Pesquisa Operacional (2024) 44: e286745 p.1-30
doi: 10.1590/0101-7438.2023.043.00286745

Printed version ISSN 0101-7438 / Online version ISSN 1678-5142
www.scielo.br/pope
ARTICLES

EVALUATION OF LOGISTICS RISK FACTORS WITH BWM METHOD; SIVAS PROVINCE EXAMPLE

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Received May 19, 2024 / Accepted October 4, 2024

ABSTRACT. This study investigates the logistics risk factors impacting Sivas, a strategically significant region in Turkey's logistics network, especially within the Belt and Road Initiative (BRI) framework. Using the Best-Worst Method (BWM), the study analyzes nine main criteria and twenty-seven sub-criteria that can cause delays or disruptions in logistics activities. Data were collected from 15 logistics experts in Sivas through questionnaires and analyzed using Lingo 20.0 software. The analysis reveals that transportation risk is the most critical factor affecting logistics activities in Sivas, while organizational risks have the least impact. Specifically, accidents during transportation were identified as the most significant sub-criterion, whereas worker strikes were deemed the least significant. This study contributes to the literature by offering a detailed categorization and prioritization of logistics risks, providing actionable recommendations for mitigating these risks. Furthermore, it presents a transferable model applicable to other regions with similar logistical and economic profiles, offering valuable insights for policymakers and industry stakeholders.

Keywords: logistics risk factors, best and worst method (BWM), multi criteria decision making.

1 INTRODUCTION

Today, with the rapid advancement of technology, there has been a significant increase in the speed of accessing information and technology, thereby greatly facilitating businesses in their

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market outreach endeavors. The field of logistics, which originated as a military discipline in the annals of history, has now permeated every aspect of our lives. It encompasses a wide range of essential services such as transportation, storage, inventory management, packaging, and product handling. By efficiently managing these logistics functions, companies gain a competitive edge, allowing them to concentrate on their core activities in both local and global markets. In its essence, logistics can be described as the vital link within the supply chain, where the seamless flow of information, services, and products is established in a bidirectional manner. Its purpose is to ensure that the right product reaches the right place, at the right time, and at the right price, all while meeting the precise conditions and requirements of the customers. By forging strategic partnerships with various business entities, logistics strives to create added value for customers.

However, it is important to acknowledge that logistics operations also entail certain risk factors. These risks arise due to the diverse nature of logistics activities and the vast expanse of their operational scope. Such factors can lead to delays in logistics operations, potentially impacting the timely delivery of goods and services.

Despite these challenges, the ever-evolving realm of logistics continues to adapt and innovate. Technological advancements, coupled with effective risk management strategies, help mitigate these inherent risks, ensuring smooth and efficient logistics operations in today's dynamic business landscape. Logistics risk can be defined as natural or human factors that cause a disruption or breakdown in the process of logistics activities at any stage. Companies can minimize these threats, which are generally considered unfavorable, by identifying them beforehand and reducing them to a minimum during their operations, thereby preventing time and cash losses. Barriers that are typically addressed after they arise affect the success of companies due to the additional costs and delays, they cause in operations, and they are crucial for the continuity of both private and public institutions' futures, necessitating identifying possible risks and damages beforehand and planning solutions (Kaba 2013: 37-38).

This article makes a significant contribution to the state of the art by offering an in-depth analysis of the logistics risks associated with Sivas's strategic role in Turkey's logistics network, particularly within the context of the Belt and Road Initiative (BRI). It advances the discourse on logistics risk management by identifying and systematically categorizing the key risks that Sivas faces, including transportation, supply chain, and organizational challenges. By prioritizing these risks, the paper offers actionable recommendations for public and private institutions to mitigate them according to their severity. Furthermore, it presents a transferable model that can be applied to other regions with comparable logistics and economic profiles. As a result, this study enriches the current body of literature on regional logistics risk management and offers valuable insights for policymakers, industry stakeholders, and researchers focused on optimizing logistics networks in emerging economies.

In this study, logistics risk factors of companies in the logistics sector in Sivas province were evaluated using the Best and Worst Method (BWM), one of the Multi-Criteria Decision Making (MCDM) methods. Data obtained from experts through a survey was analyzed using Lingo 20.0 software. The chosen method was preferred in this study as it is newly developed in the literature, requires less pairwise comparisons than the Analytic Hierarchy Process (AHP). Since the evaluation of logistics risk factors using BWM has not been encountered in the literature, this study contributes to the literature in this regard.

The study consists of five sections. The next section will provide a literature review on both the risk factors and studies conducted using the BWM method. In the third section, the method used in the study will be introduced. The fourth section will present the application of the study based on the collected data. The final section will provide the results of the study.

2 LITERATURE REVIEW

In the study, literature review was conducted in three ways: (1) Studies Related to Risk Factor, (2) Studies using MCDM in assessing supply chain risks (3) Studies Using BWM.

2.1 Studies Related to Risk Factor

In conducting a literature review on risk factors, prior studies that aim to identify and select relevant factors were first examined to guide the determination of risk factors for this research.

Zsidisin and Ellram (2003) applied the agency theory framework to manage supplier behavior as a tool to mitigate supply risk and reduce the impact of harmful events. The main criteria assessed in the study included behavior-based management, buffer-focused management, and sources of supply risk. Sub-criteria such as requiring suppliers to hold inventory, inability to meet quality requirements, inability to meet delivery requirements, technological lagging, supplier development, and developing target costing with suppliers were considered. Additionally, factors like using multiple supply sources, inability to meet volume demand changes, competitive pricing, and supplier certification were examined.

Chopra and Sodhi (2004) explored the risk factors faced by companies in the supply chain. The main criteria assessed included systems, distribution, delays, capacity, intellectual property, inventory, procurement, and forecasts. Sub-criteria like system integration issues, supplier bankruptcy, war and terrorism, dependency on a single source, natural disasters, and high-capacity utilization at the supply source were evaluated. Other factors included e-commerce, excessive handling due to border crossings, forecast inaccuracies due to long lead times, sales promotions causing information distortion, short product life cycles, global outsourcing, fluctuating demand, exchange rate risk, and industry capacity utilization.

Wu et al. (2006) proposed an integrated methodology to classify, manage, and assess risk factors in inbound logistics activities. The study focused on criteria such as engineering/production, financial and insurance issues, market characteristics, accidents, quality, and natural/man-made disasters. Sub-criteria included supply continuity, delivery errors, financial health, technical innovation rate, knowledge management, employee accidents, and unexpected risk attacks. Other factors such as legal claims by customers, supplier management, IT/internet security, and natural disasters were also considered.

Cucchiella and Gastaldi (2006) developed a framework aimed at protecting businesses from risk factors. The study analyzed both internal and external sources such as information delays, customs regulations, capacity, internal organization, political environment, price fluctuations, and stochastic supplier quality factors.

Tang (2006) aimed to classify supply chain risk factors to provide practical access to these classifications. The study categorized the risk factors under four main headings in terms of strategic and tactical plans: supply management, product management, demand management, and information management. In the strategic planning group, product variety and supply chain visibility were assessed, while information sharing, vendor-managed inventory, and collaborative planning, forecasting, and supply criteria were evaluated in the tactical planning group.

Manuj and Mentzer (2008) developed an integrated global supply chain risk management model by drawing from various disciplines such as operations management, supply chain management, logistics, strategy, and international business. The authors categorized risk factors under eight main headings: demand risks, operational risks, security risks, supply risks, macro risks, competitive risks, policy risks, and resource risks.

Ritchie and Brindley (2009) examined risk criteria that affect supply chain performance under five main headings: timeliness, support, price, related costs, and quality. They emphasized the importance of creating reliable, robust, and practical measurement systems, highlighting the positive and negative effects of risk management activities on businesses in the supply chain.

Ho et al. (2015) conducted a comprehensive review of 224 international articles published between 2003 and 2013 on supply chain risk factors. They categorized risk factors under five common groups: production risks, macro risks, supply risks, demand risks, and infrastructure risks (financial, transportation, and information risks). They also examined supply chain risk management processes such as risk identification, mitigation, assessment, and monitoring.

Chatterjee and Kar (2016) used the fuzzy TOPSIS method to identify supply chain risks. They found that the most significant criterion was supply risk, while the least significant was control risk.

Kırılmaz and Erol (2017) conducted a study aimed at reducing supply-related risks, evaluating them under five main and 30 sub-criteria. They developed a procedure to apply these identified risks to an international automotive company, categorizing them into control, flexibility, avoidance, and collaboration.

Yolaç et al. (2019) conducted a literature review on logistics risk factors in Istanbul and analyzed the impact of risk management activities on business performance. The study revealed that managing supply and IT-related risks positively impacted supply chain performance, while managing demand, logistics, and environmental risks did not have a significant effect.

Demirkol (2019) conducted a study to identify risk factors in the supply chain and evaluate their impact on business performance, specifically focusing on the automotive industry in Turkey.

The study examined the relationship between processes designed to mitigate environmental, economic, security, and supplier-related risks and their impact on operational and supplier risks.

Panjehfouladgaran and Lim (2020) identified and clustered risk factors in reverse logistics activities, categorizing 42 logistics risk criteria into tactical, operational, and strategic groups.

Moktadir et al. (2024) reviewed the current and future status of multi-criteria decision-making (MCDM) methods in sustainable supply chain risk assessment. The authors analyzed 101 articles published since 2010, concluding that sustainable supply chain risks are generally assessed using one or two MCDM methods.

Gaudenz and Borghesi (2006) used the AHP method to evaluate supply chain risk factors, focusing on micro factors, information factors, demand factors, supply factors, production factors, and transportation factors. They found that delays and deficiencies in orders had the greatest impact, while waiting during production had the least.

Kull and Talluri (2008) evaluated supply chain risk factors using the AHP method and identified five main and 14 sub-criteria: delivery errors, flexibility errors, quality errors, cost errors, and trust errors. Delivery errors were found to be the most important criterion, while trust errors were the least important.

Schoenherr et al. (2008) conducted a case study in a U.S. manufacturing company, assessing supply chain risks in international procurement using AHP. They evaluated the risks of supply chain activities in Mexico and China, finding that product cost was the most significant risk factor, while engineering and innovation were the least.

Faisal (2009) used the AHP method to prioritize supply chain risk factors, grouping them into relational, financial, physical, and informational sub-chains. The most significant risk criterion was found to be financial, while the least important was relational.

Tuncel and Alpan (2010) conducted an industrial case study to identify and analyze supply chain risk factors, categorizing them into four main groups: manufacturer, inbound/outbound logistics, customers, and suppliers. The authors concluded that system performance could be improved and overall system costs reduced through risk management actions and mitigation scenarios.

Korucuk and Erdal (2018) examined logistics risk factors in Samsun using AHP and VIKOR methods. The study focused on five main criteria: packaging risks, transportation-related risks, organizational risks, purchasing risks, and inventory-related risks. The analysis revealed that packaging risks were the most significant factor, followed by transportation-related risks.

Mital, Del Giudice, and Papa (2018) used cognitive maps and AHP methods to identify supply chain risks for four different product groups, including rice, mobile phones, milk, and cigarettes. The main criteria evaluated in the study were buyer-supplier relationships, quality, continuity of supply, supplier service, and cost. The results showed that the risk varied depending on the product supply chain.

2.2 Studies using MCDM in assessing supply chain risks

The second part of the literature review consists of studies using MCDM in assessing supply chain risks. Table 1 shows studies using MCDM in assessing supply chain risks.

Table 1 – Studies using MCDM in assessing supply chain risks.

Author(s)	Year	Aim	Method (s)
Moeinzadeh et al.	2009	Identifying supply chain risks of the power, oil and gas industry.	ANP and Fuzzy VIKOR
Samvedi et al.	2013	To identify risks in the supply chain in the Indian textile and steel industry.	Fuzzy AHP and Fuzzy TOPSIS
Jovic	2014	To determine the internal and external supply chain risks of a food company operating in Istanbul.	DEMATEL
Rajesh et al.	2015	Reducing electronics industry supply chain risks.	Grey DEMATEL
Sun et al.	2015	Assessing supply chain risks of a Chinese manufacturer.	Fuzzy TOPSIS
Venkatesh et al.	2015	To assess supply chain risks in the apparel industry in India.	Interpretative Structural Modeling (ISM) and Fuzzy MICMAC
Mangla et al.	2015	To identify green supply chain risks of a poly plastic manufacturing company.	Fuzzy AHP and IRP
Chand et al.	2015	To assess supply chain risks in the Indian manufacturing industry.	ANP and MOORA
Mangla et al.	2016	Assessing green supply chain risks of a plastic manufacturer in India in turbid environment.	Fault-tree analysis (FTA) and Fuzzy AHP
El Mokrini et al.	2016	Evaluating outsourcing logistics risks in the pharmaceutical industry.	Fuzzy AHP-PROMETHEE
Wang et al.	2016	To assess supply chain risks of fresh agricultural products.	The improved TOPSIS method
Govindan et al.	2016a	To identify risks related to the customers of the cement manufacturing company's third-party logistics service providers.	DEMATEL
Govindan et al.	2016b	To evaluate the supply chain risks of the original equipment manufacturer of brake shoes.	ELECTRE TRI-C
Khemiri et al.	2017	Managing performance and risk in integrated supply-production planning.	Fuzzy TOPSIS

to be continued

Table 1 – Continuation.

Author(s)	Year	Aim	Method(s)
Song et al.	2017	To identify supply chain risk factors in the telecommunications industry in China.	DEMATEL
Rostamzadeh et al.	2018	To assess petrochemical industry supply chain risks in Iran.	Fuzzy TOPSIS and Fuzzy CRITIC
Danışman	2019	Selecting the warehouse location by evaluating the risk factors in hazardous material logistics.	AHP, TOPSIS and WASPAS
Chowdhury et al.	2019	To assess supply chain risks for the garment industry in Bangladesh.	ISM and MICMAC
Zubayer et al.	2019	Assessing supply chain risks in the ceramics industry.	Fuzzy TOPSIS
Abdel-Basset et al.	2019	Assessing risks in the supply chain.	Neutrosophic AHP and Neutrosophic TOPSIS
Ali et al.	2019	Identifying risks in the supply chain in the food industry.	Grey DEMATEL
Mzougui et al.	2020	Assessing supply chain risks in the automotive industry.	Failure Mode, Effects and Criticality Analysis (FMECA), AHP and DEMATEL
Abdel-Basset et al.	2020	To assess Telecommunications Equipment Company's supply chain risks.	TOPSIS and CRITIC
Benabdallah et al.	2020	Assessing agri-food supply chain risks in Tunisia.	Rough DEMATEL
Çalık	2021	To evaluate the green supply chain risks of a furniture products manufacturing business in Turkey.	Fuzzy TOPSIS, Fuzzy VIKOR and Fuzzy ARAS
Shahed et al.	2021	Reducing supply chain risks during the COVID-19 pandemic.	Genetic Algorithm (GA)
Moktadir et al.	2021	Assessing supply chain risks in the leather industry.	Pareto Analysis and BWM
Thakkar et al.	2021	To assess supply chain risks in the oil sector in India.	DEMATEL and ANP
Khan et al.	2022a	To identify supply chain risks in public sector agricultural development projects in Bangladesh.	Delphi and AHP
Khan et al.	2022b	To identify supply chain risks in public sector agricultural development projects in Bangladesh.	Delphi, BWM, ISM and MICMAC

to be continued

Table 1 – Continuation.

Author(s)	Year	Aim	Method(s)
Bhalaji et al.	2022	To assess risks in the collaborative supply chain of a medical equipment manufacturing industry in India.	Grey DEMATEL
Yılmaz et al.	2022	To determine the risk factors of logistics management in hospitals.	DEMATEL
Raian et al.	2022	Assessing textile industry supply chain risks.	Fuzzy synthetic evaluation (FSE)
Raihan et al.	2022	To assess soft drink industry supply chain risks.	Fuzzy comprehensive evaluation method (FCEM) and Fuzzy AHP
Yalçınkaya et al.	2022	To assess supply chain risks in the pharmaceutical industry and analyze the risk performance of 3PL businesses.	Pythagorean fuzzy AHP and Pythagorean fuzzy WASPAS
Sutrisno et al.	2023	To evaluate the small and medium enterprise (SME) supply chain risks of small and medium-sized enterprises producing handicrafts.	PSI and Shannon Entropy
Korucuk et al.	2023	To list the success criteria of agile supply chain management and determine the risk reduction strategy in businesses that produce cleaning and cleaning products.	Bipolar Neutrosophic SWARA and Bipolar Neutrosophic TOPSIS
Khan et al.	2023	Assessing supply chain risks for international development agriculture projects.	FGD- Fuzzy Delphi
Silva et al.	2023	To assess supply chain risks in Sri Lanka's spice sector and create mitigation strategies.	AHP and TOPSIS
Das et al.	2023	To assess food grain supply chain risks in India.	Fuzzy AHP and Fuzzy TOPSIS
Krstić et al.	2024a	Assessing agri-food supply chain risks.	Grey BWM and Grey COBRA
Krstić et al.	2024b	Assessing circular supply chain risks.	Fuzzy Delphi, Fuzzy AHP and Fuzzy ADAM
Hosseinpour et al.	2024	Assessing healthcare supply chain risks.	Fuzzy BWM and Fuzzy DEMATEL

2.3 Studies Using BWM

The studies conducted using the BWM method in the third part of the literature review are listed in Table 2.

Table 2 – Studies Using BWM.

Author(s)	Year	Problem(s)
Rezaei	2015	Mobile phone selection problem
Rezaei	2016	Evaluation of the criteria for car purchase
Ahmadi et al.	2017	Evaluation the social sustainability of supply chains
Salimi et al.	2018	Evaluation of companies' R&D performance
Askarifar et al.	2018	Evaluation of investment opportunities
Rezaei et al.	2018	Evaluation of the weights of logistics performance index criteria
Norouzi et al.	2019	Evaluation of risk factors threatening mega projects
Malek et al.	2019	Measuring the weights of risk factors affecting production factors
Khanmohammadi et al.	2019	Criteria evaluation for motorcycle wheel
Demir and Bircan	2020	Evaluation of the support programs provided by KOSGEB
Yıldırım	2020	Determining the importance levels of the supports provided by KOSGEB
Ali et al.	2020	Robot selection problem
Ulutaş	2020	Vehicle selection problem of cargo companies
Arslanhan and Tosun	2021	The transport mode selection problem of the logistics company
Topal et al.	2021	Evaluation of the criteria used in the selection of transportation vehicles by cargo companies
Ulutaş	2021	The supplier selection problem of the furniture workshop
Aksakal et al.	2022	Insulation material evaluation
Aghaloo et al.	2023	Optimal site choosing for the solar-wind renewable energy systems
Khan et al.	2023	Evaluation of barriers of blockchain technology in food supply chain
Altay et al.	2023	Location selection of e-scooter sharing stations
Badi et al.	2023	Wind farm site selection

As a result of the literature review, the main criteria and sub criteria included in the logistics risk factors were determined. The determined criteria are listed in Table 4. Additionally, as a result of the literature review, BWM, one of the MCDM methods, was deemed appropriate to evaluate logistics risk factors.

BWM has some important advantages that make it reliable (Rezaei, 2015:56).

a. BWM can determine criteria weights alone and can be integrated with different MCDM methods.

b. Only integers are used in BWM. This makes the use of BWM even easier.

c. The BWM method assesses the consistency of responses provided in the questionnaire.

3 METHODOLOGY

In this section, the BWM used in the study will be introduced.

3.1 Best and Worst Method (BWM)

BWM (Best and Worst Method) was developed as the MCDM method by Rezeai in 2015 (Rezeai, 2015). In this method, the best and worst criteria are determined by the decision maker, and then pairwise comparisons are made to find the weights of the criteria. In this study, logistics risk criteria were evaluated with linguistic terms specified in Table 3 by decision makers using BWM.

Table 3 – Linguistic Expressions.

Numerical Equivalent	Linguistic Equivalent
1	Equally Important
2	Equally Important - Moderately Important
3	Moderately Important
4	Moderately Important - Highly Important
5	Highly Important
6	Highly Important - Very Highly Important
7	Very Highly Important
8	Very Highly Important - Utterly Important
9	Utterly Important

Source: (Demir and Bircan 2020: 174).

The steps of the Best and Worst method are as follows (Rezaei, 2015):

Step 1. Determining the criteria ($C_1, C_2, C_3, \ldots, C_n$)

Step 2. Involves determining the decision maker's best and worst criteria. Here, the best refers to the most important criteria and the worst refers to the least important criteria.

Step 3. In this step, the importance of the best criterion (most important criterion) relative to other criteria is determined using Table 2. As a result of the comparisons, the Best-Others (A_B)

vector is obtained, which shows the importance of the best criterion compared to other criteria. The vector A_B is shown in Equation 1.

$$A_B = a_{B1}, a_{B2}, a_{B3}, \ldots, a_{Bn} \tag{1}$$

Each a_{Bj} in the vector A_B shown in Equation 1 shows the importance of the best criterion, B according to the j criterion. Also, since the criterion A_{BB} is compared with itself, the degree of importance becomes 1 (Equally Important).

Step 4. In this step, the importance levels of the other criteria according to the worst criterion (least important criterion) are determined using Table 2. As a result of the comparisons, the Others-Worst (A_W) vector is obtained, which shows the importance of other criteria compared to the worst criterion. The vector A_W is shown in Equation 2.

$$A_W = (a_{1W}, a_{2W}, a_{3W}, \ldots, a_{nW})^T \tag{2}$$

Each a_{jW} in the vector A_W shown in Equation 2 shows the degree of importance of the criterion j relative to the worst criterion W. Also, since the criterion A_{WW} is compared with itself, the degree of importance becomes 1 (Equally Important).

Step 5: With the model shown in Equation 3, the optimum weights of the criteria ($w_1^*, w_2^*, \ldots, w_n^*$) and the consistency indicator (ξ^L) are calculated. If the consistency indicator is close to "0", it indicates high consistency (Rezaei, 2016).

$$\begin{aligned}
&\min \xi^L \\
&\left|w_B - a_{Bj} w_j\right| \leq \xi^L \ \textit{(for each j criterion)} \\
&\left|w_j - a_{jw} w_w\right| \leq \xi^L \ \textit{(for each j criterion)} \\
&\sum_{j=1}^{n} w_j = 1 \\
&w_j \geq 0
\end{aligned} \tag{3}$$

4 APPLICATION

This study identifies the factors that have the greatest and least impact on logistics activities in Sivas, Turkey, based on nine main criteria and twenty-seven sub-criteria that may cause delays and/or disruptions in logistics processes. The determined criteria were selected from the studies under the heading 2.1 Studies Related to Risk Factors of the literature review. The selected criteria were evaluated as logistics risk factors. The selected criteria are given in Table 4. Surveys were conducted with 15 experts consisting of private sector companies, public institutions, and academic professionals from the international trade and logistics department in Sivas province. These surveys were developed by adapting the criteria related to logistics risk factors.

Each expert was individually surveyed, and the survey results were applied to the BWM using Lingo 20.0 software.

Table 4 – Logistics Risk Factors Used in The Study.

Main Criteria	Sub-Criteria	Author(s)
Macro Risk Criteria (MRC)	Natural Disasters (ND) War and Terrorism (WT) External Legal Issues (ELI)	Chopra & Sodhi (2004) Chopra & Sodhi (2004) Wu, Blackhurst & Chidambaram (2006)
Transport Risk Criteria (TRC)	Accidents (AC) Packaging Risk (PR) Risk of Disruption on the Road (RDR)	Wu, Blackhurst & Chidambaram (2006) Korucuk & Erdal (2018) Sodhi et al. (2012)
Supply Risk Criteria (SRC)	Inability to Handle Volume Demand Changes (IHVDC) Capacity and Responsiveness of Alternative Suppliers (CRAS) Unable to Provide Competitive Pricing (UPCP)	Zsidisin & Ellram (2003) Zsidisin & Ellram (2003) Zsidisin & Ellram (2003)
Production Risk Criteria (PRC)	Capacity Cost (CC) Manufacturing Yield (MY) Capacity Flexibility (CF)	Zsidisin & Ellram (2003) Cucchiella &Gastaldi (2006) Zsidisin & Ellram (2003)
Information Risk Criteria (IRC)	Information Infrastructure Breakdown (IIB) System Integration and Closed System Networking (SICSN) Internet Security (IS)	Chopra &Sodhi (2004) Chopra & Sodhi (2004) Wu, Blackhurst, & Chidambaram (2006)
Financial Risk Criteria (FRC)	Low Profit Margin (LPM) Price Fluctuations (PF) Exchange Rate (ER)	Wu, Blackhurst, & Chidambaram (2006) Cucchiella & Gastaldi (2006) Chopra & Sodhi (2004)
Technology Risk Criteria (TCRC)	Not Keeping Up with Technology (NKT) Lack of Expert Personnel and Equipment (LEPE) Technologically Staying Behind Competitors (TSBC)	Tuncel & Alpan (2010) Tuncel & Alpan (2010) Zsidisin & Ellram (2003)
Organizational Risk Criteria (ORC)	Workers' Strikes (WS) Lack of Experience or Education (LEE) Staff Shortage (SS)	Tuncel & Alpan (2010) Tuncel & Alpan (2010) Tuncel & Alpan (2010)
Inventory Risk Criteria (IVRC)	Risks Caused by the Material Flow System (RCMFS) Stock Keeping Risk (SKR) Product Obsolescence Rate (POR)	Jüttner et al. (2003) Chopra & Sodhi (2004) Zsidisin & Ellram (2003)

Some risk factors shown in Table 4 are classified as supply chain risks while others are classified as logistics risks.

- Logistics Risks: Transport Risk Criteria (TRC), Inventory Risk Criteria (IVRC), Information Risk Criteria (IRC)
- Supply Chain Risks: Macro Risk Criteria (MRC), Supply Risk Criteria (SRC), Production Risk Criteria (PRC), Financial Risk Criteria (FRC), Technology Risk Criteria (TCRC), Organizational Risk Criteria (ORC).

The principal objective of this study was to analyze the specific logistics risks associated with Sivas' strategic role within the Turkish logistics network. Nevertheless, it is acknowledged that some of the risk criteria examined also overlap with broader supply chain risks. This is due to the close interconnectivity of logistics and supply chain processes, whereby disruptions in logistics can have cascading effects throughout the supply chain. For example, risks pertaining to transportation and supply directly impact the performance of the supply chain. Delays or disruptions in logistics can result in supply shortages or inefficiencies throughout the chain.

Furthermore, in accordance with the opinions of the 15 experts who participated in the study for a more comprehensive analysis, it was deemed appropriate to consider the supply chain risks outlined in Table 4 as part of the logistics risk factors.

The analysis of main criteria and sub-criteria according to Decision Maker 1 (DM 1) is presented in Table 5 and Table 6, respectively, to show the implementation steps of BMW.

Table 5 – Analysis of Main Criteria According to DM 1.

Step 2: Determining the best and worst criteria									
Best: MRC	**Worst:** PRC								
Step 3: Finding vector A_B									
	(MRC)	**(TRC)**	**(SRC)**	**(PRC)**	**(IRC)**	**(FRC)**	**(TCRC)**	**(ORC)**	**(IVRC)**
(MRC)	1	3	2	9	7	6	8	5	4
Step 4: Finding vector A_W									
	(MRC)	**(TRC)**	**(SRC)**	**(PRC)**	**(IRC)**	**(FRC)**	**(TCRC)**	**(ORC)**	**(IVRC)**
(PRC)	9	7	8	1	3	4	2	5	6

According to Table 5, A_B= $\{1,3,2,9,7,6,8,5,4\}$ and A_W= $\{9,7,8,1,3,4,2,5,6\}$. With Equation 3, the main criteria weights are found for DM 1. DM 1 assessed the sub-criteria in an analogous manner. Table 6 presents the evaluation of the sub-criteria of the FRC main criterion by decision maker DM 1 as an example of this assessment. The main criteria weights found are shown in Table 7.

According to Table 6, A_B= $\{1,9,7\}$ and A_W= $\{9,1,7\}$. With Equation 3, the sub-criteria weights are found for DM 1. The sub-criteria weights found are shown in Table 7.

The same procedures are applied to other decision makers in order to calculate the weights of the main and sub-criteria. Then the weights of the main criteria are multiplied by the weights of the sub-criteria and the combined weights of the sub-criteria are found. The criteria weights and consistency rates for DM 1 are shown in Table 7.

Table 6 – Analysis of Sub-Criteria According to DM 1.

Step 2: Determining the best and worst sub-criteria			
Best: LPM **Worst:** PF			
Step 3: Finding vector A_B			
	(LPM)	**(PF)**	**(ER)**
(LPM)	1	9	7
Step 4: Finding vector A_W			
	(LPM)	**(PF)**	**(ER)**
(PF)	9	1	7

Table 7 – Criteria Weights for DM 1.

Main criteria	Weight of main criteria	Consistency rate (ξ^L)	Arrangement	Sub-criteria	Sub-criteria weight	Consistency rate (ξ^L)	Combined weight	Rankings
				ND	0,071		0,022	11
MRC	0,315		1	WT	0,768	0,196	0,242	1
				ELI	0,161		0,051	6
				AC	0,806		0,103	3
TRC	0,128		3	PR	0,056	0,305	0,007	20
				RDR	0,139		0,018	13
				IHVDC	0,142		0,027	10
SRC	0,192		2	CRAS	0,053	0,331	0,01	16-17
				UPCP	0,805		0,155	2
				CC	0,154		0,004	22-23
PRC	0,027		9	MY	0,79	0,290	0,021	12
				CF	0,056		0,002	27
				IIB	0,767		0,042	8
IRC	0,055	0,068	7	SICSN	0,067	0,233	0,004	22-23-24-25
				IS	0,167		0,009	18
				LPM	0,791		0,051	6
FRC	0,064		6	PF	0,059	0,261	0,004	22-23-24-25
				ER	0,15		0,01	16-17
				NKT	0,172		0,008	19
TCRC	0,048		8	LEPE	0,766	0,265	0,037	9
				TSBC	0,063		0,003	26
				WS	0,056		0,004	22-23-24-25
ORC	0,077		5	LEE	0,79	0,290	0,061	5
				SS	0,154		0,012	15
				RCMFS	0,785		0,075	4
IVRC	0,096		4	SKR	0,067	0,251	0,006	21
				POR	0,148		0,014	14

According to DM 1, while the most important main criterion is Macro Risk criteria, it is seen that the least important criterion is production risk criteria. Again, according to DM 1, while the most important sub-criteria is the risks arising from war and terrorism, it has been concluded that the least important sub-criterion is capacity flexibility. Since the consistency ratios were found close to 0 in the analyzes performed for DM 1, it can be said that the results are consistent.

After applying the same procedures to other decision makers, the results of 15 decision makers are combined in the last step. The geometric mean is used in the merging process. The overall combined weights are obtained by taking the geometric mean of the combined weights of the main criteria and sub-criteria. The overall combined weight averages of the main criteria are shown in Table 8 and the sub-criteria in Table 9.

Table 8 – General Combined Weights of Main Criteria.

Main Criteria	General Combined Weights of Main Criteria	Rankings
MRC	0,087	4
TRC	0,147	1
SRC	0,104	2
PRC	0,084	5
IRC	0,078	6
FRC	0,096	3
TCRC	0,078	6
ORC	0,059	9
IVRC	0,069	8

In Table 8, it is seen that the most important main risk criteria among 9 main criteria are “transportation risk criteria” and the least important main risk criteria are “organizational risk criteria”.

Table 9 – General Combined Weights of Sub-Criteria.

Sub-Criteria	General Combined Weights	Rankings
ND	0,024	7
WT	0,015	19
ELI	0,014	20-21-22
AC	0,085	1
PR	0,018	14-15-16
RDR	0,017	17-18
IHVDC	0,019	11-12
CRAS	0,018	14-15-16
UPCP	0,033	3
CC	0,019	11

to be continued

Table 9 – Continuation.

Sub-Criteria	General Combined Weights	Rankings
MY	0,026	6
CF	0,014	20-21-22
IIB	0,021	8-9
SICSN	0,001	27
IS	0,021	8-9
LPM	0,019	11-12
PF	0,017	17-18
ER	0,028	4
NKT	0,014	20-21-22
LEPE	0,027	5
TSBC	0,012	23
WS	0,005	26
LEE	0,018	14-15-16
SS	0,02	10
RCMFS	0,034	2
SKR	0,011	24
POR	0,009	25

Based on the analysis presented in Table 9, "accidents during transportation" emerges as the most significant sub-risk criterion among the 27 sub-criteria, while "system integration or covered system network" ranks as the least significant.

Furthermore, a sensitivity analysis was carried out in this study by varying the weights of the main criteria using Monte Carlo simulation. The simulation included fifty scenarios with different weight variations for the main criteria. The results of the sensitivity analysis are displayed in Figure 1.

In each of the fifty different scenarios, the weights of the main criteria are different, as can be seen in Figure 1.

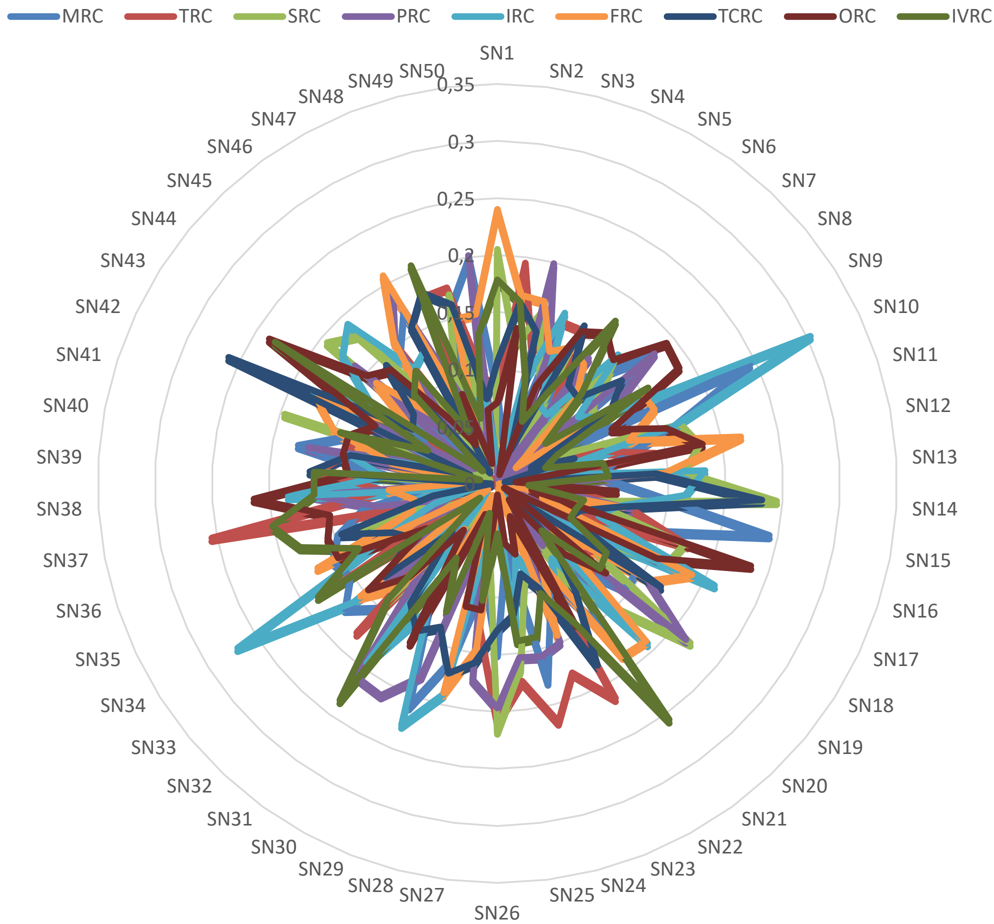

Figure 1 – The Sensitivity Analysis.

5 DISCUSSION

5.1 The Aggregation Methodology

The geometric mean application for aggregating weights is a significant methodological decision in this study and offers numerous essential benefits. The geometric mean is particularly effective for merging weights due to its capacity to maintain proportional relationships among data. The arithmetic mean is calculated by averaging the sum of the data, whereas the geometric mean is derived from the product of the data. This allows each weight to contribute to the aggregate value, more precisely representing the proportional disparities between the weights. For instance, if a multiplier effect or proportional relationship exists among certain criteria, the geometric mean may effectively represent this structure, whereas the arithmetic mean may overlook it.

The geometric mean facilitates a more equitable outcome by diminishing the effect of extreme high or low weights on the aggregate value. Outliers can significantly influence the total and distort the outcomes in arithmetic mean. The geometric mean mitigates the influence of outliers and offers a more equitable representation of the entire spectrum of weights in a composite measure. This enhances the robustness and reliability of our analytical results.

Another significant rationale for employing the geometric mean in weight aggregation is its compatibility with nonlinear data. Certain variables and weights in our study may exhibit a proportional or multiplicative relationship rather than a linear combination. In such instances, the geometric mean more accurately reflects these non-linear correlations.

The application of the geometric mean is more rational and significant when derived from the product of two components or the computation of growth rates. The geometric mean is an average defined exclusively for non-zero and positive numbers, ensuring mathematical and conceptual consistency. This ensures the significance and conceptual coherence of the combination when all weights are non-negative and equal to non-zero. This is a significant advantage, particularly when dealing with ratios, indices, or percentage expressions, and enhances the mathematical coherence of integrating weights in this study's analysis.

In conclusion, the use of the geometric mean furnishes a cohesive depiction of weights in this study, while presenting significant benefits such as maintaining proportional relationships, mitigating the influence of outliers, and encapsulating non-linear structures. Consequently, the geometric mean is regarded as a significant and judicious selection that bolsters the methodological rigor of this study and the validity of the analytical outcomes.

5.2 Logistics Risks and Opportunities in the Sivas Region

Sivas, with its central location in Turkey, diverse economic structure, and significant logistics potential, holds strategic importance. The geopolitical position, economic framework, and logistical significance of Sivas, especially in the context of the Belt and Road Initiative (BRI), warrant detailed discussion. Sivas's central location places it at the crossroads of major trade routes, making it a critical hub in the logistics network. This strategic position facilitates the distribution of goods and enhances the efficiency of logistics operations.

The economic structure of Sivas is diverse, encompassing industries such as manufacturing, agriculture, mining, and services. The production of cement, textiles, and food products significantly contributes to both local and national economies. The agricultural sector is robust, with the production of cereals, fruits, and livestock playing a vital role in the province's economic stability. Additionally, Sivas possesses substantial mineral resources, including iron and coal, which support local industries and generate employment opportunities. This diversity makes Sivas economically dynamic.

From a logistics perspective, Sivas's importance is multifaceted. The province serves as a major transit point for goods moving between the eastern and western regions of Turkey. Well-established road and rail networks facilitate seamless transportation, reducing transit times and costs. Furthermore, the Belt and Road Initiative presents significant opportunities for Sivas by integrating it into the larger international trade network. Infrastructure development under the

BRI can lead to increased trade volumes, improved supply chain efficiency, and greater economic integration with global markets. Inclusion in the BRI framework can attract investments in infrastructure, such as the modernization of railways, highways, and logistics centers, further bolstering Sivas's role as a logistics hub.

However, it is crucial to acknowledge that Sivas faces various logistics risks that can disrupt operations. The primary risks identified in this study include transportation risks (such as accidents and road disruptions), supply risks (like the inability to handle volume demand changes), and organizational risks (including worker strikes and staff shortages). To mitigate these risks and ensure smooth logistics operations, effective risk management strategies are essential.

Transportation risks emerged as the most critical, with accidents during transportation being the most significant sub-risk. To mitigate this, improving road safety measures, regular maintenance of transport infrastructure, and enhancing driver training programs are essential. The inability to handle volume demand changes is a major supply risk. Strategies such as diversifying suppliers, maintaining safety stock, and improving demand forecasting can help mitigate these risks. Worker strikes and staff shortages are identified as significant organizational risks. Implementing fair labor practices, providing competitive wages, and investing in employee training and development can reduce these risks.

In conclusion, Sivas holds a strategic position in Turkey's logistics network due to its central location and robust economic structure. The province's logistical importance is further enhanced by its potential integration into the Belt and Road Initiative, which promises increased trade connectivity and infrastructure development. However, managing logistics risks effectively is crucial to fully leveraging these advantages. By addressing transportation, supply, and organizational risks through targeted strategies, Sivas can strengthen its role as a logistics hub and contribute significantly to Turkey's economic growth.

5.3 Risks Analysis

In the previous section, a brief introduction to the logistics risks in the Sivas region is provided, and in this section, the risk analysis is detailed, examining the impact of various risk factors on the logistics network in depth. The analysis of logistics risks in Sivas, conducted through the BWM, provides a nuanced understanding of the varying degrees of impact that different risk factors have on the logistics network. The results indicate that "transportation risk criteria" hold the highest importance, while "organizational risk criteria" are considered the least significant. This prioritization offers valuable insights into the logistics dynamics of Sivas and guides risk management strategies.

1. Transportation Risk Criteria as the Most Critical: The prioritization of transport risk criteria, with "accidents during transportation" being the most significant sub-criterion, underscores the vital role of transportation in Sivas's logistics network. Sivas's strategic location at the crossroads of major trade routes increases the volume and frequency of transportation activities, inherently elevating the risk of accidents and disruptions. The high ranking of transport risks highlights the

vulnerability of logistics operations to transportation-related issues, suggesting that any delays or disruptions in transport can have cascading effects on the entire supply chain. This finding indicates that efforts to improve transportation safety, infrastructure, and management in Sivas are crucial for enhancing the overall efficiency and reliability of the logistics network.

2. Supply Risks as a Key Concern: The analysis also identifies supply risk criteria as another significant concern, particularly the "inability to handle volume demand changes". This reflects the dynamic nature of demand in logistics operations, where fluctuations in volume can pose substantial challenges. Sivas's role as a logistics hub requires it to adapt quickly to changes in demand, and failure to do so can lead to delays, shortages, and inefficiencies. This result suggests that supply chain flexibility and responsiveness are essential for maintaining a smooth flow of goods. Mitigating these risks involves strategies such as diversifying suppliers, maintaining safety stock, and improving demand forecasting to ensure that supply chains are robust and adaptable to market changes.

3. Organizational Risks as the Least Significant: The finding that organizational risks, including worker strikes, lack of experience, and staff shortages, are the least important criteria may initially seem counterintuitive. However, this result can be interpreted within the specific context of Sivas's logistics operations. Organizational risks generally have a more indirect and long-term impact compared to the immediate effects of transport or supply disruptions. In a region where the logistics network's efficiency heavily depends on the uninterrupted movement of goods, the immediate operational risks take precedence. This does not imply that organizational risks are unimportant; rather, it suggests that, in the current context, their impact is perceived as less critical compared to other risk factors. It also points to a potentially well-managed organizational framework in Sivas, where such risks are either well-mitigated or have less direct influence on logistics outcomes.

4. Macro and Financial Risks: The moderate ranking of macro and financial risks further emphasizes the focus on operational efficiency in Sivas. While macro risks like natural disasters and geopolitical issues are important, their infrequency compared to day-to-day operational risks like transport and supply disruptions makes them relatively less significant in the eyes of decision-makers. Similarly, financial risks such as price fluctuations and exchange rates, while influential, do not directly disrupt logistics operations in the short term. This suggests a risk management approach in Sivas that prioritizes operational continuity and immediate risk mitigation over more sporadic and long-term financial and macroeconomic concerns.

5.4 Implications for Management

The results of this analysis have important implications for both public and private stakeholders in Sivas's logistics sector. The prioritization of transport and supply risks indicates that investments in infrastructure, safety measures, and supply chain flexibility are key to enhancing the resilience of Sivas's logistics network. Addressing transport risks through improved road safety, infrastructure development, and enhanced driver training programs can significantly reduce the likelihood of disruptions. Additionally, enhancing the supply chain's responsiveness to demand changes through strategic planning and supplier diversification can further stabilize logistics operations.

In summary, the results of this study provide a clear roadmap for mitigating logistics risks in Sivas by emphasizing the areas that require the most attention and resources. By focusing on transport and supply risks while maintaining a proactive approach to less critical risks, such as organizational and financial factors, Sivas can strengthen its position as a strategic logistics hub in Turkey.

6 CONCLUSION

Logistics risk can be defined as natural or human criteria that may occur at any stage of logistics activities and cause disruption of business processes or processes. The aim of the study is to determine the logistics risk factors that affect the logistics activities the most and least in the province of Sivas, which has geopolitical importance due to Turkey's central location and is desired to be turned into a logistics center in order to evaluate this feature. The data used in the study were obtained by means of a questionnaire created by compiling the criteria used in similar studies in the literature with a team of 15 experts, consisting of experts from the private sector, public institutions, and logistics departments operating in Sivas. The data obtained from the questionnaires were adapted to BWM using the Lingo 20.0 program. The logistics risk factors of Sivas province were determined and ranked according to their importance (weights). Thus, it is aimed to provide a new contribution to the literature by obtaining different results on the most significant risk criteria, although there are similar studies and the possibility of taking precautions against the risks that may occur in the activities to be carried out in the logistics center to be established.

This article contributes to the state of the art by providing a comprehensive analysis of the logistics risks of Sivas having a strategic role in Turkey's logistics network, particularly within the framework of the Belt and Road Initiative (BRI). The paper develops the logistics risk management discourse by identifying and categorizing the main risks facing Sivas, including transport, supply and organizational challenges. By prioritizing the logistics risks in Sivas, the paper suggests various public and private institutions to mitigate these risks in order of importance, as well as proposes a model that can be adapted to other regions with similar logistics and economic profiles. Hence, this study enriches the existing literature on regional logistics risk management and can provide valuable insights for policymakers, industry stakeholders, and researchers interested in optimizing logistics networks in emerging economies.

This article presents the results obtained through the BWM analysis within the context of Sivas's role in the logistics network, focusing on the overall evaluation of these results. According to the main findings of the article, the most significant main risk criterion was identified as "transportation risk criteria" while the least significant was "organizational risk criteria". To gain a deeper understanding of the reasons behind these outcomes, the following details should be examined:

1. Importance of Transportation Risk Criteria: Given Sivas's critical role in Turkey's logistics network, transport risks hold significant importance. As a key intersection point for major trade routes, the safety and efficiency of transportation operations in Sivas are vital. In the analysis, "accidents during transportation" were identified as the most critical sub-criterion under the "transportation risk criteria". This indicates that any disruption in transportation activities, particularly accidents, can significantly impact the overall effectiveness of the supply chain. The success of the logistics network heavily relies on the smooth functioning of the transportation process; hence, risks such as accidents directly affect Sivas's logistics performance. Consequently, transport risks are seen as the most critical factor in the overall risk assessment.

2. Relative Insignificance of Organizational Risks: Organizational risks include factors such as staff shortages, worker strikes, and lack of employee experience. In the context of Sivas, these risks are considered less critical compared to transport risks for several reasons. First, the impact of organizational risks on logistics operations is generally longer-term and indirect. For instance, while staff shortages or strikes can affect logistics activities, these effects are often not as immediate and severe as those caused by transport accidents or road disruptions. Second, in Sivas's logistics activities, the effective management of transportation and supply chain operations emerges as a higher priority compared to organizational risks. As a result, such organizational risks are evaluated as having lower importance in the overall outcomes of the BWM analysis.

This analysis indicates that the logistics risk profile of Sivas needs to be optimized with a focus on transportation safety and efficiency. The prioritization of transport risks emphasizes the need to concentrate on this area to enhance the reliability of logistics activities in Sivas. Therefore, improving transportation infrastructure, preventing accidents, and ensuring the safety of the transportation process emerge as critical strategies to enhance Sivas's effectiveness in the logistics network.

In the method applied based on the rating made by the decision makers participating in the study, considering the institutions/organizations they work for, it is seen that the most significant main criterion according to DM 1 is Macro Risk criteria, while the least significant criterion is production risk criteria. Again, according to DM 1, while the most significant sub-criteria is the risks arising from war and terrorism, it has been concluded that the least significant sub-criterion is capacity flexibility. According to DM 2, while the most significant main criterion is macro risk criteria, it is seen that the least significant criterion is technology risk criteria. Additionally, according to DM 2, it was concluded that the most significant sub-criteria was war and terrorism, and the least significant sub-criterion was the inability to keep up with the technology. According to DM 3, while the most significant main criterion is supply risk criteria, it is seen that the least significant criterion is macro risk criteria. Besides, according to DM 3, the most significant sub-criterion was the risks arising from not being able to manage volume demand changes, while it was concluded that the least significant sub-criterion was caused by natural disasters. According to DM 4, while the most significant main criterion is transportation risk criteria, it is seen that the least significant criterion is macro risk criteria. Furthermore, according to DM 4, while the most significant sub-criteria is the risks arising from accidents occurring during transportation, it has been concluded that war and terrorism and foreign legal problems are less significant than other criteria. According to DM 5, the most significant main criterion is organizational risk criteria, while the least significant criterion is information risk criteria. Again, according to DM 5, it was concluded that the most significant sub-criteria was the risks arising from not being able to provide competitive pricing, while the least significant sub-criterion was caused by internet security. According to DM 6, the most significant main criterion is production risk criteria, while the least significant criterion is organizational risk criteria. Furthermore, according to DM 6, it was concluded that while the most significant sub-criteria was the risks arising from production efficiency, the sub-criterion with the least importance was caused by the lack of experience or education. According to DM 7, while the main criterion with the most significant criterion weight is production risk criteria, it is seen that the least significant criterion is macro risk criteria. Besides, according to DM 7, while the most significant sub-criteria is the risks arising from production efficiency, it has been concluded that the sub-criteria with the least importance degree and equal criterion weight are wars and terrorism and foreign legal problems. According to DM 8, while the most significant main criterion is macro risk criteria, it is seen that the least significant criterion is production risk criteria. Besides, according to DM 8, while the most significant sub-criteria is the risks from natural disasters, it was concluded that the least and equally significant sub-criteria are the risks arising from the capacity cost and capacity flexibility. According to DM 9, the most significant main criterion is supply risk criteria, while the least significant criterion is information risk criteria. Besides, according to DM 9, the most significant sub-criteria is the risks arising from not being able to provide competitive pricing, while the least-significant sub-criterion is seen to arise from the risk of system integration or covered system network. According to DM 10, the most significant main criterion is transportation risk criteria, while the least significant criterion is production risk criteria. Furthermore, according to DM 10, while the most significant sub-criteria is the accidents occurring during transportation, it is seen that the least significant sub-criterion is the risk criteria arising from production efficiency. According to DM 11, the most significant main criterion is production risk criteria, while the least significant criterion is inventory risk criteria. Besides, according to DM 11, the most significant sub-criteria is the risks arising from production efficiency, while the least significant sub-criterion is the risks arising from the product obsolescence rate. According to DM 12, the most significant main criterion is transportation risk criteria, while the least significant criterion is financial risk criteria. Besides, according to DM 12, the most significant sub-criterion is the accidents that occur during transportation, while the least significant sub-criterion is the risks arising from the low profit margin. According to DM 13, the most significant main criterion is transportation risk criteria, while the least significant criterion is inventory risk criteria. Besides, according to DM 13, while the most significant sub-criteria is the accidents occurring during transportation, it is seen that the least significant sub-criterion is the product obsolescence rate. According to DM 14, the most significant main criterion is supply risk criteria, while the least significant criterion is transportation risk criteria. Furthermore, according to DM 14, the most significant sub-criteria is the risks arising from the capacity and responsiveness of alternative suppliers, while the least-significant sub-criteria are the risks arising from the risk of deterioration on the road. According to DM 15, the most significant main criterion is transportation risk criteria, while the least significant criterion is the risk criteria arising from production efficiency. Besides, according to DM 15, it is seen that the most significant sub-criteria are the accidents that occur during transportation, while the least significant sub-criteria are the risks arising from production efficiency.

In addition, according to the combined criteria weights as a result of the study, the most significant main criterion affecting the logistics processes in Sivas province is transportation risk criteria, the least affecting risk factor is organizational risk criteria, the most significant sub-criteria is accidents during transportation, the least significant sub-criteria is system integration, or it was found that there is a covered system network.

Among the significant reasons why this study gave different results from other studies, it can be said that the variety of criteria used, the difference of decision makers, and the difference in the logistics activity conditions and requirements of the city where the study was carried out. In future studies, fuzzy or gray method can be evaluated using the FUCOM method or the Entropy methods. They can also apply BWM to other MCDM problems, such as prioritizing supply chain management drivers, logistics risks, and purchasing risks.

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How to cite

ÖLMEZ U, ULUTAŞ A, ÜRE S, YÜRÜYEN AA & MEIDUTE-KAVALIAUSKIENE I. 2024. Evaluation of logistics risk factors with BWM method; Sivas province example. *Pesquisa Operacional*, **44**: e286745. doi: 10.1590/0101-7438.2023.043.00286745.