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Weighted Interpretive Structural Modeling for Supply Chain Risk Management: An Application to Logistics Service Providers in Turkey

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Abstract: *Background*: The aim of this paper is to introduce weighted interpretive structural modeling approach to supply chain risk management efforts by presenting an application to identify micro risks of logistics service providers at the industry level in Turkey. *Methods*: In this research, eighteen risk factors in the logistics sector have been identified through both literature review and recommendations from a group of academicians and experts in the sector. A survey was conducted to rank these risks. They were further analyzed through a weighted interpretive structural modeling (WISM) approach in order to demonstrate mutual relationships among these risks. *Results*: Finally, using a WISM approach, an analysis was conducted to identify the driving and dependence power of the risk factors. This study covers a variety of micro-risk factors of logistics service providers and demonstrates the relationships among them and clusters them based on their driving and dependence power. *Conclusions*: Such a clustering of the risk factors helps us identify those that affect the others and are of paramount importance in risk management and mitigation.

Keywords: weighted interpretive structural modeling (WISM); supply chain risk management; logistics service providers; driving power; dependence power; Turkey

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1. Introduction

The logistics industry is considered one of the fastest growing markets in today's global economy. The share of the logistics sector in the world gross domestic product (GDP) is approximately 15% and industry growth rate has currently exceeded average growth rate of the economies of European Union (EU) member States. This is also relevant to the Turkish logistics industry, since Turkey has an advantageous position between the Middle East and Europe and functions as a transfer center between these regions [1], and the logistics sector appears to be one of the most important growth industries in Turkey [2]. With the rise of competition and the increase in supply chain complexity, logistics service providers (LSPs), today, increasingly recognize the potential and significance of supply chain risk management (SCRM).

For effective risk management in supply chains, researchers have developed various approaches. These mainly consist of mathematical models such as mathematical programming [3], multi-criteria decision making such as analytic hierarchy process (AHP) and the "technique for order preference by similarity to ideal solution" (TOPSIS) [4–7]; and a decision tree approach [8]. Prior research on supply chain risk management in the logistics industry has investigated possible risk factors and their impact on performance. However, they have not been studied in the context of the degree to which a given risk factor drives or influences other risk factors, nor have they investigated the extent to which a given risk factor is dependent on the other risk factors. As Tavakolan and Etemadinia [9] have pointed out, if risk managers take into account the interaction of one risk with those of others, the interaction of risk factors with other risks changes the potential and impact of that risk, allowing for a more in-depth analysis of the assessment, response, control, and monitoring of that particular risk.

Given this gap in the literature, the goal of this paper is to introduce WISM approach to supply chain risk management efforts. The focus of this paper is to explore the drive and dependency power, relatively speaking, of the various risk factors. Based on the cluster in which a given risk factor is categorized, it will have an impact in terms of prioritized decision making. As Jüttner et al. [10] emphasized that more empirically grounded research in specific industries is needed on supply chain risk management. To the best of our knowledge, previous studies on risk factors of logistics service providers in Turkey have not been examined on an inter-relational level. To fill this gap, research objectives (ROs) of this study are as follows:

- To identify micro-risk factors of logistics service providers in general, and those of logistics service providers in Turkey;
- To reveal inter-relationships among these risk factors (through measures of driving and dependence power);
- To rank the significance of the risk factors;
- To discuss the implications of the findings for effective risk management of logistics service providers in Turkey.

The rest of the paper is organized as follows: the next section provides a brief conceptual background and literature review, while Section 3 touches on logistics industry in Turkey. Then, Section 4 presents the methodological framework, while Section 5 discusses the results. Finally, Section 6 provides some concluding remarks.

2. Conceptual Definitions and Literature Review

The terms logistics and supply chain management are sometimes used interchangeably, but they have a clear usage. Logistics refers to the movement, storage and flow of goods, services and information throughout the supply chain, and supply chain management means an integrated philosophy. In doing so, several processes are linked to each other and manage the entire flow of distribution channels from the supplier to the end user in order to achieve a competitive advantage [11].

Norrman and Jansson [12] defined supply chain risk management (SCRM) "to collaborate with partners in a supply chain to apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources".

2.1. Categorization of Supply Chain Risks

In a contemporary world, supply chains operate in a dynamic environment and risk management has a vital role in logistics networks in the existence of various risk factors. Thus, through the years, SCRM has attracted the attention of academicians and practitioners alike. For an effective SCRM, many researchers have identified and categorized supply chain risks. Additionally, far-reaching literature reviews have been published to brand and assess previous studies' risk classifications [13–15]. Even though different researchers have identified multiple risk factors such as supply risks, demand risks, process risks, operational risks, environmental risks, physical risks, financial risks, informational risks, and behavioral and political/social risks [7,16–18], a majority of the researchers has categorized the supply chain risks as internal and external risks [19–21]. A similar categorization includes macro and micro risks. Macro risks present the negative effects of rare external situations such as war and earthquakes. Micro risks are relatively frequent events that arise directly from a company's internal activities or relationships with other partners in the supply chain [22]. When it comes to the likelihood of an event occurring, micro risks have a greater impact on SCRM than macro risks.

Reviewing the existing literature on supply chain risk sources, Jüttner et al. [10] and Jüttner [23] identified risk concepts that are relevant to particular sectors and also those that are exclusive to supply chains [24]. One reason is that the industry-specific concept of risk seems to help managers assess and manage risk in their supply chain. Based on this proposal, the practical part of the proposed research focuses on the risk factors of Turkish logistic service providers. It may then shed light on the details of the risk factors in Turkey's logistics sector. Based on the proposed analytical method that leverages the driving force and dependence of risk factors, it may further influence management's decision-making in a preferential sense.

2.2. Methods and Approaches in SCRM Research

Since risk identification/classification is the first step in SCRM, many qualitative and quantitative approaches have been used and applied to SCRM over the last decade. The second category of work in this area deals with SCRM methods. Several literature reviews have made important contributions to this body of knowledge [10,13,22,24–27].

With regard to the methodology used in SCRM papers, Ho et al. [22] reviewed 224 studies published between 2003–2013 and demonstrated that the number of studies using quantitative methods is much higher than those using qualitative methods. Tran et al. [15] also conducted similar research for SCRM articles published between 2002 and the beginning of 2017. Supporting the results of Ho et al. [22], Tran et al. [15] concluded that in half of the reviewed work, quantitative approaches (including single and multiple methods) were most commonly used to assess supply chain risk. Quantitative methods have been used primarily to classify or identify the risks of SCRM studies, or to explain the stages of SCRM, but qualitative studies that explain how the SCRM approach can be applied to real-world case studies are limited [22]. Thus, future research that integrates qualitative approaches and quantitative methods and show applications to real life case studies can help our understanding and present a practical insight into SCRM [15]. To this end, using the exploratory interviews conducted to discover industry experts' risk perceptions, this study seeks to provide new solutions to logistics service providers' SCRM efforts by integrating qualitative and quantitative information.

The structural evaluation of quantitative studies clearly demonstrates that most of the quantitative studies used a single method, such as linear programming [28], Bayesian network [29–34], or other approaches. Multiple regression models [35–38], i.e., structural equation modeling [39], covariance-based structural equation model [40], input-output (I-O) models [41], conjoint analysis [42], and correlation analysis [43], are examples of other approaches. Integrated methods that combine two or more approaches have not attracted much attention in the literature [15]. Among the integrated methods, fuzzy methods, analytic hierarchy process (AHP), and data envelopment analysis (DEA) are some of the most frequently used methods [22]. Recently, de Souza Feitosa et al. [44] has proposed a supply chain risk management (SCRM) maturity model combined with a fuzzy TOPSIS classification method to evaluate and sort an organization into a pre-defined maturity level. Presenting results of a systematic literature review and content analysis in order to provide a comprehensive overview of the methods that are currently used for SCRM, Bier et al. [45] indicated that research in this field is interdisciplinary and that no common modeling language has emerged thus far. Past research mainly based on to graph theory and/or social network analysis although a few methods have been developed recently specifically for supply chain risk management. As one of them, Chalmeta and Barqueros-Muñoz [46] have combined quantitative and qualitative methods for SCRM using Big Data analytics. As an integrated method, WISM can overcome the restrictions or improve the performance of the single methods. As one of the integrated methods, weighted interpretive structural modeling (WISM) is not widely used in the SCRM area. To the best of our knowledge, there are no other studies using WISM in this area. Using a similar method, interpretive structural modeling (ISM), there are several papers that focus on SCRM. In one of them, Nishat et al. [47] suggested an approach to influence supply chain risk lessening by comprehending the dynamics between various providers that help to decrease risk in a supply chain. Pfohl et al. [48] also showed how ISM helps managers in SCRM. Using the same approach, Diabat et al. [49] have developed a model in which the various risks involved in a food supply chain are analyzed. Indrawati et al. [50] used ISM and the analytical network process in describing supply chain risks interrelationships. Venkatesh et al. [51] also analyzed supply chain risks in the Indian apparel retail chains using ISM. Ganguly and Das [52] developed a morphological model for supply risk management processes and link it to a supplier selection process. Shahabadkar et al. [53] presented an overview in deployment of ISM in SCRM and emphasized the need for new studies in this field. An advantage of WISM over ISM is that weights are assigned to the risk factors based on their perceived importance.

The criticism of current quantitative research is that analytical methods are much more focused in the SCRM literature than empirical methods. One of the main reasons is that it is difficult for analysts to communicate with experts, access industry data and conduct empirical research [22]. Therefore, to fill this gap, the risk factors of Turkish logistics service providers were identified in this study through both literature reviews and recommendations from a group of experts in the sector.

2.3. Industries Used in SCRM Research

As for the industries that have been considered in SCRM research, it was found that nearly all industries have been addressed. However, a major part is still focused on manufacturing supply chains [54]. Literature reviews show that the foremost applications are in the automobile industry, followed by the gadgets and aviation industry, while service supply chains are quite unexplored. Given the significance of service supply chains, it is imperative for analysts to increase their attention to this sector [22]. As one of the service supply chains, the logistics industry needs to be further developed, since there are a relatively limited number of studies. Chang et al. [55] analyzed the risks of container transportation from the perspective of logistics. Govindan and Chaudhuri [56] analyzed the interrelationships between the threats faced by third-party logistics service providers (3PL) by using Dematel. Wang [57] investigated the role of supply chain and risk in logistics performance in the Australian courier industry. Meyer et al. [58] investigate the key causes of supply chain disruption and vulnerability in South African logistics companies and establishes current tools or methods used by supply chain practitioners to mitigate supply chain risks. Cheung et al. [59] reviewed studies on measures that enhance cybersecurity in logistics and supply chain management. Amin et al. [60] looked at the sustainable supply chain risk management in Pakistan's logistics industry using a novel fuzzy VIKOR–CRITIC technique. Focusing on the integrated supply chain of logistics services, we used the optimistic behavior of integrators as a starting point for research and investigated the factors that influence the performance of the logistics services supply chain.

In summarizing prior research in this area, we find that there are many studies that identify various types of risk factors that exist in supply chains. Some papers proceed to measure the "degree of risk" through qualitative or quantitative methods. Consequently, they either optimize a chosen objective (such as maximizing net profit or minimizing transportation costs), or discuss trade-offs between multiple objectives. Some papers prioritize the risk factors through a chosen scheme.

However, a fundamental gap that exists in the prior literature is that they do not study the relationships (as in a network) between the various risk factors, so as to establish which factors most impact the other factors. In our study, we establish these factors through a measure called the "driving power". Second, we also establish the cluster of factors that are mostly impacted by the other factors. Here, again, we identify these factors through a measure called the "dependence power". Some major advantages occur through such cluster identification in the mitigation of risk. It is based on the driving and dependence power of the risk factors, not a single measure as a priority weight, as identified in prior research. For risk factors identified with a high "driving power" and a low "dependence power", for risk mitigation, these are of utmost importance to management. For risk factors with high "dependence power" and low "driving power", since these do not significantly impact the other factors, management may adopt a strategy to control these factors to make them robust, such that the effect of other risk factors on them can be somewhat mitigated. Such analysis of risk mitigation through some prioritization scheme has not been explored in the prior literature in this sector. To sum up, the original contribution of this study is to introduce WISM as a new approach to supply chain risk management efforts by presenting an application to identify micro risks of logistics service providers at the industry level in Turkey, further providing insight on the driving and dependence factors.

3. Logistics Industry in Turkey

In Turkey, after the automotive and textile industry, the logistics industry represents the third largest sector in the economy [61]. Since Turkey is advantageously located between the center of transport corridors connecting Asia, Europe, and the Middle East [62], it has links to important energy, trade, and transport networks, and has the potential to meet ambitious foreign trade targets that are within the realm of Turkey's national strategic plans [63]. This strategic position strengthens the potential of the country to become one of the world's leading international logistics centers. As a widely recognized indicator of growth published by the World Bank, the logistics performance index (LPI) scores also verify this assertion. Accordingly, Turkey is a leading performer in Europe and the Central Asian region and is classified 39th in relation to total logistics performance worldwide [64]. Moreover, Turkey is the 11th pre-eminent country in logistics out of 41 emerging markets, according to Agility Emerging Markets Logistics Index provided by Transport Intelligence [65]. Both internal (growing international trade) and external (foreign investments and EU integration process) dynamics have contributed to the rapid growth of the logistics sector [66].

Cavusoglu and Keskin [1] stated that the two-fold digit development rates in the sector have drawn numerous players. There are many small-, medium-, and large-sized local companies in the sector. Arkas, Borusan, Horoz, Omsan, and Balnak are some of the leading local companies in the Turkish logistics industry [65]. Since growth rates in the logistics sector continue to rise, Turkey has also become significant to many international logistics companies. Today, DHL, UPS, and TNT have expanded their presence in the Turkish logistics market [2]. Additionally, all of the leading 10 world-wide third-party logistics corporations are quite active in Turkey by either operating directly or through associated agencies [65]. Moreover, the future of the sector is promising. Through a Delphi study, Özcan and Çetin [67] have forecasted the future of the Turkish logistics industry and claimed that the market position would improve with respect to the Logistics Performance Index. Turkey could arise as an international logistics center because of its geographically favorable location, and new foreign logistics companies would get into the market where the competing profits of the global logistics firms, over their Turkish competitors, would expand. These aspects make Turkey an interesting and a relevant case to study.

4. Materials and Methods

Interpretive structural modeling was introduced by Warfield [68–70]. It is a means that can impose an order for different relationships that exist between elements in complex systems. The theoretical roots of the interpretive structural modeling come from graph theory in such a way that theoretical, conceptual, and computational advantage are exploited to explain the complex pattern of conceptual relations among the variables [71].

This method is classified as an interpretive method because the evaluation of the participants affects whether and how the items are related to each other. Cross-impact matrix multiplication applied to classification (Matrice d'Impacts Croises-Multipication Applique en Classment) is abbreviated as MICMAC. It was developed by Duperrin and Galet [72] and developed to study the response path and loop impact on the development of hierarchies for the set members. The MICMAC principle is based on the matrix multiplication property. This indicates that if element A directly affects element B and element B directly affects element C, changes that affect A can affect C. Therefore, there is an indirect connection between A and C that cannot be displayed in the direct relationship matrix.

However, squaring (multiplying the matrix by itself) the matrix using Boolean algebra reveals a quadratic relationship, e.g., second-order relations are revealed, such as A to C. Similarly, if the 3rd, 4th, 5th, ... nth powers of the direct relationship matrix are obtained, the 3rd, 4th, 5th, ... nth order reveals indirect connections. Each time the process repeats a new hierarchy can be derived between the elements. MICMAC analysis is used to analyze the drive power and dependence power of various factors that exist in the system.

An aggregate research method consisting of a questionnaire-based survey to obtain the opinions of professionals and experts in the field was used utilizing an *ISM* approach in order to identify the relationships between the chosen factors. The mean rating, based on a 5-point Likert scale, is calculated for each risk factor. Thereafter, the mean scores are ranked, from the highest to the lowest. For each factor, the inverse rank (K_i) is found, based on which Log K_i is calculated. Here, a weight is assigned to each risk factor based on its perceived risk. The weight, W_i, is determined next by using the definition in Equation (1) shown below:

A weight score W_i, associates with risk factor I, is designated to be *strong* when its value is 1, it is designated to be *neutral* when its value is 0, and is designated to be *weak* when its value is −1. Note that the value of the weight score, W_i, is influenced by its corresponding percentage score, log K_i, with the cut-off values as indicated in Equation (1)

For each risk factor i, a weighted measure of importance is given by:

$$IMP_i = W_i \times \text{Log } K_i \tag{1}$$

Finally, an effectiveness index (EI) of the process is given by [73] summing the importance measures over all the risk factors:

$$EI = \sum_i W_i \times \text{Log } K_i \tag{2}$$

The effectiveness index (EI) = 14.1771, is the sum of the entries in the last column (W_i Log K_i). Theoretically, EI may range between −15.7982 and +15.7982, in this case. This is because the upper and lower limits of the EI are equal to $\sum$Log K_i and $-\sum$Log K_i, respectively, when all the weights (W_i) are i or $-i$, respectively. For the sake of brevity, detailed explanation of this procedure is omitted and may be found in Cleveland [73], Chand et al. [74,75], and Singh et al. [76]. A weighting factor (W_i) was determined for each factor based on the logarithm of the inverse rank (K_i), which is found based on the mean score of the responses. The factor with the highest mean score is assigned the highest inverse rank. This assures that factors with high mean scores will have a higher weighted measure of importance. Subsequently, an effectiveness index (EI) is calculated based on the sum of the product of the weights and the log (inverse ranks). These methodologies and their associated results are discussed in the following sections.

4.1. Overview of the ISM Technique

Weighted *ISM* (*WISM*) is a more advanced variant of *ISM* that was created by Chand et al. [74]. Each factor is given a weight in order to calculate the efficiency index (EI). The process of creating a relationship map in which a collection of directly or indirectly connected elements/factors is organized into a comprehensive systematic model is known as *ISM*. The model uses visuals and words to describe the structure of a complex topic or problem, a system, or a subject of study in a well-organized pattern. The following are the steps in the *ISM* methodology:

Step 1: Determine the level of uncertainty and risk factors associated with the described problem (through literature review and expert opinion)

Step 2: Using a survey or a group problem-solving technique, identify uncertainty and risk factors. With respect to pairs of risk factors, a contextual relationship is formed between the uncertainty and risk factors.

Step 3: A structural self-interaction matrix (SSIM) is created, indicating the link between the system's numerous risk variables.

Step 4: SSIM is then transformed into a binary matrix (Initial reachability matrix)

Step 5: The SSIM is used to create a reachability matrix (RM), which is then regulated to represent transitivity. In ISM, the assumption of transitivity of a contextual connection asserts that if element A is related to B and B is related to C, then A is related to C.

Step 6: Iterations are used to split the RM into different levels until all of the risk factors' levels are found in the diagram. The RM is transformed into its conical form, with the majority of zero (0) elements in the upper diagonal half and the majority of unitary (1) elements in the lower diagonal half.

A diagram or, as previously noted, a relationship map with transitive links is generated based on the relationships specified in the reachability matrix. The risk factor nodes are replaced with statements in the resulting diagram, which is then turned into an ISM-based model. A diagram is produced based on the above study, and transitivity linkages are deleted. After that, the digraph is transformed into an ISM model by replacing the risk factor nodes with statements.

Step 7: The model is examined for conceptual inconsistencies and any necessary changes are made. The consecutive steps in this procedure are depicted in Figure 1.

Step 8: A MICMAC analysis is used to categorize the components according to their driving and reliance power.

4.2. Questionnaire-Based Survey

The major goal of the survey was to rank the various aspects according to experts' opinions so that a relationship matrix could be developed as a first step toward constructing an ISM model. The questionnaire had a lot of different study objectives; thus, there were a lot of questions. On a five-point Likert scale, respondents were asked to rate the importance of the thirty-four risk variables included in the questionnaire. On this scale, a rating of 'very low' to 'very high' corresponded to 1 and 5, respectively. The respondents were asked to rate how challenging it is for logistics service providers to manage these uncertainty and risk issues. Chief executives, general managers, and senior executives from Turkish logistics companies were asked to complete the survey.

As a preliminary study, interviews with 19 branch managers in the Black Sea Region were conducted to determine risk factors of importance in Turkey. All branch managers were fairly in agreement in terms of the chosen risk factors. Subsequently, a convenience sampling method was employed. Sixty-four branch managers in the Black Sea Region were chosen and a face-to-face survey was conducted. As a demographic profile of the 64 branch managers, 56 of the respondents (87.5%) were male and 8 (12.5%) were female. The average age was about 42.

Table 1 shows the logistics service providers operating in Turkey. As can be seen, cargo companies in Turkey have a total number of branches of 8127, along with the number of branches from each company represented in our sample. Because of the technical and financial limitations, the sample was constrained to only the Black Sea Region of the country. However, it was further verified that no new opinions were offered through interviewing additional managers.

Table 1. Logistics service providers in Turkey.

Logistics Providers	The Number of Branches in Turkey	The Number of Branches in Our Study
PTT (Posta ve Telgraf Teşkilati)	4250	12
MNG (Mehmet Nazif Günal) KARGO	800	14
YURTICI KARGO	900	13
ARAS KARGO	900	10
SURAT KARGO	800	9
DHL (Dalsey Hillblom Lyn)	57	1

Table 1. *Cont.*

Logistics Providers	The Number of Branches in Turkey	The Number of Branches in Our Study
UPS (United Parcel Service)	154	1
TNT (Thomas Nationwide Transport)	45	1
INTER GLOBAL	36	-
METRO KARGO	185	2
FEDEX (Federal Express)	TNT assigned.	-
Total	8127	64

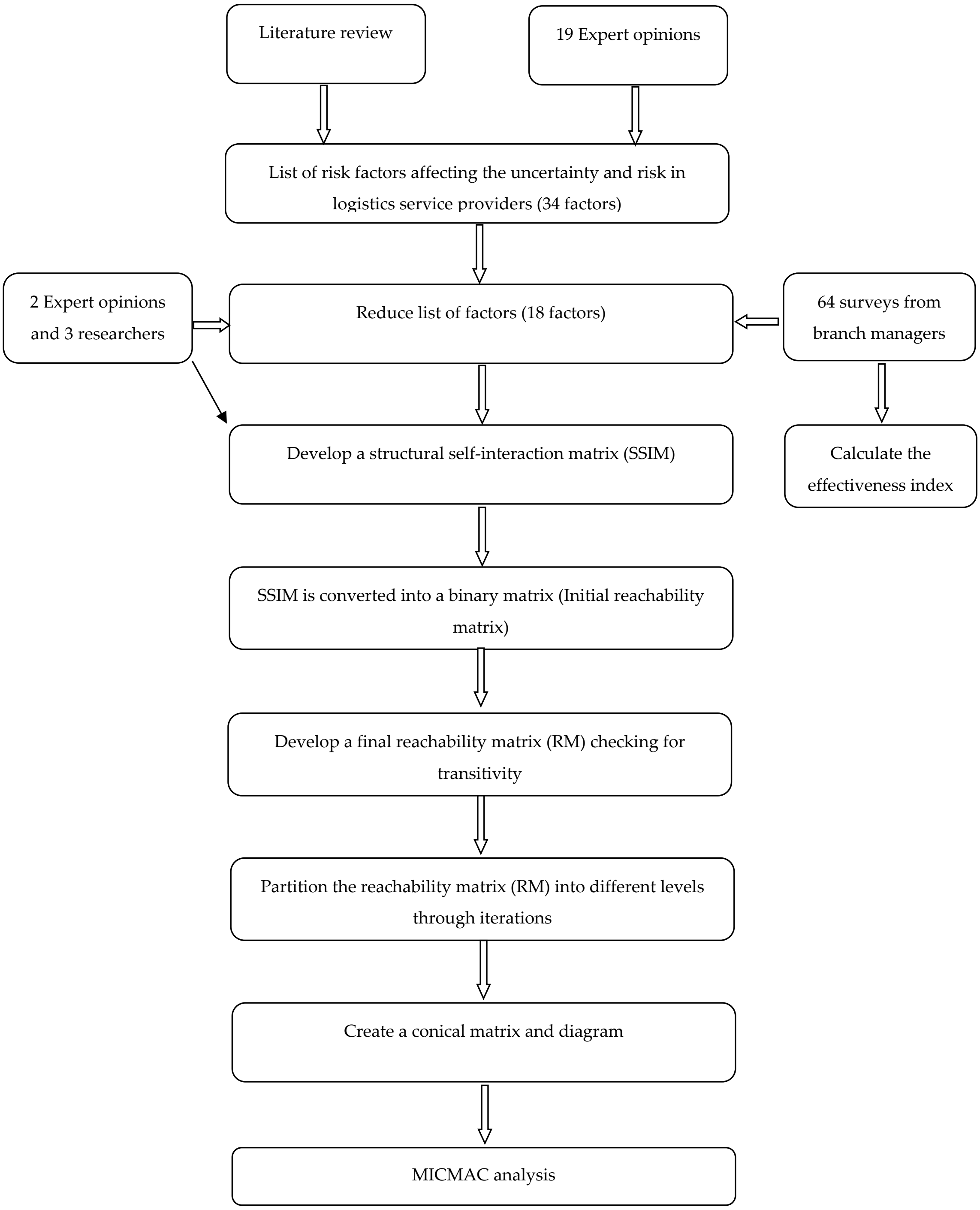

Figure 1. Flowchart for ISM.

4.3. Evaluation of the Effectiveness Index (EI)

The thirty-four risk factors mentioned previously were reduced to eighteen. This reduction was accomplished by considering "lead to" type factors and using the opinions of the sixty-nine experts in this domain. The 64 branch managers from industry, 2 experts, and 3 researchers from academia were consulted in developing the contextual relationship among these factors. The factors, with their mean score and rank, are shown in Table 2.

Table 2. Mean score, rank, and weighted measure of importance of selected factors.

S. No.	Factors (n = 64)	Mean	Rank	Inverse Rank (K_i)	Log K_i	Weight (W_i)	$W_i \times$ Log K_i
1.	Delays in cargo delivery times	4.5625	1	18	1.2552	1	1.2552
2.	Accepting unclear, concise, and inaccurate address information	4.5469	2	17	1.2304	1	1.2304
3.	Carelessness and a lack of motivation among workforce	4.5313	3	16	1.2041	1	1.2041
4.	Conflicts between workers and customers	4.5156	4	15	1.1760	1	1.1760
5.	Storage and handling damages on parcels	4.4531	5	14	1.1461	1	1.1461
6.	Lack of skilled workers	4.3906	6	13	1.1139	1	1.1139
7.	Lack of information technology equipment (Barcode devices etc.)	4.3906	7	12	1.0791	1	1.0791
8.	Problems arising from the address-based information system (data and addresses are incorrect)	4.3906	8	11	1.0341	1	1.0341
9.	Logistics service providers forms not adequately designed	4.3125	9	10	1	1	1
10.	Lack of adequate promotion standards and requirements for high level managers	4.2344	10	9	0.9542	1	0.9542
11.	Conflicts between workers and managers	4.2188	11	8	0.9030	1	0.9030
12.	Lack of strategic planning and failure to sense and respond to market changes	4.2188	12	7	0.8450	1	0.8450
13.	Accepting packages that do not meet standards	4.2031	13	6	0.7781	1	0.7781
14.	Delays in delivery reports (both branches and headquarters)	4.1875	14	5	0.6989	1	0.6989
15.	Lack of transportation trucks/equipment	4.1875	15	4	0.6020	0	0
16.	Lack of customer relationship management (CRM)	4.1406	16	3	0.4771	0	0
17.	Lack of information infrastructure	4.0781	17	2	0.3010	−1	−0.3010
18.	High employee turnover rates	4.0469	18	1	0	−1	0

This *EI* value helps the organization to benchmark its performance to national and international standards. Here, the qualitative values of the factor ratings are converted into quantitative values representing weighted importance values. Management may incorporate these values to make decisions regarding appropriate risk remedial actions.

4.4. ISM Technique for Modeling the Risk Factors of Uncertainty and Risk in Logistics Service Providers

The various steps which lead to the development of the model are illustrated below:

Steps 1 and 2: Establish the contextual relationship between factors

Initially, in the preliminary study phase, risks and uncertainties were determined by face-to-face interviews with nineteen branch managers of parcel service companies from seven geographical regions. As a result of data obtained from interviews and also via a literature review, 34 risk factors were determined. Subsequently, these factors were reduced to 18 (see Table 2).

The existence of a relation between any two factors (*i* and *j*) and the related direction of this link is determined while keeping in mind the contextual relationship for each factor. The direction of the relationship between two factors (*i* and *j*) has been denoted by the following four symbols:

- If factor *i* influences or reaches factor *j*, V is utilized.
- If factor *j* influences ore reaches factor *i*, A is utilized.
- If factors *i* and *j* interact, X is utilized.
- If factors *i* and *j* are unrelated, O is utilized.

Step 3: Development of a structural self-interaction matrix (SSIM)

- The SSIM is created based on the contextual relationship between factors. The SSIM was discussed with a group of specialists in order to reach an agreement. The SSIM has been finalized and is provided in Table 3 based on their responses. The statements below show how to use the symbols in SSIM.
- For example, risk factor 4 leads to 18, indicated by the symbol V in the corresponding cell; there was no relationship between risk factors 3 and 7, indicated by the symbol O in the corresponding cell.

Table 3. Structural self-interaction matrix.

	18	**17**	**16**	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	O	A	A	A	X	A	A	A	O	A	A	A	A	O	V	A	A
2	O	A	A	O	V	X	O	O	O	A	A	A	A	O	O	A	
3	O	O	O	O	O	O	O	A	A	O	O	O	O	V	X		
4	V	O	A	O	A	A	A	X	O	A	A	O	A	A			
5	O	A	O	A	O	A	O	A	O	O	O	O	A				
6	V	O	V	O	V	O	A	A	A	O	O	O					
7	O	O	O	O	V	O	A	V	O	O	O						
8	O	X	V	O	V	X	O	O	O	X							
9	O	A	O	O	V	V	A	O	O								
10	V	O	O	O	O	O	A	V									
11	V	O	O	A	A	O	O										
12	V	V	V	V	O	V											
13	O	O	O	O	O												
14	O	A	O	O													
15	O	O	O														
16	O	A															
17	O																

Steps 4 and 5: Development of the reachability matrix (RM)

- The SSIM is used to create the reachability matrix (RM). The initial and final reachability matrixes are the two types of reachability matrixes. By swapping the V, A, X, and O with 1 and 0, the SSIM is turned into a binary matrix termed the initial reachability matrix. The following rules govern the replacement of 1s and 0s.
- If cell (*i*, *j*) is denoted by the symbol V in the SSIM, then the cell (*i*, *j*) is replaced by 1, implying that *i* leads to *j* and the cell (*j*, *i*) becomes 0 (implying that *j* does not lead to *i*) in the initial reachability matrix.
- If the cell (*i*, *j*) is denoted by the symbol A in the SSIM, then the cell (*i*, *j*) becomes 0 and the cell (*j*, *i*) becomes 1 in the initial reachability matrix.
- If the cell (*i*, *j*) is denoted by the symbol X in the SSIM, then both the cells (*i*, *j*) and (*j*, *i*) become 1 (implying that there is a mutual relationship) in the initial reachability matrix.
- If the cell (*i*, *j*) is assigned with symbol O in the SSIM, then both the cells (*i*, *j*) and (*j*, *i*) become 0 (implying that there is no relationship between these factors) in the initial reachability matrix.

- The RM developed is known as the initial RM, which is shown in Table 4. For developing the final reachability matrix, transitivity is applied so that some of the cells of the initial reachability matrix are filled through inference. The transitivity concept is used in order to develop a more complete model and relationship map. Transitivity is applied once in this study and it can be thought as the composite function or applying function in matrices to express the relationship between two nodes. Simply speaking, if *i* leads to *j* and *j* leads to *k*, when applying transitivity, it can be said that *i* may lead to *k*. The final reachability matrix after incorporating the concept of transitivity is presented in Table 5. The numbers with an asterisk, for example **1***, implies that it was derived using the principle of transitivity.

Table 4. Initial reachability matrix.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
3	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	0	1	1	1	0	0	0	0	0	0	0	1	0	1	0	1
7	1	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0
8	1	1	0	1	0	0	0	1	1	0	0	0	1	1	0	1	1	0
9	1	1	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0
10	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1
11	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1
12	1	0	0	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1
13	1	1	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0
14	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0
15	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0
16	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
17	1	1	0	0	1	0	0	1	1	0	0	0	0	1	0	1	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 5. Final reachability matrix.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1	0	**1***	1	0	0	0	0	0	0	**1***	0	0	1	0	0	0	**1***
2	1	1	0	**1***	**1***	0	0	**1***	0	0	**1***	0	1	1	0	0	0	0
3	1	1	1	1	1	0	0	0	0	0	**1***	0	**1***	**1***	0	0	0	**1***
4	**1***	**1***	1	1	**1***	0	0	0	0	0	1	0	0	0	0	0	0	1
5	0	0	**1***	1	1	0	0	0	0	0	**1***	0	0	0	0	0	0	**1***
6	1	1	0	1	1	1	0	0	0	0	**1***	0	**1***	1	0	1	0	1
7	1	1	**1***	**1***	**1***	**1***	1	0	0	0	1	0	**1***	1	0	0	0	**1***
8	1	1	**1***	1	**1***	0	0	1	1	0	**1***	0	1	1	0	1	1	**1***
9	1	1	**1***	1	**1***	0	0	1	1	0	**1***	0	1	1	0	**1***	**1***	**1***
10	**1***	**1***	1	**1***	**1***	1	0	0	0	1	1	0	0	**1***	0	**1***	0	1
11	1	**1***	1	1	1	1	0	0	0	0	1	0	0	**1***	0	**1***	0	1
12	1	**1***	**1***	1	**1***	1	1	**1***	1	1	**1***	1	1	**1***	1	1	1	1
13	1	1	**1***	1	1	0	0	1	**1***	0	**1***	0	1	**1***	0	**1***	**1***	**1***
14	1	0	**1***	1	**1***	**1***	0	0	0	0	1	0	0	1	0	0	0	**1***
15	1	0	**1***	**1***	1	**1***	0	0	0	0	1	0	0	**1***	1	0	0	**1***
16	1	1	**1***	1	0	0	0	0	0	0	**1***	0	**1***	0	0	1	0	**1***
17	1	1	0	**1***	1	0	0	1	1	0	**1***	0	**1***	1	0	1	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

1* entries are included to incorporate transitivity.

Step 6: Partitioning the reachability matrix (RM)

Based on Warfield [68–70], from the final RM, the reachability set (RS) and antecedent set (AS) consist of uncertainty and risk factors. After finding the RS and AS, the intersection set (IS) of these two is determined. Those factors for which the RS and IS have the same elements take their place at the top level in the ISM hierarchy. This rule is used for each iteration until no risk factors are left to be assigned.

Once the top-level risk factor(s) is identified, it is extracted from all the remaining factors' RS, AS, and IS and thereby modified. This method is repeated until all of the structure's levels have been identified. The construction of the diagram and the final model is enabled by these indicated phases. The digraph's top-level factor(s) are placed at the top, and so on. Using Table 5, a data risk factor of 18, whose RS and IS set consists of factor 18, is found to be at the top level I, and is positioned at the top of the hierarchy. This may also be viewed in Figure 2.

Tables 6–13, depicting iterations 1–8, respectively, show the RS, AS, and IS sets and also the appropriate hierarchy levels of the risk factors.

Table 6. Iteration 1.

Factors	RS	AS	IS	Levels
1	1, 3, 4, 11, 14, 18	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 3, 4, 11, 14	
2	1, 2, 4, 5, 8, 11, 13, 14	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17	2, 4, 8, 11,13	
3	1, 2, 3, 4, 5, 11, 13, 14, 18	1, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 3, 4, 11, 13, 14	
4	1, 2, 3, 4, 5, 11, 18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 2, 3, 4, 5, 11	
5	3, 4, 5, 11, 18	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	3, 4, 5, 11	
6	1, 2, 4, 5, 6, 11, 13, 14, 16, 18	6, 7, 10, 11, 12, 14, 15	6, 11, 14	
7	1, 2, 3, 4, 5, 6, 7, 11, 13, 14, 18	7, 12	7	
8	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17, 18	2, 8, 9, 12, 13, 17	2, 8, 9, 13, 17	
9	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17, 18	8, 9,12, 13, 17	8, 9, 13, 17	
10	1, 2, 3, 4, 5, 6, 10, 11, 14, 16, 18	10, 12	10	
11	1, 2, 3, 4, 5, 6, 11, 14, 16, 18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 11, 14, 16	
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	12	12	
13	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17, 18	2, 3, 6, 7, 8, 9, 12, 13, 16, 17	2, 3, 8, 9, 13, 16, 17	
14	1,3, 4, 5, 6, 11, 14, 18	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 3, 6, 11, 14	
15	1, 3, 4, 5, 6, 11, 14, 15, 18	12, 15	15	
16	1, 2, 3, 4, 11, 13, 14, 16, 18	6, 8, 9, 10, 11, 12, 13, 16, 17	11, 13, 16	
17	1, 2, 4, 5, 8, 9, 11, 13, 14, 16, 17	8, 9, 12, 13, 17	8, 9, 13, 17	
18	18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	18	I

Table 7. Iteration 2.

Factors	RS	AS	IS	Levels
1	1, 3, 4, 11, 14	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 3, 4, 11, 14	II
2	1, 2, 4, 5, 8, 11, 13, 14	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17	2, 4, 8, 11,13	
3	1, 2, 3, 4, 5, 11, 13, 14	1, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 3, 4, 11, 13, 14	
4	1, 2, 3, 4, 5, 11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 2, 3, 4, 5, 11	II
5	3, 4, 5, 11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	3, 4, 5, 11	II
6	1, 2, 4, 5, 6, 11, 13, 14, 16	6, 7, 10, 11, 12, 14, 15	6, 11, 14	
7	1, 2, 3, 4, 5, 6, 7, 11, 13, 14	7, 12	7	
8	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17	2, 8, 9, 12, 13, 17	2, 8, 9, 13, 17	
9	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17	8, 9,12, 13, 17	8, 9, 13, 17	
10	1, 2, 3, 4, 5, 6, 10, 11, 14, 16	10, 12	10	
11	1, 2, 3, 4, 5, 6, 11, 14, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 11, 14, 16	II
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	12	12	
13	1, 2, 3, 4, 5, 8, 9, 11, 13, 14, 16, 17	2, 3, 6, 7, 8, 9, 12, 13, 16, 17	2, 3, 8, 9, 13, 16, 17	
14	1, 3, 4, 5, 6, 11, 14	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 3, 6, 11, 14	
15	1, 3, 4, 5, 6, 11, 14, 15	12, 15	15	
16	1, 2, 3, 4, 11, 13, 14, 16	6, 8, 9, 10, 11, 12, 13, 16, 17	11, 13, 16	
17	1, 2, 4, 5, 8, 9, 11, 13, 14, 16, 17	8, 9, 12, 13, 17	8, 9, 13, 17	

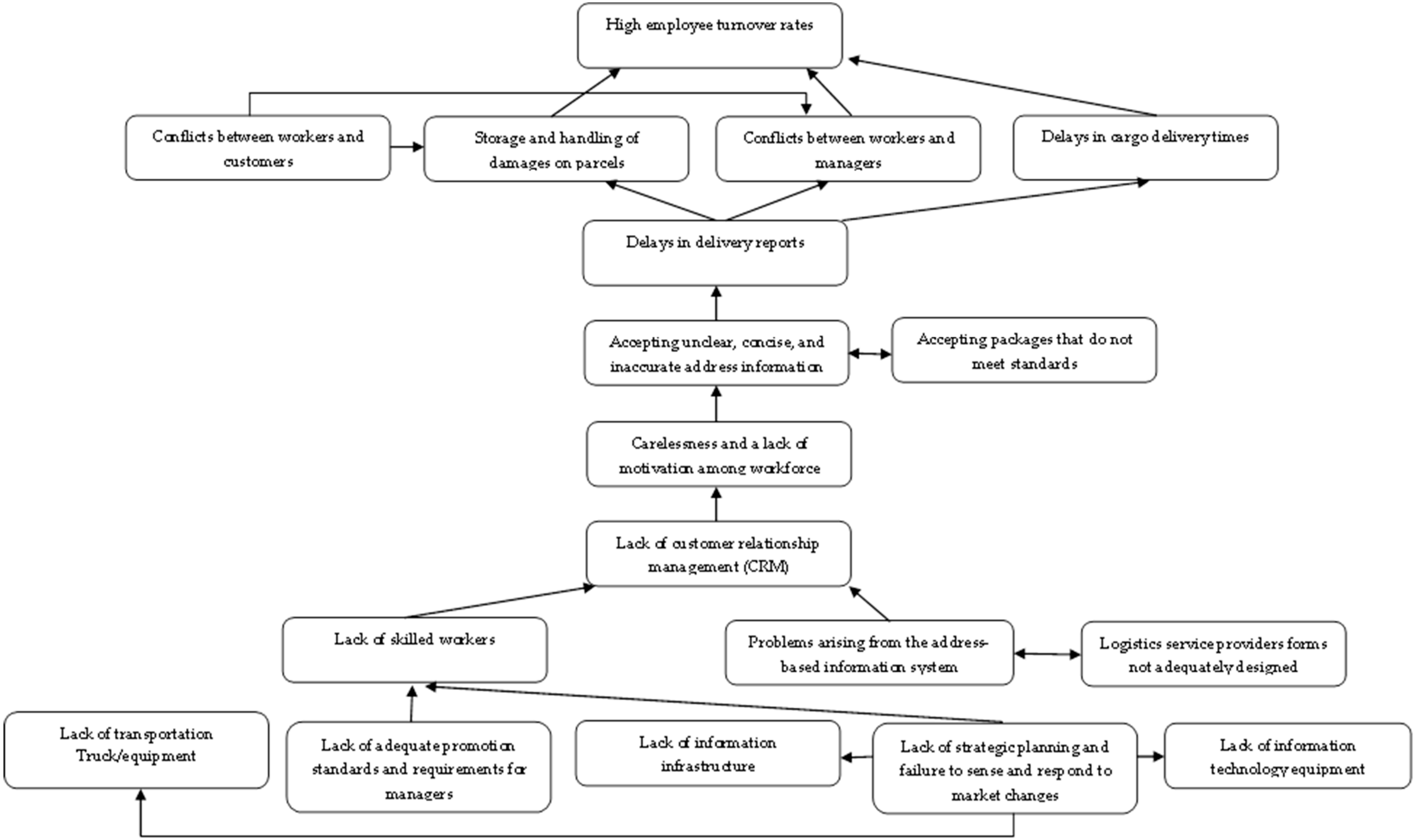

Figure 2. ISM model.

Table 8. Iteration 3.

Factors	RS	AS	IS	Levels
2	2, 8, 13, 14	2, 3, 6, 7, 8, 9, 10, 12, 13, 16, 17	2, 8, 13	
3	2, 3, 13, 14	3, 7, 8, 9, 10, 12, 13, 14, 15, 16	3, 13, 14	
6	2, 6, 13, 14, 16	6, 7, 10, 12, 14, 15	6, 14	
7	2, 3, 6, 7, 13, 14	7, 12	7	
8	2, 3, 8, 9, 13, 14, 16, 17	2, 8, 9, 12, 13, 17	2, 8, 9, 13, 17	
9	2, 3, 8, 9, 13, 14, 16, 17	8, 9,12, 13, 17	8, 9, 13, 17	
10	2, 3, 6, 10, 14, 16	10, 12	10	
12	2, 3, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17	12	12	
13	2, 3, 8, 9, 13, 14, 16, 17	2, 3, 6, 7, 8, 9, 12, 13, 16, 17	2, 3, 8, 9, 13, 16, 17	
14	3, 6, 14	2, 3, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17	3, 6, 14	III
15	3, 6, 14, 15	12, 15	15	
16	2, 3, 13, 14, 16	6, 8, 9, 10, 12, 13, 16, 17	13, 16	
17	2, 8, 9, 13, 14, 16, 17	8, 9, 12, 13, 17	8, 9, 13, 17	

Table 9. Iteration 4.

Factors	RS	AS	IS	Levels
2	2, 8, 13	2, 3, 6, 7, 8, 9, 10, 12, 13, 16, 17	2, 8, 13	IV
3	2, 3, 13	3, 7, 8, 9, 10, 12, 13, 15, 16	3, 13	
6	2, 6, 13, 16	6, 7, 10, 12, 15	6	
7	2, 3, 6, 7, 13	7, 12	7	
8	2, 3, 8, 9, 13, 16, 17	2, 8, 9, 12, 13, 17	2, 8, 9, 13, 17	
9	2, 3, 8, 9, 13, 16, 17	8, 9,12, 13, 17	8, 9, 13, 17	
10	2, 3, 6, 10, 16	10, 12	10	
12	2, 3, 6, 7, 8, 9, 10, 12, 13, 15, 16, 17	12	12	
13	2, 3, 8, 9, 13, 16, 17	2, 3, 6, 7, 8, 9, 12, 13, 16, 17	2, 3, 8, 9, 13, 16, 17	IV
15	3, 6, 15	12, 15	15	
16	2, 3, 13, 16	6, 8, 9, 10, 12, 13, 16, 17	13, 16	
17	2, 8, 9, 13, 16, 17	8, 9, 12, 13, 17	8, 9, 13, 17	

Table 10. Iteration 5.

Factors	RS	AS	IS	Levels
3	3	3, 7, 8, 9, 10, 12, 15, 16	3	V
6	6, 16	6, 7, 10, 12, 15	6	
7	3, 6, 7	7, 12	7	
8	3, 8, 9, 16, 17	8, 9, 12, 17	8, 9, 17	
9	3, 8, 9, 16, 17	8, 9,12, 17	8, 9, 17	
10	3, 6, 10, 16	10, 12	10	
12	3, 6, 7, 8, 9, 10, 12, 15, 16, 17	12	12	
15	3, 6, 15	12, 15	15	
16	3, 16	6, 8, 9, 10, 12, 16, 17	16	
17	8, 9, 16, 17	8, 9, 12, 17	8, 9, 17	

Table 11. Iteration 6.

Factors	RS	AS	IS	Levels
6	6, 16	6, 7, 10, 12, 15	6	
7	6, 7	7, 12	7	
8	8, 9, 16, 17	8, 9, 12, 17	8, 9, 17	
9	8, 9, 16, 17	8, 9,12, 17	8, 9, 17	
10	6, 10, 16	10, 12	10	
12	6, 7, 8, 9, 10, 12, 15, 16, 17	12	12	
15	6, 15	12, 15	15	
16	16	6, 8, 9, 10, 12, 16, 17	16	VI
17	8, 9, 16, 17	8, 9, 12, 17	8, 9, 17	

Table 12. Iteration 7.

Factors	RS	AS	IS	Levels
6	6	6, 7, 10, 12, 15	6	VII
7	6, 7	7, 12	7	
8	8, 9, 17	8, 9, 12, 17	8, 9, 17	VII
9	8, 9, 17	8, 9,12, 17	8, 9, 17	VII
10	6, 10	10, 12	10	
12	6, 7, 8, 9, 10, 12, 15, 17	12	12	
15	6, 15	12, 15	15	
17	8, 9, 17	8, 9, 12, 17	8, 9, 17	

Table 13. Iteration 8.

Factors	RS	AS	IS	Levels
7	7	7, 12	7	VIII
10	10	10, 12	10	VIII
12	7, 10, 12, 15, 17	12	12	
15	15	12, 15	15	VIII
17	17	12, 17	17	VIII

Step 7: Development of the conical matrix, digraph and ISM model

A conical matrix is created in this stage by grouping factors that are on the same level across the rows and columns of the final reachability matrix. Counting the "1" values in the rows and columns, respectively, yields the factor's drive and dependence power. The highest ranks are given to the components that have the greatest number of "1" values in the rows and columns, respectively, as shown in Table 14.

Table 14. Conical matrix.

Uncertainty and Risk Factors	18	5	1	4	14	2	16	3	15	11	6	17	7	10	13	8	9	12	Driving Power
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	5
1	1	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	6
4	1	1	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	7
14	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	8
2	0	1	1	1	1	1	0	0	0	1	0	0	0	0	1	1	0	0	8
16	1	0	1	1	0	1	1	1	0	1	0	0	0	0	1	0	0	0	8
3	1	1	1	1	1	1	0	1	0	1	0	0	0	0	1	0	0	0	9
15	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	9
11	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	10
6	1	1	1	1	1	1	1	0	0	1	1	0	0	0	1	0	0	0	10
17	0	1	1	1	1	1	1	0	0	1	0	1	0	0	1	1	1	0	11
7	1	1	1	1	1	1	0	1	0	1	1	0	1	0	1	0	0	0	11
10	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	11
13	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1	0	13
8	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1	0	13
9	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1	0	13
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Dependence power	16	15	16	17	14	13	9	14	2	17	7	5	2	2	10	6	5	1	

An initial diagram with transitivity relations is created using the conical matrix. This is accomplished by forming nodes and connecting them with lines of edges. After the indirect links are removed, a final digraph is created. The digraph is then transformed into an ISM model by replacing the element nodes with statements, as shown in Figure 2. The top-level factor(s) are placed at the top of the digraph, the second level factor(s) at the second position, and so on until the bottom level factor(s) are placed at the lowest position in the diagram.

Step 8: Classification of uncertainty and risk factors on the basis of MICMAC analysis

The goal of the MICMAC study is to look at factors in terms of their drive and dependence power. The drive and dependence power matrices are then generated and illustrated in Table 15. All of the risk factors are grouped into four categories in this section. The first cluster (Cluster I) is made up of 'autonomous measures' with low drive and dependence power. They are relatively cut off from the system, with which they have only a few tenuous relations. These factors do not affect the system and are not affected by the system. Factor 15 (lack of transportation trucks/equipment) and Factor 16 (lack of customer relationship management) are autonomous factors in our study.

Table 15. Clusters of uncertainty and risk factors in logistics service providers.

18	12																	
17																		
16																		
15					IV									III				
14																		
13					9	8				13								
12																		
11		7, 10			17													
10							6										11	
9		15												3				
8									16				2	14				
7																	4	
6																1		
5															5			
4					I									II				
3																		
2																		
1																18		
Driving/Dependence power	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

The second cluster (Cluster II) consists of 'dependent measures' which have weak drive power but strong dependence power. These have strong links with the general system. Factors 1, 2, 3, 4, 5, 14, and 18 are dependent factors.

The third cluster (Cluster III) contains 'linkage measures', which have both high driving and dependence power. These are unstable. Any action taken in response to these will have an impact on others as well as a self-feedback effect. The study's connection factors are Factor 13 (accepting packages that do not meet standards) and Factor 11 (conflicts between workers and managers).

The fourth cluster (Cluster IV) consists of the 'independent measures' that have strong drive power but weak dependence power. These affect the other factors so that they are crucial parameters. They deserve a high priority in terms of management decision making to mitigate risk. Factors 6, 7, 8, 9, 10, 12, and 17 are independent factors.

5. Discussion of Results

Several guidance themes that are of interest to top management may be drawn from the analyses of the results and the developed ISM model. It seems that lack of strategic planning and failure to sense and respond to market changes is a critical issue that has an enormous impact on a majority of the risk factors. It has the strongest driving power. Placing due emphasis on strategic planning and creating an agile environment, so that the organization may readily adapt to the dynamic changes in the market, will serve to diminish information technology (IT) infrastructure-related issues as well as information technology equipment-related needs.

Another outcome of placing an emphasis on strategic planning is that it impacts many other risk factors, such as lack of skilled workers, lack of customer relationship management, lack of motivation among workforce, and delays in delivery reports, to name just a few. This is observed from the developed ISM model, where "lack of strategic planning", being at the lower level of the ISM model, is found to impact quite a few of the risk factors. This is the single most factor with enormous impact. Top management, by focusing on this measure, can therefore address many of the other issues associated with the risk mitigation of the logistics industry.

Two other risk factors that have a high driving power are "problems arising from the address-based information system" and "logistics service providers forms not adequately designed". From the model, it is observed that the latter factor has a direct impact on the former factor, which subsequently impacts many other risk factors, such as "lack of customer relationship management", "carelessness and a lack of motivation among workforce", "accepting unclear, concise, and inaccurate address information", "delays in delivery reports", and others. Thus, by creating "adequately designed forms", the organization should be able to address many of these issues.

From the analyses and the developed model, it is found that "accepting packages that do not meet standards" has a driving power similar to that of "logistics service providers forms not adequately designed", discussed previously. Its dependence power is slightly higher than that of the risk factors of "logistics service providers' forms not adequately designed" and "problems arising from the address-based information system". We observe from the ISM model that addressing the factor "accepting packages that do not meet standards" obviously impacts the factor "accepting unclear, concise, and inaccurate address information" and vice versa. Furthermore, addressing this issue will also have an impact on some of the other risk factors at the upper level of the hierarchy. From the ISM model, the risk factors impacted will be "delays in delivery reports" and, consequently, those factors impacted by it.

Moving on to the risk factors at the next level of driving power, these are found to be "lack of information technology equipment", "lack of information infrastructure", and "lack of adequate promotion standards and requirements for managers". The dependence power for each one of these risk factors is rather low. From the ISM model, we observe that addressing the factor of "lack of strategic planning and failure to sense and respond to market changes" directly impacts all three of the risk factors at this level, namely, "lack of information technology equipment", "lack of information infrastructure", and "lack of transportation trucks/equipment". Hence, by dealing with the factor "lack of strategic planning and failure to sense and respond to market changes", as the one with the highest driving power, initially, the risk factors at this level have been dealt with implicitly. Of the remaining risk factors, the one with a high driving power is "lack of skilled workers". While this directly impacts "lack of customer relationship management" and, consequently, other risk factors up the chain of hierarchy, it is impacted by the other previously considered risk factors, which have a higher driving power. For example, the risk factors with the highest driving power, namely "lack of strategic planning" and the factor "lack of adequate promotion standards and requirements for managers", with a higher driving power than that of this factor, have an impact on "lack of skilled workers".

Insights on the Turkish Logistics Industry

Some insightful results, related to the logistics industry in Turkey, are observed from the analysis. Based on joint consideration of the driving power and dependence power of risk factors, a priority action for risk mitigation is to have a futuristic and participative strategic planning process that is responsive to market changes. Such an action seems logical, since the Turkish logistics sector meets demand from Europe, Middle East, and Asia. Supply and demand in these regions will impact the business of logistics industries in Turkey. Changes in the European Union policies may affect logistics operations in Turkey, and consequently, top management may have to be prepared to be agile. Several countries in the Middle East are also under conditions of instability, such as the war in Syria. This affects the logistic sector in Turkey as well.

Another distinctive result observed from the analysis is the factors of lack of forms not adequately designed and problems with address-based information systems. Both of these factors have high driving power and relatively small dependence power. For mitigation of risk, these should also be high on the list for consideration by top management. A reason for these two factors being of high importance in the Turkish logistics sector could be that the address Registration System in Turkey is not integrated with an urban information system. As a result, there are some functional problems in the Standardized Address Database [77]. Thus, the addressing system has not been comprehended adequately and implemented properly in Turkey [78]. Another reason could be the practices of changing names of places, such as streets and squares, as a popular method of attaching national values to public space in Turkey [79]. These changes may also create some problems in addressing systems.

Furthermore, another reason could be that all parts of the form are either not being filled out completely or that certain information required for sorting is not specifically identified in the forms. The burden of rectification, to some extent, may fall on the hands of the logistics providers. Since these two factors are more generic in nature, addressing them, initially, should improve the effectiveness and efficiency of operations. Goods will arrive faster and fewer wrong deliveries will be made with effective action on these two factors. Hence, this recommendation could be expanded to logistics industries, in general.

Another observation from the analysis, pertinent to the Turkish logistics sector for risk mitigation, seems to be the creation of adequate promotion standards and requirements for high level managers. This particular factor has generally not surfaced in prior studies. Possible reasons could be that nepotism exists in the filling of senior management. Alternatively, favoritism based on personal relationships are possibly rewarded over professional qualifications. Lack of such standards will obviously have an effect on the morale and motivation of employees who are impacted by these undeserving promoted personnel.

6. Conclusions

In the current century, it is not feasible to be agile to market needs unless an adequate IT infrastructure is in place for rapid dissemination of information requirements at all levels of the organization. Such actions will improve both effectiveness and efficiency and make the company more robust to related risk factors. With the high driving power of the factor, lack of strategic planning, it is imperative for senior management to firmly implant such a structure within the organization. Doing so will create other benefits, such as a forward-thinking organization that is constantly looking ahead to identify the changing and unmet needs of the customer. It will also assist in keeping the organization ahead of its competitors.

On an overall basis, we are in a position to summarize our conclusions for risk mitigation in the logistics industry of Turkey. Top management needs to put the highest emphasis on strategic planning. In developing their goals and objectives, they need to be cognizant of market changes, since customer needs are dynamic and change with time. Beyond this important action item, designing adequate forms for logistics service providers seems to be of importance. The impact of both of these action items permeates throughout all levels of the organization. The first action item has a direct impact on keeping the organization at the forefront of the industry. It indirectly affects morale and motivation of the workforce as well as customer relationship management, an important consideration in the logistics industry. All of this helps to improve effectiveness and efficiency. The second action item is more specific and deals with design of the appropriate forms for the service providers. Adequate design will reduce errors in delivery, improve delivery time, and, consequently, also improve customer relationship management, since there will be fewer customers who will be displeased. An indirect benefit of this action may be a reduction in "accepting packages that do not meet standards", since clear guidelines will be specified on completing information requirements on the stipulated forms. This will also help in reducing delays in service as well as delivery reports. The third action item is to improve "lack of adequate promotion standards and requirements for high level managers". Addressing this will impact the "skill level of workers" and foster improvement in "customer relationship management". Direct benefits of such an action include reduction in errors and improvement in efficiency. Indirect benefits of this action include improved morale and motivation of the workforce and fewer conflicts between workers and managers.

Since the data were collected from logistics companies in Turkey, the conclusions are relevant to such organizations in Turkey. However, we feel that the general conclusions drawn from the study could be of interest to logistics companies in general. The rationale behind this statement is based on the thoroughness of the study. Given the variety of risk factors considered in the study, eighteen to be precise, and the network relationship between the factors, we believe that for logistics companies in other countries, similar risk mitigation actions could be relevant. Furthermore, feedback from practitioners and academics, all familiar with the logistics industry, provides us with some degree of confidence regarding the issues that are faced by logistics service providers in Turkey and possibly beyond its boundaries.

As emphasized by Pfohl et al. [48], one point to be careful of when determining the relationships between risks is that participating experts have to be instructed to focus solely on bi-directional linkages between two risks. If transitive dependencies are used, the model will produce too many cycles, and therefore, will not derive a hierarchy based on the input. With a careful research design, WISM can be used as an applicable methodology to supply chain risk management efforts.

There are some limitations of the interpretive structural modeling (ISM) procedure. First, it is not practical in systems with too many elements in operation. Second, while ISM cannot be statistically validated, using a Delphi method by seeking input from experts in the field provides some validation to the chosen risk factors and their relative importance. Third, ISM cannot deal with the dynamic and time-related behavior of the risk factors. Fourth, since convenience sampling was used in this study, future studies could perhaps draw a larger sample size of Turkish managers that represents a broader geographical region. Fifth, based on the risk classification of Ho et al. [22], we considered only micro-level risk factors of the service providers in Turkey. Perhaps, future studies could include micro- and macro-level risk factors and in order to yield an in-depth understanding of the sectoral risks in Turkey.

Other areas of future research in this context are as follows. Since the ISM technique is static in nature, perhaps system dynamic models could address the dynamic and time-related behavior of risk factors. Furthermore, for future studies, perhaps structural equation modeling (SEM) techniques could be used in order to derive statistically valid inferences. However, in that situation, for testing of research hypothesis, assumptions may have to be made on the data for proper use of a specified technique. Finally, in-depth interviews with top management teams of logistic service providers in Turkey can be used to collect holistic data on the risks of supply chain management in future studies.

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