\right) \quad (3)$$

$$R_j = max_i \left[w_i \left(f_i^* - f_{ij}\right) \Big/ \left(f_i^* - f_i^-\right) \right] \quad (4)$$

Step 3: Calculating Q_j values

Q_j(j = 1, 2, …, J) values, established with formula no (5) for each alternative depending on evaluation criteria, show maximum group utility.

$$S^* = \min_j S_j$$

$S^- = \max_j S_j$
$R^* = \min_j R_j$

$R^- = \max_j R_j$ (5)

In the formula above, S^* and R^* show minimum S_j and R_j values, and S^- and R^- show maximum S_j and R_j values. The value q represents the weight for strategy, providing maximum group utility and (1-q) represent minimum regret weights of the opponents. A compromise solution might be obtained with the majority (q > 0,5), "consensus" (q = 0,5) or "veto" (q < 0,5).

$$Q_j = \frac{q\left(S_j - S^*\right)}{\left(S^- - S^*\right)} + \frac{\left(1-q\right)\left(R_j - R^*\right)}{\left(R^- - R^*\right)} \quad (6)$$

Q_j is calculated using the equation (6) in which the parameters are included.
Step 4: Ranking S_j, R_j and Q_j values
Three ranking lists are obtained where ranking among alternatives are established as ranking S_j, R_j and Q_j values.
Step 5: Establishing Acceptable Advantage (C1) and Acceptable Consistency (C2) Sets
Alternatives are ranked by sorting $\tilde{Q}_i$ values in increasing order. Alternative ranked first is compromised solution if the following conditions are satisfied.

Condition 1 - Acceptable advantage: $Q_{A^{(2)}} - Q_{A^{(1)}} \geq 1/\left(j-1\right)$, where $Q_{A^{(2)}}$ is alternative in second position of ranking list and *j* is number of alternatives.
Condition 2 - Acceptable stability in decision-making: Alternative $A^{(1)}$ must also be the best when ranked by *S* and/or *R*.

A series of compromise solutions is proposed unless one of the above conditions is satisfied. The set of compromise solutions is as follows;

1) Alternatives $A^{(1)}$ and $A^{(2)}$ if condition 1 is satisfied, but condition 2 is not.
2) Alternatives $\mathrm{A}^{(1)}$, $\mathrm{A}^{(2)}$, …, $\mathrm{A}^{(M)}$ if condition 1 is not satisfied. Note that $\mathrm{A}^{(M)}$ is determined by relation $\mathrm{Q}_{\mathrm{A}^{(M)}} - \mathrm{Q}_{\mathrm{A}^{(1)}} < 1/\left(j-1\right)$ for maximum M.

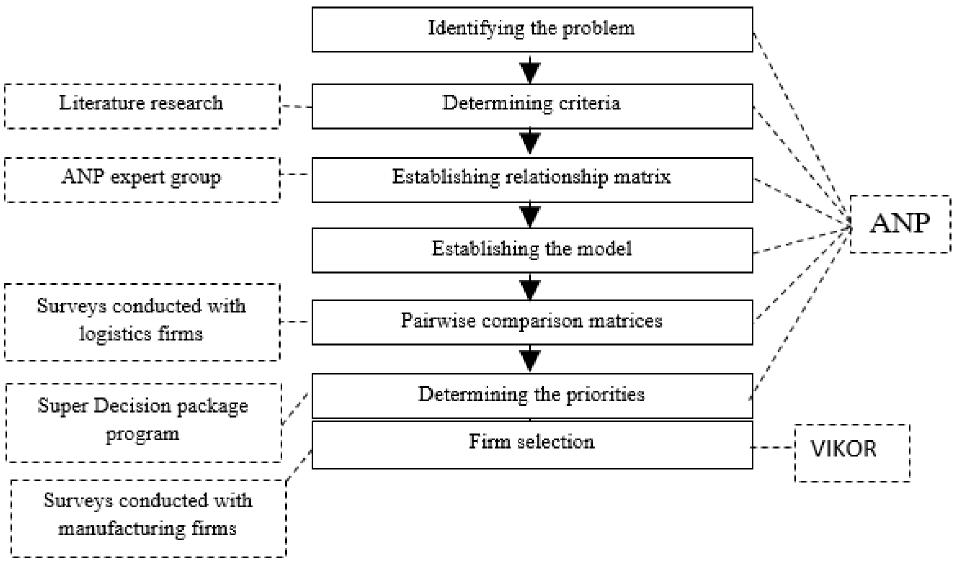
APPLICATION

The application steps of the study conducted for the purpose of offering an approach to selecting logistics firm are provided in Figure 1. In this study, firstly, the weights of the logistics risk factors are determined on the basis of expressions of logistics firms by using ANP, secondly firms are ranked by VIKOR according to logistics risk factors based on manufacturing firms' perspectives.

Identifying the Problem and Determining Criteria

This study proposes an approach for determining logistics risk factors and ranking by these factors of logistics firms. Based on the literature research, the criteria presented by Fusch and Wohinz (2009) are adopted in this study. These criteria are as follows; Logistics risk sources (Material flow system, information flow system, suppliers, customers and environment), logistics risk errors (Human errors,

Figure 1. The application steps of the research



technical errors, organizational errors and force majeure) and logistics risk characteristics (Value, volume, weight, special application requests, commitment, honesty, and substitution ability).

Establishing Relationship Matrix and Research Model

Relationship matrix, which shows the correlation between the criteria, and constitutes the basis of ANP survey, is determined by ANP expert group (the first two authors of this study and two logistics service provider firms' representatives). Accordingly, the research model is created as in Figure 2.

Determining Pairwise Comparison Matrices and Priorities

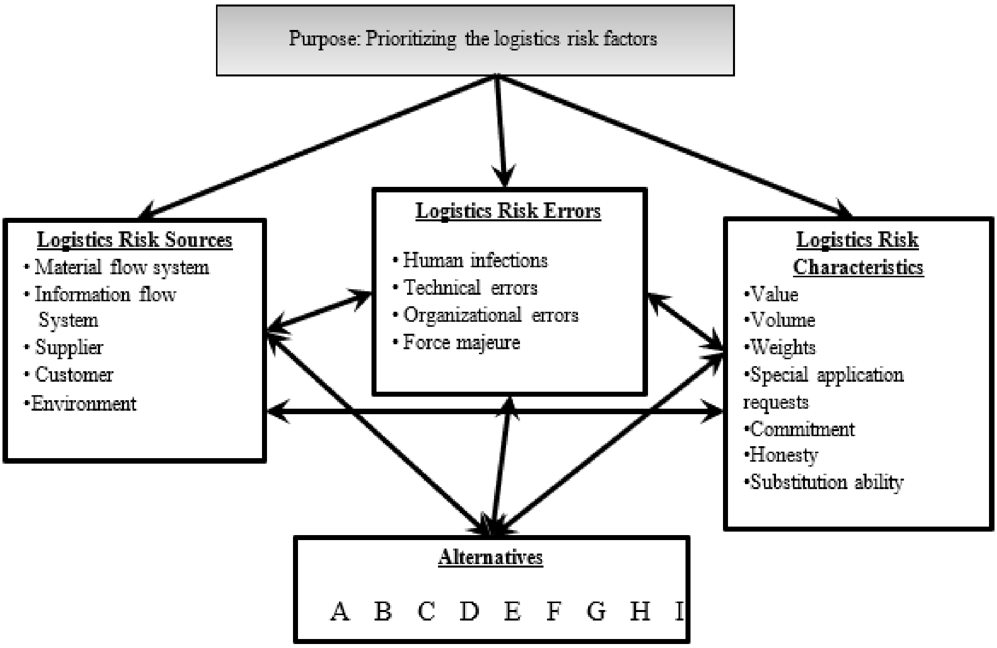
The ANP survey (Appendix A) created in the previous phase of this study is submitted to representatives of 9 logistics firms listed in Fortune 500 Turkey 2015. The obtained results are transferred to Super Decisions package program, thus the priorities of the criteria are determined as presented in Table 1.

According to the degree of importance, the main criteria are ranked as; logistics risk sources, logistics risk errors, and logistic risk characteristics (Table 1). Additionally, customer appears as factor that has the highest level of importance, and followed by the risk factors of supplier, environment, human errors and technical errors. To check the inconsistency in decision making, the consistency ratio (CR) of the proposed model is calculated for all pair-wise comparisons and it is found that it varies between 0.06-0.09, which is within the tolerable limit (Agarwal et. all, 2006).

Firm Selection

Taking into consideration the importance level of the logistics risk factors, VIKOR method is used in this phase in order to select the firm which has the lowest level of logistics risk. VIKOR survey is submitted to 7 manufacturing firms listed in Turkey's first 500 industrial firms, announced by the Istanbul Chamber of Industry, and working/worked in cooperation with the related logistics firms. Formulas (2)-(6) are used respectively to obtain VIKOR results. According to logistics risk levels, the firms are ranked depending on different v values in Table 2.

Figure 2. The research model



According to Table 2, firm B is has the lowest logistics risk level among all v values and is followed by A and H. On the contrary, Firm E has the highest logistics risk level for all v values. However, the rankings of C, D, G, and I firms differ based on different v values.

CONCLUSION

Firms have been trying to decrease the risks in supply chain in order to increase their effectiveness since 1990s (Vanany et al., 2009). This effort has brought forward the question of "how can we operate our logistics activities with less risk"? Starting from the point of view that in order to be able to answer that question accurately the possible risks of logistics activities are needed to be evaluated altogether, a MCDM model suggestion is aimed to determine importance levels of logistics risk factors and to select the logistics firm with lowest logistics risk. For this purpose, ANP method is used for weighting the risk factors and VIKOR method is used for firm selection.

By analyzing the previous studies, it can be stated that this study makes a contribution to the existing literature in two different aspects. Firstly, it weights logistics risk factors with ANP method. Secondly, it uses VIKOR method for the logistics firm selection by considering logistics risk factors. According to the ANP results, customer and supplier are the logistics risk factors that have the highest level of the relative importance. During the interviews conducted with logistics firm representatives, customer is claimed as the most important factor which prevents logistics activities to be operated flawlessly. The uncontrollable structure of customer attitudes and their ever-changing expectations are attributed to this factor. Manuj & Mentzer (2008) emphasized the importance of customer and supplier in terms of the logistics risks, similar to the current study. Additionally, substitution ability which has the lowest level of importance.

Table 1. Relative significance levels of logistics risk factors

Criteria and Sub Criteria	Normalized Priorities	Limited Priorities
Logistics risk sources (0.428)		
● Material flow system	0.110	0.047
● Information flow system	0.141	0.060
● Supplier	0.248	0.106
● Customer	0.266	0.114
● Environment	0.235	0.101
Logistics risk errors (0.337)		
● Human errors	0.371	0.097
● Technical errors	0.302	0.094
● Organizational errors	0.201	0.088
● Force majeure	0.126	0.058
Logistics risk characteristics (0.235)		
● Value	0.116	0.027
● Volume	0.138	0.032
● Weights	0.154	0.036
● Special application requests	0.179	0.042
● Commitment	0.134	0.031
● Honesty	0.158	0.037
● Substitution ability	0.121	0.028

Table 2. VIKOR Results

Firm	Q_1(v = 0)	Q_2(v = 0.25)	Q_3 (v = 0.5)	Q_4(v = 0,75)	Q_5(v = 1)
A	0.143 (2)	0.178 (2)	0.201 (2)	0.229 (2)	0.251 (2)
B	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
C	0.384 (5)	0.378 (4)	0.403 (4)	0.447 (5)	0.469 (5)
D	0,542 (7)	0.498 (6)	0.582 (7)	0.602 (7)	0.628 (7)
E	1 (9)	1 (9)	1 (9)	1 (9)	1 (9)
F	0.624 (8)	0.645 (8)	0.657 (8)	0.667 (8)	0.685 (8)
G	0.357 (4)	0.398 (5)	0.426 (5)	0.420 (4)	0.442 (4)
H	0.256 (3)	0.282 (3)	0.300 (3)	0.324 (3)	0.341 (3)
I	0.441 (6)	0.502 (7)	0.497 (6)	0.513 (6)	0.554 (6)

In the analysis of VIKOR results, B is found to be the most preferred logistics firm. In other words, it is the logistics firm which has the lowest level of logistics risk. This result is also valid with different values. The obtained result is also parallel with the fact that B is placed in the upper ranks in Fortune 500 Turkey 2015 list which is made according to firms' net sales profits.

The fact that the logistics risk factors used in the study are obtained from a single study and consequently all criteria in the literature could not be included can be stated as an important limitation. Additionally, it should be remembered that subjective answers of evaluators of ANP method might differentiate in any time, by the nature of the method. Another limitation could be highlighted is that the number of the VIKOR surveys conducted, which is limited to 7 manufacturing firms.

The related literature and the current study clearly show that a general framework for logistics risk factors should be created with future studies that gather ideas of logistics sector stakeholders (firms outsourcing logistics services, logistics service providers, non-governmental organizations, academicians, and public sector representatives). The problem of selecting the best logistics firm based on logistical risk by weighting the logistic risk factors should be analyzed considering the interaction of the related factors in terms of the criteria considered. That is, a sub-criterion of any main criteria that is thought to be effective in solving the problem can affect a sub-criterion of another main criteria. For this reason, Analytic Network Process (ANP) enables creating mutual dependence between criteria, creating feedback opportunity, and demonstrating this relationship in a network. On the ground of these characteristics, the ANP method is preferred in this study. However, different MCDM methods (TOPSIS, ELECTRE etc.) can also be used in future studies for firm selection or MCDM methods can be expanded by adding fuzzy logic and the obtained results can be compared with current results.

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APPENDIX A: A SAMPLE PAIRWISE COMPARISON MATRIX FOR THE ANP SURVEY

Which one is more important in terms of Logistics Risks:

Table 3. Logistics risks

Logistics risk sources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Logistics risk errors
Logistics risk sources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Logistics risk characteristics
Logistics risk errors	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Logistics risk characteristics