Assessment of Collaboration-Based and Non-Collaboration-Based Logistics Risks with Plithogenic SWARA Method

Alptekin Ulutaş [1], Ieva Meidute-Kavaliauskiene [2,*], Ayse Topal [3] and Ezgi Demir [4]

1   International Trade and Logistics Department, Sivas Cumhuriyet University, Sivas 58140, Turkey; aulutas@cumhuriyet.edu.tr
2   Business Management Faculty, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
3   Business Department, Niğde Ömer Halisdemir University, Nigde 51240, Turkey; ayse.topal.ohu@gmail.com
4   Management Information System Department, Faculty of Management, Gebze Technical University, Gebze 41400, Turkey; ezgidemir@gtu.edu.tr
*   Correspondence: ieva.meidute-kavaliauskiene@vilniustech.lt

Abstract: *Background*: Uncertainty is the major source of hazards, and it is present in a wide range of business activities. Due to the high level of unpredictability in logistics operations, the logistics sector has traditionally operated in a high-risk environment. These risks have become considerably more complicated as the corporate environment has changed in recent years, such through globalization, environmental concerns, and changes in demand. As a result, in order for a logistics firm to thrive, it is necessary to evaluate and assess the risks associated with logistics. *Methods*: The Plithogenic Stepwise Weight Assessment Ratio Analysis (SWARA) has been used in this study to assess the logistics risks. The logistics risk considered in this study are transportation-related risks, purchasing-related risks, inventory-related risks, information-related risks, packaging-related risks, operational-related risks, geographical location-related risks, natural disaster-related risks, and organization-related risks. *Results*: The most significant logistics risks are found to be Inventory-Related Risks, while the least significant are Geographical Location-Related Risks. When compared to the standard SWARA approach, the Plithogenic SWARA method may be employed in group decision-making issues without losing information. *Conclusions*: The proposed technique will help logistics professionals make informed decisions and manage and analyze risks more efficiently. This study will also contribute to the literature as it is the first time that logistical risks have been addressed by utilizing the Plithogenic SWARA technique.

Keywords: logistics risks; MCDM; plithogenic SWARA

1. Introduction

Uncertainty is the main source of the risks, and it is involved in many business operations. Companies are getting more concerned about risk and risk management processes as the markets getting more dynamic and unpredictable due to several factors such as demand, financial issues, and environmental factors. Besides, the company often faces risks in its own departments, such as the marketing department, operations department, human resources department, and finance department, etc. Therefore, risk has been widely researched in the literature and different definitions appeared for risk term as risk encompasses a wide range of concepts and can be classified according to a variety of factors. Risk refers to the likelihood of unfavorable outcomes from a certain event [1]. The International Organization for Standardization ISO Norm 31000 provides the widest definition of risk as the impact of uncertainty on objectives [2]. It is usually expressed in terms of risk sources, which are elements having the potential to cause risk, potential events which are incidences or changes in a specific set of conditions, their consequences, which are the consequence

of an occurrence that has an impact on objectives, and their probabilities, which are the chances of something occurring [2,3].

Business risk, according to Deloach [4], is the amount of uncertainty that the organization must comprehend and successfully manage while it executes its plans to achieve its business goals and produce or generate value. From a quantitative perspective, risk has been defined as a characteristic that represents the set of possible outcomes, as well as the range of relative probability for each outcome [5].

Risk management procedure, which has three important steps; identification, categorization, and assessment, has been designed to mitigate risks [6]. Identification entails evaluating all potential risks in a given situation. Risks are classified into homogenous categories for risk assessment and risk reduction techniques in categorization. Managers determine how to respond to categorised risks during risk assessment. Several researches on risk assessment and management in various sectors can be found in the literature. Radanliev et al. [7] conducted risk assessment for the internet of things (IoT) in the cyber market. Birkel et al. [8] explored the potential risks in Industry 4.0 and presented a framework for the risks that may occur during Industry 4.0 adoption. Lyu et al. [9] assessed risks in construction with fuzzy Analytic Hierarchy Process (AHP).

The logistics sector has always operated in a high-risk environment due to uncertainty in logistics operations since the beginning, such as robbery, weather conditions and environmental factors. Humanitarian logistics has especially involved high risks due to the uncertain environmental conditions brought by unexpected disasters. Disasters either natural (earthquakes, floods) or man-made (terrorist attracts) have devastating effects on people and states; therefore, humanitarian logistics to deal with the consequences of these effects is a significant operation. Van Wassenhove [10] stated that humanitarian logistics are constantly confronted with unknown conditions, unlike in private sector logistics.

Hapeman [11] categorized humanitarian logistics risks into 5 groups: economic, social, environmental, infrastructural, and political. However, with changing conditions in the business environment in recent years such as globalization, environmental issues and changes in demand, risks in private sector logistics have evolved to be much more complex. Now, it is critical to examine and assess the risks related to logistics for a logistics company to succeed. The risks in logistics have been summarized by Oklander and Yashkin [12] as the possibility of business risk such as a cut in supply flow and loss in production, property damage due to natural disasters such as earthquakes and floods, robbery, legal risks, and technological risks. Baharmand et al. [13] identified risks in "in-country transportation" of humanitarian aid supply chains. Chand et al. [14] explored the risks and uncertainties in a supply chain of Indian companies by using Analytic Network Process (ANP) and Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) methods. Kubasova et al. [15] discussed logistics risk in construction projects. Khan et al. [16] identified the risk factors related to halal food supply chains and prioritized them with fuzzy AHP. Panjehfouladgaran and Lim [17] identified risk variables and their clusters in reverse logistics. The risks and uncertainties related to logistics are examined and the most significant logistics risk is identified in this study by using plithogenic Stepwise Weight Assessment Ratio Analysis (SWARA) method. The proposed method will assist in making accurate judgments and efficiently managing and analyzing group decision-making problems without losing information. In the traditional SWARA method, individual judgments of decision-makers cannot be fully addressed in group decision-making problems, so information loss occurs. The proposed method prevents this loss of information by means of the plithogenic aggregated operators. This study will contribute to the literature by developing a new MCDM method called Plithogenic SWARA. Since the multi-criteria decision-making methodology has been studied, the literature review has been examined in two parts: logistics risk and multi-criteria decision-making studies in logistics risks.

This study consists of six sections. In the next section, literature about the risks and MCDM methods to deal with the risks has been reviewed. In the third section, Plithogenic

SWARA method has been explained. In the fourth section, Plithogenic SWARA method has been applied for assessment of logistics risks. In the fifth section, results are discussed, while in the sixth section, a conclusion is made.

2. Literature Review

Within the scope of risk studies, Cavinato [18] gathered risks in international supply chain and network structure. These risks were classified as physical, financial, informational, relational, and innovational, respectively. Kubasova et al. [15] considered risk management as the sustainability of businesses. In this context, they examined logistics risks as a source of structural support. Construction projects have been considered as a case study and operational logistics activities have been discussed. Jereb et al. [19] discussed logistics process risks in the supply chain and determined that the lack of standardization and model are important factors in the supply chain risk. Pokrovskaya et al. [20] devoted the logistics risks for optimizing company's transportation process, aiming to reduce uncertainty in the organizations. Prakash et al. [21] handled a multi-echelon closed-loop supply chain model in the supplier's quality risks and logistics risks. These risks have been modelled by using mixed integer linear programming. Cagliano et al. [22] studied risks in a special logistics area: blood transfusion. Wang and Regan [23] handled third party logistics (3PL) risks and discussed the measures of risk prevention. They discussed the risk reduction measures for logistics outsourcing to structure distribution networks and gained competitive advantages. Wang et al. [24] studied supply chain risks for logistic innovation in the Australian courier firms.

Ofluoglu et al. [25] identified and analyzed disaster logistics risks in the literature from January 2011 to December 2018. It was found that demand risk is the most considered disaster logistics risk and the facility location problem is the most indicated disaster logistics issue. Also, it was identified that stochastic programming is the most used methodology under risk conditions. Kodym et al. [26] proposed a risk framework in the concept of Logistics 4.0. It has classified risk as economic risks, technical and IT risks, social risks, ecological risks, and legal/political risks. Selviaridis et al. [27] conducted a survey in the concept of buyers and suppliers of logistics services in UK. They classified risks as strategic, financial and operational risks. Li-jun [28] discussed different risks in logistics outsourcing as contract risks, management risks, information risks, market risks, and financial risks, respectively. Salanta and Popa [29] handled main outsourcing logistics risks for avoiding failure and termination of agreements for Romanian practitioners and academics. These risks are loss of control, informational risks, vendor opportunism, deterioration of service, poor communication, poor provider competence, lack of shared goals, loss of power, poor strategic development, and internal governance risks, respectively. Liu et al. [30] investigated the risks for dangerous goods in marine logistics. They provided preventative measures to avoid accidents in marine logistics for dangerous goods to increase sustainability and security. Babazadeh and Razmi [31] used robust stochastic programming for overcoming operational and disruption risks in the agile supply chain. It has been shown that the robust model is efficient in terms of cost. Moslemi et al. [32] analyzed risk factors in container shipping and logistics services using a dual perspective. Varzandeh et al. [33] handled global supply chain management risks associated with global economy. The risks in this study have been categorized for small, medium and large organizations. Wu and Chaipiyaphan [34] conducted delivery vulnerability in logistics risk management. They investigated accumulated data to utilize pragmatic business analytics insights on logistic management. Pfohl et al. [35] proposed a structural analysis for supply chain risks in two German trade companies. Yongsheng and Li [36] handled logistics risks of enterprises by using balanced scorecard (BSC) in order to increase the performance of companies. Jia and Zhang [37] studied risks in maritime logistics services because of higher uncertainty. In this study, an early warning model has been built for decreasing maritime logistics service risks by stimulating other risks. Liu & Wang [38] handled cold chain logistics risks for fresh food in the circulation process. For this purpose, a game

model was established for operating risks. Then, the impact of different parameters was analyzed. Chang et al. [39] conducted the risks in container shipping operations. Risks have been classified as information, physical, and payment risks. Roşca et al. [40] discussed risks in a port logistics system. The significant risks in port logistics have been investigated. Chen et al. [41] handled emergency logistics in the rescue process after sudden disasters. In this study, reliability factors of materials have been introduced. Then, emergency logistics system was identified. The improved epidemic model to analyze the influencing factors of risk propagation mechanism was developed. Yan and Suo [42] classified logistics risks in financial businesses. A Bayesian network has been constructed to identify the risk levels. Lai et al. [43] discussed port risks in maritime transportation networks. A conceptual discussion of port logistics risks was conducted and define-measure-analyse-improve-control (DMAIC) implementation framework for potential risk management operations was used. Gao [44] discussed the features and development of the logistics of fresh goods in e-commerce, and the risks involved. Lee [45] proposed arctic shipping logistics risks in the concept of fourth industrial technology. Lakehal & Tachi [46] discussed several constraints, such as delays, flexibility, diversity of merchandise, and road risks in road transportation. Wang [47] studied impacts of the supply chain risks of the transportation sector in Australia. In this study, risks have been classified from company, customer, and environmental perspectives.

Behl and Dutta [48] studied supply chain management focused on humanitarian logistics for the purpose of drawing a roadmap a performance evaluation. Sahin et al. [49] proposed a mathematical model to define the location and quantity of containers, as well as the type and amount of relief supplies to store. Also, it has been tested using earthquake risk data, estimates of population under risk, and the distances between cities. Baporikar and Liina [50] studied global and sudden disasters such as earthquakes, tsunamis, hurricanes, and epidemics to evaluate the challenges faced by humanitarian logistics in Namibia. Beresford and Pettit [51] proposed a Humanitarian Aid Logistics research for identifying, assessing, and resolving key problems in humanitarian aid logistics and supply chain relationships to the reduction of the human cost of disasters. Oloruntoba et al. [52] suggested new theory driven research themes and outlines potential directions for future of operations management in humanitarian contexts.

Cozzolino [53] underlined the critical role of logistics and supply chain management in the humanitarian logistics concept for the disaster management. Oloruntoba and Gray [54] identified "agility" in supply chain management for humanitarian aid by developing a model. Kosacka–Olejnik [55] studied academic signs of progress in logistics maturity of the service industry. Oleśków–Szłapka and Stachowiak [56] discussed the framework of Logistics 4.0 maturity model to develop a road map for businesses' pilot research. Facchini et al. [57] proposed a model to optimize the production process and organization structures in Industry 4.0 vision. In this study it has been defined to overcome the growing uncertainty and dissatisfaction in implementing Industry 4.0 vision. The model highlighted the pros and cons of two investigated companies regarding the transition towards Logistics 4.0 technologies.

When the literature review was examined from multi-criteria decision-making viewpoints, the following studies were found.

Chand et al. [14] conducted risk management in supply chain by using ANP based MOORA methodologies. Khan et al. [16] handled halal food supply chain risk by using fuzzy AHP. Duran and Zafeirakopoulos [58] discussed reverse logistics risks by using ANP based Complex Proportional Assessment (COPRAS) methodologies. Mzougui et al. [59] handled supply chain risks with the framework of Failure Mode, Effects and Criticality Analysis (FMECA), AHP, and fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) methods. Teniwut [60] conducted an integrated multi-criteria decision-making (MCDM) with fuzzy AHP to provide a better decision in the problems involving various related complicated factors. Vishwakarma et al. [61] developed a model to sustain global health of human beings and businesses. For this purpose, fuzzy AHP was used

to prioritize and sort risks in the pharmaceutical supply chain. Senthil et al. [62] ranked risks with AHP based fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodology in reverse logistics. Ulutaş et al. [63] developed a new method called Plithogenic PIvot Pairwise RElative Criteria Importance Assessment (PIPRECIA) to prioritize logistics risks.

Govindan and Chaudhuri [64] analyzed the relationships among risks in 3PLs by using DEMATEL method. Karakurt et al. [65] proposed a new risk analysis method for the logistic sector with fuzzy Best Worst Method (FBWM). Yousefi et al. [66] ranked logistics processes risks with a sequential multi-stage fuzzy cognitive map (SMFCM) and process failure mode and effects analysis (PFMEA). They discussed all logistics sub-processes to make a risk prioritization. Thakkar [67] used DEMATEL-ANP (DANP) to measure the overall supply chain risk. Gaudenzi and Borghesi [68] evaluated supply chain risks with AHP. Shanker et al. [69] handled 3PL supply chain risks in a restaurant with fuzzy AHP and fuzzy TOPSIS methods. Cheng and Yu [70] studied risks in emergency logistics regarding natural disasters with fuzzy logic and Delphi method. Kwak et al. [71] discussed international supply chains by means of failures in international logistics processes. For this purpose, international logistics risks have been proposed in a holistic approach based on Delphi method.

Integration and collaboration have become popular during the 1980s and 1990s in supply chain management [72]. Logistics management is a part of supply chain management; thus, these two terms also became applicable in logistics management. Integration and collaboration are critical for maintaining a strong relationship and improving performances [73]. Integration is needed among the companies working together in the same network or chain in order to know what is delivered to the end consumer in terms of cost and service [72]. Collaboration among companies develops long-term relationships based on personal trust, resulting in benefits such as collaborative knowledge generation, sharing expertise, and understanding the partner's goals, as well as lower logistical costs and the production of value for supply chain [74,75]. Trust is regarded as a binder among collaborating companies [76]. It can be defined as the readiness to become subject to someone whose actions are beyond his control [77]. Communication is another element that is needed for effective collaboration. It is the glue that holds companies in a supply chain together in a bilateral way with a balanced multilevel interaction [78].

Unlike the studies related to logistics, risks were studied via the concept of humanitarian logistics and maturity models. Also, in MCDM methodologies the criteria of logistics risks have been discussed in the literature. However, in this study, two main groups of risks will be examined: collaboration-based risks and non-collaboration-based risks. In addition, these risks are valid throughout all of the logistics industry. The proposed methodology is discussed for the first time in this study.

3. Materials and Methods

In comparison to other multi criteria decision making methods for determining criteria weights based on human knowledge, the SWARA method appears to be simple and adaptable [79]. The neutrosophic set, in combination with the contradiction degree, are used with SWARA method in this study to determine the experts' collective judgment effectively. The Plithogenic SWARA method is developed to assess the logistics risks and to identify the most significant logistics risk in this study.

3.1. Neutrosophic Set

The neutrosophic theory is used effectively in the presence of inconsistency in the data. It provides a three-way decision with the neutrosophic set to make successful decisions [80]. Three neutrosophic membership functions are presented to aid in the computation of weights related to alternatives and criteria for selecting the best option. $\widetilde{b} = \langle (b_1, b_2, b_3) ; \alpha, \theta, \beta \rangle$ can be determined as a single-valued triangular neutrosophic set

consisting of falsity membership function $S_b(x)$, indeterminate membership $I_b(x)$, and truth membership $K_b(x)$ as follows [81]:

$$K_b(x) = \begin{cases} \alpha_b \left(\frac{x - b_1}{b_2 - b_1} \right) & if\ b_1 \leq x \leq b_2 \\ \alpha_b & if\ x = b_2 \\ 0 & otherwise \end{cases} \tag{1}$$

$$I_b(x) = \begin{cases} \left(\frac{b_2 - x + \theta_b(x - b_1)}{(b_2 - b_1)} \right) & if\ b_1 \leq x \leq b_2 \\ \theta_b & if\ x = b_2 \\ \left(\frac{x - b_2 + \theta_b(b_3 - x)}{(b_3 - b_2)} \right) & otherwise \end{cases} \tag{2}$$

$$S_b(x) = \begin{cases} \left(\frac{b_2 - x + \beta_b(x - b_1)}{(b_2 - b_1)} \right) & if\ b_1 \leq x \leq b_2 \\ \beta_b & if\ x = b_2 \\ \left(\frac{x - b_2 + \beta_b(b_3 - x)}{(b_3 - b_2)} \right) & if\ b_2 \leq x \leq b_3 \\ 1 & otherwise \end{cases} \tag{3}$$

3.2. Plithogenic SWARA

The beginning, creation, development, and evolution of new entities from the synthesis of contradictory (dissimilar) or non-contradictory numerous old entities are referred to as plithogeny [82]. A plithogenic set is defined as a set enclosing several elements described by a number of properties, and each property has values [81]. In this study, plithogenic aggregation operators, which are a part of the plithogenic set, will be used to enhance SWARA method in terms of decreasing information loss. When compared to the traditional SWARA method, the Plithogenic SWARA method may be used in collaborative decision-making situations without sacrificing information. The proposed method will assist logistics professionals in making better informed decisions and managing and analyzing risks. The Plithogenic SWARA method's steps are represented below.

Step 1: Factors are identified by decision-makers (DMs). DMs sequenced these factors from the most significant to the least significant.

Step 2: Beginning with the second factor, the jth factor and the $j - 1$ th factor are compared.

Step 3: A contradiction degree acquires better accuracy for plithogenic aggregation operations [83]; therefore, the contradiction degree is identified between each criterion and the dominant criterion value [82]. Thus, the contradiction degree ($c : V \times V \to [0, 1]$) is determined.

Step 4: The opinions of all decision-makers are integrated with Equation (4).

$$\begin{aligned} ((b_{i1}, b_{i2}, b_{i3}), 1 \leq i \leq n) &\wedge p((t_{i1}, t_{i2}, t_{i3}), 1 \leq i \leq n) \\ &= \left(b_{i1} \wedge_F t_{i1}, \tfrac{1}{2}(b_{i2} \wedge_F t_{i2}) + \tfrac{1}{2}(b_{i2} \vee_F t_{i2}), b_{i3} \vee_F t_{i3} \right), 1 \leq i \leq n \end{aligned} \tag{4}$$

where $\vee_F$ and $\wedge_F$ indicate the fuzzy t-conorm and t-norm, respectively.

Step 5: The crisp values (v_j) are obtained from the conversion of the neutrosophic values ($\tilde{v}_j = \langle (v_{1j}, v_{2j}, v_{3j}); \alpha_j, \theta_j, \beta_j \rangle$) as follows [63]:

$$U(v_j) = \frac{1}{9} (v_{1j} + v_{2j} + v_{3j}) \times (2 + \alpha_j - \theta_j - \beta_j) \tag{5}$$

Step 6: The last ranking of the factors is acquired by uniting the rankings of the factors of the DMs with the arithmetic mean. After this, the process is continued with steps of the traditional SWARA [84].

Step 7: y_j coefficient is calculated as:

$$y_j = \begin{cases} 1 & j = 1 \\ 1 + v_j & j > 1 \end{cases} \tag{6}$$

Step 8: z_j recalculated weight is acquired as:

$$z_j = \begin{cases} 1 & j = 1 \\ \frac{z_{j-1}}{y_j} & j > 1 \end{cases} \tag{7}$$

Step 9: The final weights (w_j) of criteria are obtained as follows:

$$w_j = \frac{z_j}{\sum_{k=1}^{n} z_k} \tag{8}$$

4. Application

Logistics risks are assessed with the Plithogenic SWARA method in this study. Data were obtained from five experts working in the field of logistics for the evaluation of these risks. Especially during COVID-19, logistics risks have become a crucial part of supply chain. In order to overcome the problem of logistics risks, the project has been studied in this paper. In this light, a consultancy service was received for logistics risk management. In this consultancy, experts have been proposed according to their expertise in the different parts of logistics and sectors they are working on. The study was carried out for 8 weeks. Firstly, the consultancy firm suggested 20 experts who have been working in the logistics sector for many years. Emails were sent to each of these experts. Only 5 of these experts responded to e-mails. Therefore, in this study there are five experts. Expert 1 is a general manager who has 20 years experience in the field of logistics. Expert 2 is a consultant. Additionally, he has a PhD, and has 22 years of experience in the field of logistics. Expert 3 is an associate professor, and he has been working in the logistics sector for 12 years. Expert 4 is an industrial engineer, and she has been working in the logistics area for nearly 15 years. She is a department member in a logistics company. Expert 5 is also a consultant. She has been working at least 10 years in the field of risk assessment. In this study criteria have been determined by literature review. Later, the methodology was developed by an associate professor academician. In addition, the other people in the consultancy company discussed in the meetings. In the 8-week meetings, the criteria in the literature were discussed, and new criteria were added and removed. While determining the criteria, the risk criteria have been divided by the parts by means of a risk expert consultant. In addition, the criteria were developed by examining the distance functions in detail.

The logistics risks to be used in the assessment were determined by these experts. Nine logistics risks were determined by experts and were classified into two main groups, which are collaboration-based and non-collaboration-based logistics risks. Collaboration-based risks can be defined as the risks faced in the logistics activities carried out in collaboration. In other words, it can be defined as the risks that arise in performing logistics activities with outsourcing companies (third-party logistics provider, fourth-party logistics provider and fifth-party logistics provider, etc.). Non-collaboration-based risks can be defined as risks that are independent of any collaboration. Collaboration-based logistics risks in this study are transportation-related risks, purchasing-related risks, inventory-related risks, information-related risks, packaging-related risks and operational-related risks. On the other hand, non-collaboration-based risks are geographical location-related risks, natural disaster-related risks, and organization-related risks. Detailed descriptions of these nine logistics risks are presented below. The risks explained above have been selected in this study because they cover most of the risks faced in logistics sector as suggested by the experts interviewed.

Geographical Location-Related Risks (GLR): With the globalization, logistics operations spread to the outside of the certain locations. A business that is offering logistics in a specific location began to give service in regional and international markets. Although expanding location increased the profit, it brought risks such as challenges in transporting products to or from a certain location due to the differences in landscapes, climate and cultures. The risks caused by geographical difficulties according to transportation modes

used are called GLR. These geographic challenges can be as follows: the difficulty of transportation by road and/or rail due to landforms, the presence of a climate that adversely affects transportation by air, or being in a region far from the airport, and being in a region far from the railways, etc.

Transportation-Related Risks (TPR): Transportation is the main operation in logistics. Goods are moved from seller to buyer with transportation and logistics' main objective is to handle transportation effectively. Therefore, transportation risk is important. Transportation risks encompass concerns such as driver mistakes, missing and improper procedures involving products exposed to trade in packing and loading processes. These risks include as follows: delays in logistics activities due to transportation, incomplete delivery of goods/products, damage to goods in transportation, loading and unloading processes, etc.

Natural Disaster-Related Risks (NDR): These risks originate from the nature; therefore, they are difficult to prospect before. The examples to natural disasters can be given as storms, floods, and earthquakes which can render equipment and safety of transportation systems useless. The following examples can be given for these risks: damage to the logistics warehouse in flood/earthquake, landslides preventing road transport, and storms preventing air transport, etc.

Purchasing-Related Risks (PCR): Purchasing risks refers to the possibility of a failing in the procurement process. Failures in the purchasing process can result in financial losses and delays. This involves purchasing consumables, capital investments, estate, equipment, services (consultancies, professional services, building management), and outsourcing.

Inventory-Related Risks (IVR): Clients expect from logistics businesses to deliver the goods in a timely fashion and satisfactorily. Businesses must reduce inventory risks to guarantee that these expectations are regularly met to satisfy clients. Inventory risk refers to the probability that the quality or worth of the business's products would deteriorate in the storage. Incorrect forecasting, incorrect supplier selection and theft can be given as an example to inventory risks. In addition, the deterioration of goods, the expiration of the goods, the emergence of excess inventory costs, etc., are caused by incorrect inventory management.

Information-Related Risks (INFR): Every business has information that is important to its success such as information about customers and production management, product ideas, marketing strategy, and so on. The likelihood that the information provided by a business is incorrect or deceptive is known as information risk and it affects the whole operation of a business. Information-Related Risks that are very common in logistics, in general, are as follows: wrong goods shipped, wrong quantity order delivered, wrong delivery date, etc.

Organization-Related Risks (ORR): It can be defined as the logistics risks associated with the organization. Organizations operate in a very volatile environment. Regulators, rivals, consumers, and social expectations are just a few of the external factors that a company faces. An example of organizational risk can be given as threats to stakeholders, including failing to comply with regulatory requirements or damage to a company's reputation or brand.

Packaging-Related Risks (PKR): Packaging is important in logistics to avoid breakings, spoiling and hygiene of the goods transported. Packages may be subjected to a variety of accidents such as falling during handling. Any product can be compressed at some point during its storage or transit. The integrity of the goods in the packaging is affected by vibrations, which can lead to breakage or degradation. The durability of packages may be affected by temperature and humidity. Examples of these risks are as follows: damage or deterioration of the product due to incorrect packaging, easy damage to the packaging, and reduced carrying capacity due to the large packaging, etc.

Operational-Related Risks (OPR): An incident that has a negative impact on the functioning of an operation after it has been commissioned is referred to as operational risk. These risks are mostly under the company's control. Safety control, human factors,

and other activities that have an impact on the performance, reputation, or security of an organization can be given as examples of operational risks.

Logistics risks in two main groups will be examined collectively; in other words, they will not be examined separately. The experts sequenced the logistics risks are shown above in order of importance. The logistics risks ranking of the experts is represented in Table 1.

Table 1. Experts' Ranking of Logistics Risks.

Logistics Risks	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
GLR	8	9	9	8	9
TPR	2	3	2	2	2
NDR	9	8	8	9	7
PCR	3	2	4	3	3
IVR	1	1	1	1	1
INFR	5	4	3	4	5
ORR	7	5	5	5	4
PKR	4	6	7	7	6
OPR	6	7	6	6	8

Beginning with the second logistics risk, each expert uses triangular neutrosophic values (TNV) to each logistics risk for comparison. As an example, the logistics risk comparisons of Expert 1 are given in Table 2.

Table 2. Expert 1's Logistics Risks Comparisons.

Risks	Rankings	Risks	Linguistic Values	TNV
GLR	8	IVR	-	-
TPR	2	TPR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
NDR	9	PCR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
PCR	3	PKR	FWS	((0.40, 0.35, 0.50), 0.60, 0.10, 0.20)
IVR	1	INFR	VWS	((0.10, 0.30, 0.35), 0.10, 0.20, 0.15)
INFR	5	OPR	VWS	((0.10, 0.30, 0.35), 0.10, 0.20, 0.15)
ORR	7	ORR	VSS	((0.90, 0.85, 0.90), 0.70, 0.20, 0.20)
PKR	4	GLR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
OPR	6	NDR	ES	((0.65, 0.60, 0.70), 0.80, 0.10, 0.10)

Each logistics risk's contradiction degree is equally determined as 1/8. As shown in Table 2, a logistics risk comparisons table is created for each expert. TNVs in these tables are combined with Equation (4). In other words, it means that all judgments of all experts are aggregated. These aggregated values are converted into crisp numbers by Equation (5). Aggregated triangular neutrosophic values and crisp values (v_j) are represented in Table 3.

Table 3. Aggregated Triangular Neutrosophic Values and Crisp Values.

Risks	Aggregated TNV	v_j
IVR	-	-
TPR	((0.018, 0.300, 0.690), 0.028, 0.188, 0.526)	0.165
PCR	((0.020, 0.288, 0.616), 0.064, 0.188, 0.583)	0.133
INFR	((0.044, 0.432, 0.877), 0.057, 0.200, 0.371)	0.223
ORR	((0.034, 0.354, 0.840), 0.046, 0.163, 0.475)	0.192
PKR	((0.178, 0.594, 0.939), 0.209, 0.138, 0.445)	0.309
OPR	((0.043, 0.354, 0.768), 0.149, 0.169, 0.500)	0.192
NDR	((0.160, 0.547, 0.924), 0.236, 0.113, 0.363)	0.319
GLR	((0.042, 0.341, 0.684), 0.195, 0.175, 0.578)	0.171

The logistics risks' rankings with respect to experts are integrated with the arithmetic mean. Then, Equations (6)–(8) are utilized to identify logistics risks' weights. The conclusions of the Plithogenic SWARA method are indicated in Table 4.

Table 4. The Conclusions of the Plithogenic SWARA.

Risks	Rankings by Arithmetic Mean	v_j	y_j	z_j	w_j
IVR	1	-	1	1	0.202
TPR	2	0.165	1.165	0.858	0.173
PCR	3	0.133	1.133	0.757	0.153
INFR	4	0.223	1.223	0.619	0.125
ORR	5	0.192	1.192	0.519	0.105
PKR	6	0.309	1.309	0.396	0.080
OPR	7	0.192	1.192	0.332	0.067
NDR	8	0.319	1.319	0.252	0.051
GLR	9	0.171	1.171	0.215	0.043

Logistic risks are listed with respect to Table 4 as follows; IVR, TPR, PCR, INFR, ORR, PKR, OPR, NDR and GLR. According to the results of the Plithogenic SWARA method, the most important logistics risk was determined as IVR.

5. Discussion

The logistics sector has high uncertainty in its operations; therefore, the risk is higher in this sector. Recently, logistics risks have evolved to be more complex, with several issues faced within recent decades such as environmental problems and demand fluctuations. In these conditions, it has become important to analyze risks better for logistics firms to succeed. There are several studies about logistics risks in the literature [12–17]. However, in this study, a new MCDM method, the Plithogenic SWARA method, was introduced to the literature. By means of the Plithogenic SWARA method, individual decisions can be combined without the loss of information in group decision-making problems. In this study, nine logistics risks were evaluated under two main groups. Two main groups were determined as collaboration and non-collaboration-based logistics risks. However, the logistics risks in these two main groups have not been examined separately. The reason for this is to be able to determine which logistics risk is more important in general. According to the analysis results, the most important logistics risk was determined as IVR logistics risk. According to Plithogenic SWARA results, collaboration-based logistics risks are listed as follows: IVR, TPR, PCR, INFR, PKR, and OPR, on the other hand, non-collaboration-based logistics risks are listed as follows: ORR, NDR, and GLR. Since IVR is the most important risk associated with logistics in general, logistics managers should attempt to reduce this risk. ORR is the most important of the non-collaboration-based logistics risks. In general, non-collaboration-based logistics risks were identified as the least important risks. According to a similar study done by Ulutaş et al. [63], the most important logistics risk was determined as transportation-related risks, and inventory-related risks were determined as the third most important logistics risk. This study, unlike the study of Ulutaş et al. [63], examined nine criteria under two main groups. However, when both this study and Ulutaş et al. [63]'s study is examined, it is seen that the first three logistics risks, namely transportation-related risks, purchasing-related risks, and inventory-related risks, do not change. Therefore, logistics managers need to be careful against these three logistics risks.

Although logistic risks were analyzed with a novel method which is Plithogenic SWARA, the number of criteria and decision-makers used in this study is very low. Particularly, the number of non-collaboration-based risks is very low. This is one of the limitations of this study. Govindan and Chaudhuri [64] examines more criteria and considers collaboration compared to this study; however, the mitigation strategies of these risks are not mentioned. It can be suggested for the future studies that the mitigation strategies for these risks can be developed.

6. Conclusions

Because of the uncertainty in logistics operations, such as robbery, weather conditions, and environmental variables, the logistics business has traditionally operated in a high-risk environment. However, since the corporate environment has changed in recent years with globalization, environmental problems, and demand shifts, these risks have become considerably more complicated. To thrive as a logistics firm, it is important to evaluate and assess the risks associated with logistics.

In this study, the Plithogenic SWARA method is developed to assess and prioritize the logistics risks. The neutrosophic data were taken from five experts working in the logistics sector. The experts first identified nine logistics risks under two main groups, which are collaboration-based and non-collaboration-based logistics risks for assessment. By using the first steps of the Plithogenic SWARA method, neutrosophic data obtained from experts were aggregated, and then aggregated neutrosophic data were converted into crisp data. By using the final steps of Plithogenic SWARA, the crisp importance values (weights) of logistic risks are determined by means of these crisp data. According to the results of the Plithogenic SWARA method, the logistics risks are listed as follows; IVR, TPR, PCR, INFR, ORR, PKR, OPR, NDR and GLR. While the most important of these logistics risks was IVR, the least important logistics risk was determined as GLR. This study contributes to the literature as it develops a new Plithogenic MCDM method. In addition, with this study, the most important logistics risk was determined, and it was tried to help the managers working in the logistics sector. The Plithogenic SWARA method can be used without losing information in group decision making problems compared to the traditional SWARA method. The Plithogenic SWARA method can be used to solve other MCDM problems (performance evaluation, machine selection and supplier selection etc.) in future studies. Also, for further studies, this methodology can be discussed with other methodologies for consistency and comparing. In this study, for the first time the risks have been divided by two parts as collaboration-based and non-collaboration-based logistics risks. So, it will be expected as an important discussion for further studies in the literature. In future studies this risk management may be utilized for humanitarian logistics assessment and maturity levels for logistics.

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