

Research Article (Special Issue) | Araştırma Makalesi (Özel Sayı)

Analysis of Stability and Safety Risks of Rolled Loads in Intermodal Logistics Processes

Sinan Çizmecioğlu | Asst. Prof., KTO Karatay University, sinancizmecioğlu@gmail.com, [0000-0002-3355-8882](https://orcid.org/0000-0002-3355-8882)

Corresponding author/Sorumlu yazar: Sinan Çizmecioğlu

Abstract

Intermodal transportation has become increasingly important in international trade because it integrates multiple transport modes within a single logistics chain. However, the cylindrical geometry, concentrated mass, and tendency of roll-type cargoes to shift during transit and transshipment create distinctive stability and safety challenges. This study aims to identify and prioritize the most critical risk factors affecting the safe transportation of roll-type cargoes in intermodal logistics processes. Based on a comprehensive review of the relevant literature and expert evaluations, the study identified ten key risk criteria. The Level-Based Weight Assessment (LBWA) method has been employed to determine their relative importance. The findings indicate that inadequate cargo securing and stability loss at transfer points are the most critical risks, followed by personnel safety risk. These results provide an expert-based risk prioritization framework that can help logistics operators, terminal managers, and transport planners identify areas requiring greater attention to improve the safety of roll-type cargo transportation in international intermodal logistics networks.

Keywords: International Logistics, International Trade, Rolled Loads, LBWA Method

JEL Codes: L91, R41, R49, F14

İntermodal Lojistik Süreçlerinde Rulo Tipi Yüklerin Stabilitate ve Güvenlik Risklerinin Analizi

Öz

İntermodal taşımacılık, tek bir lojistik zinciri içinde birden fazla taşıma modunu entegre edebilme özelliği nedeniyle uluslararası ticarete giderek daha önemli hale gelmiştir. Bununla birlikte, silindirik geometrileri, yüksek kütle konsantrasyonları ve transit ve aktarma işlemleri sırasında hareket etme eğilimleri nedeniyle rulo tipi kargoların taşınması benzersiz güvenlik ve istikrar zorlukları sunmaktadır. Bu çalışma, intermodal lojistik süreçlerinde rulo tipi kargoların güvenli taşınmasını etkileyen en kritik risk faktörlerini belirlemeyi ve önceliklendirmeyi amaçlamaktadır. İlgili literatürün kapsamlı bir incelemesi ve uzman değerlendirmeleri yoluyla on temel risk kriteri belirlenmiştir. Bu risklerin göreceli önemini belirlemek için LBWA yöntemi kullanılmıştır. Bulgular, istikrarla ilgili faktörlerin, yetersiz kargo güvenliği riski ve aktarma noktalarında denge kaybı riski taşıma güvenliğini etkileyen en etkili boyutları oluşturduğunu ortaya koymaktadır. Sonuçlar, uluslararası intermodal taşımacılık ağlarında kargo hasarını, operasyonel aksamaları ve güvenlikle ilgili olayları azaltmak isteyen lojistik operatörleri, terminal yöneticileri ve taşımacılık planlayıcıları için pratik bilgiler sağlamaktadır.

Anahtar Kelimeler: Uluslararası Lojistik, Uluslararası Ticaret, Rulo Tipi Yükler, LBWA Yöntemi

JEL Kodları: L91, R41, R49, F14

Extended Summary

The adoption of intermodal transport systems in international trade has increased due to the growing demand for efficient freight transportation and the increasing integration of global logistics networks. Intermodal transport systems offer several advantages in terms of economic efficiency, environmental sustainability, and operational flexibility by integrating multiple transport modes, including road, rail, and maritime transportation, within a single logistics system. Nevertheless, roll-type cargo presents unique transportation challenges compared with conventional freight. Roll-type cargo is sensitive to the problem of stability during the process of transportation because of the nature of the cargo.

The stability of the load is another very important factor concerning transportation safety in the intermodal logistics network. Any reduction in its stability would cause huge financial losses along with cargo damage, operational disruptions, accidents at the workplace, and insurance expenses. Moreover, since intermodal transportation typically involves repeated cargo handling and transfers between transport modes, roll-type cargo may be exposed to additional operational risks. Despite the significance of this issue, the existing literature predominantly focuses on containerized cargo, hazardous materials, and general freight transportation. The research papers that consider issues related to the stability and especially safety risks associated with the transport of cylindrical products are rather scarce. This study aims to identify and prioritize the key risk factors affecting the

How to cite this article / Bu makaleye atıf vermek için:

Çizmecioğlu, S., (2026). Analysis of Stability and Safety Risks of Rolled Loads in Intermodal Logistics Processes. *KOCATEPEİİBFD*, 28(Special Issue), 88-99. <https://doi.org/10.33707/akuiibfd.1966443>

stability and safety of roll-type cargo during intermodal logistics processes. To accomplish this aim, an analysis of the literature concerning the issue was conducted, and opinions of experts knowledgeable in the processes of logistics operations, loading of cargo, transportation safety, and port management were obtained. There are ten main criteria of risks that were established based on the obtained information. These criteria cover cargo overturning and rolling, inadequate cargo securing, intermodal transfer, sudden motion and braking, vibration and shock, loading and unloading, cargo damage, personnel safety, and stability loss at transfer points. In this research work, the LBWA method is implemented to determine the level of importance of these risk factors. LBWA is applied since it provides a systematic approach for incorporating expert opinions with reduced complexity in pairwise comparisons for weighting. Through this approach, the expert opinions have been incorporated and translated into numerical values that can be employed in prioritizing the factors of interest. According to the analysis, stability-related factors, risk of inadequate cargo securing, and the risk of imbalance in transshipments seem to be the most significant factors affecting safety in transport. Operational handling activities and dynamic forces experienced in the process of cargo shipment and transshipments have been noted as other important factors that contribute to the overall risk. In contrast, the factors that are indirectly linked with transportation safety are less relevant. This highlights the need for enhancing cargo securing processes and operational controls, among others.

This research contributes to the field of literature on logistics and transportation safety because it focuses on the analysis of a particular cargo type that has been overlooked academically even though its application is quite widespread in fields such as paper production, steel production, cable production, textile production, and plastic production. From a practical perspective, this research provides critical insight into how to prevent cargo-related accidents and improve the performance of transportation safety. This research provides critical insight into how to allocate resources effectively and manage risks in international intermodal transportation systems.

Introduction

Increased complexities in the international trading networks have given rise to intermodal logistic networks where different means of transport such as road, rail and maritime are integrated into a single logistics system. Intermodal logistics not only increases transportation efficiency and network connectivity but is also able to assist organizations in reducing their operational costs and increasing service reliability (Rodrigue, 2020). However, despite these benefits, the increasing dependence on the various forms of transport has created further challenges associated with cargo stability, safety during handling, and consistency in transit (Caris et al., 2013). The consistency in maintaining the integrity of the cargo as it is transported from one mode of transport to another has become increasingly challenging due to this constant movement of the cargo units.

Among the numerous kinds of cargo that are shipped using international logistics supply chains, roll-type cargo ranks among the most technically sensitive ones. Due to their cylindrical shape, heavy concentration of mass, and their tendency to move while being transported in dynamic conditions, these types of cargo tend to be particularly susceptible to stability-based situations. The risks that come with the transportation of roll-type cargo tend to be more pronounced when shipping such cargo in an intermodal setting due to various stresses on the cargo (Crainic & Kim, 2007). Cargo displacement, poor securing techniques, operational errors, and transportation-related instability might not only cause goods damage but can also create substantial risks in terms of safety, operational problems, economic losses, and the reputation of logistics service providers. Even though modern literature has provided comprehensive analysis of cargo fastening techniques, transportation safety, and intermodal logistics performance, scientific studies related specifically to problems of stability and safety of roll-type goods still lack. In addition, modern research mostly concentrates on the aforementioned problems from an engineering/operational perspective without addressing their relevance in practice (Roso & Lumsden, 2009). Thus, in many cases, decision makers face challenges in assessing the risk factors that should be given more weight than others. To solve this problem, this study attempts to pinpoint the critical risk factors that affect the security and transport safety of roll cargoes in international intermodal logistics transport. It is hoped that through this research, there will be added value in terms of risk management and transportation safety studies.

To fulfill this objective, a comprehensive set of risk criteria was developed through a comprehensive review of the pertinent literature and interviews with experts who possess vast knowledge of logistics operations, freight handling, transportation management, and freight safety. Then, the level-based weight assessment (LBWA) method was employed to determine the relative importance of these risk factors. The level-based weight assessment is a structured decision-making technique that allows experts to evaluate the risk factors based on their importance while reducing the mental stress linked with a pairwise comparison method (Žižović & Pamucar, 2019). Through this analytical framework, the study evaluates the contribution of each risk element to total transportation safety and provides a prioritization system capable of assisting management decision-making processes.

Accordingly, this research seeks to address the following Research Questions (RQ):

RQ1: What are the most critical risk factors affecting the stability and transportation safety of roll-type cargoes in intermodal

logistics operations?

RQ2: How do industry experts prioritize the identified risk factors based on their potential impact on cargo integrity, operational continuity, and transportation safety?

RQ3: Which stability and safety risk criteria should be prioritized based on their relative LBWA weights?

RQ4: How does the relative weighting of the identified risk criteria reveal the priority structure of stability and safety risks in the intermodal transportation of roll-type cargoes?

The results of this study are expected to provide a structured understanding of the relative importance of stability and safety risks associated with roll-type cargo transportation in intermodal logistics systems. By identifying and prioritizing the most influential risk criteria, the study provides an expert-based basis for recognizing the areas that may require greater managerial attention. In addition, the research contributes to the transportation and logistics literature by systematically examining an under-researched cargo-specific risk context.

The core novelty of this research is the systematic identification of the priority of specific risks related to stability and safety aspects in roll cargo transport. The distinguishing characteristic of this research, as compared to other literature on the subject that mostly concentrates on separate safety aspects, is the development of a combined expert-weighting methodology demonstrating the importance of various risks simultaneously.

1.Literature

The growing complexity of intermodal transportation systems has attracted increasing scholarly attention to issues related to cargo safety, transportation reliability, and operational risk management. The literature section consists of two parts. The first part deals with cargo in international logistics, and the second part deals with MCDM (Multi-Criteria Decision Method) studies.

The review of the literature has performed by concentrating on articles dealing with such areas as intermodal transportation of cargo, stability of cargo, securing cargo, handling of special cargo, transportation safety, and logistics risk management. Special emphasis is put on those articles that considered risks that may be directly related to the roll-type cargo transportation. The results of the literature review were then discussed with the expert panel and became the basis for defining the risk criteria.

1.1 Specialized Cargo Transportation in International Logistics

The international transportation of specific and unique cargo is a very challenging process. There are several studies in the literature on this subject. Investigated freight damage risks arising from improper loading and insufficient load securement practices in mixed-load and less-than-truckload (LTL) transportation environments. The study examined how loading methods, pallet selection, and cargo unitization practices influence product damage and unloading safety. In addition, the authors discussed regulatory requirements for cargo securement and proposed practical recommendations to improve transportation safety and reduce freight damage incidents. Singh et al., (2014) explored freight damage risks arising from improper loading and insufficient load securement practices in mixed-load and less-than-truckload (LTL) transportation environments. The study examined how loading methods, pallet selection, and cargo unitization practices influence product damage and unloading safety. In addition, the authors discussed regulatory requirements for cargo securement and proposed practical recommendations to improve transportation safety and reduce freight damage incidents. Malaksiano and Melnyk (2020) analyzed the feasibility of using non-specialized vessels for the transportation of oversized project cargoes. The study focused on vessel suitability, cargo securing practices, and operational efficiency in maritime transport. Melnyk and Malaksiano (2020) investigated fleet expansion decisions in maritime transportation by considering cargo flow characteristics and fuel consumption factors. The study proposed a methodology to support investment decisions and improve operational efficiency through optimal vessel utilization. Pokrovskaya et al., (2020) explored the improvement of freight transportation planning and operational management within integrated logistics networks. The study examined freight flow management, railway operational performance, and coordination among transport stakeholders, and proposed recommendations to improve transportation efficiency and logistics service quality. Opala (2021) analyzed the stability and securing requirements of semi-trailers transported by rail in intermodal logistics operations. The authors evaluated the impacts of wind loads, braking forces, and track geometry on rollover risk and concluded that inadequate securing measures may significantly compromise transportation safety under adverse operating conditions. Pencheva et al., (2022) utilized multimodal and intermodal freight transportation systems with a particular focus on sustainable transport planning. To support transport mode selection, the study proposed a multicriteria optimization model based on cost, time, and external costs and identified Pareto-optimal transportation alternatives through a mathematical optimization framework. Gialleonardo et al., (2023) investigated the effect of wagon payload sequencing on buffer forces occurring during emergency braking in intermodal freight trains. By combining train dynamics modelling with an optimization approach, the study demonstrated that appropriate wagon arrangements can substantially reduce longitudinal forces and improve transportation

safety. Zhang et al., (2024) utilized cargo vibration and stability issues in railway freight transportation by developing a wagon–cargo dynamic simulation model. The study identified the necessary lashing stiffness under various operating conditions and showed that appropriately designed restraint systems can substantially improve cargo safety during transportation. Rong et al., (2025) investigated the ongoing transformation of China's transportation structure, with particular emphasis on the role of railway freight and its integration into modern logistics systems. Drawing on a transportation economics perspective, the study analyzed the outcomes of the “road-to-rail” policy, evaluated the current state of railway logistics and intermodal transportation, and examined the sector’s alignment with evolving market demands. The findings highlighted the need for stronger intermodal collaboration and greater coordination between railway operators and logistics service providers to enhance the competitiveness and efficiency of freight transportation. Snyder et al., (2026) investigated the vibration and environmental factors associated with the intermodal transport of frozen cargo via rail across distances in Canada. The authors conducted an investigation of vibrations, accelerations, and mechanical shocks associated with cargo transported using refrigerated double-stacked containers by placing sensors at various locations in the containers. Their results offered great insight into the physical stress that occurs during transport of frozen cargo.

1.2. MCDM Studies in Logistics

Multi Criteria Decision Methods (MCDM) have been implemented in many types of international logistics studies. These studies have a high impact rate in the literature. Alazzawi and Žak (2020) examined the combined issue of logistics corridor design and supplier selection for the shipment of electricity cables to Iraq. The study assessed potential logistics solutions by considering economic, political, social, and sustainability-related variables using AHP and ELECTRE III/IV techniques. The results provide a methodical framework for making decisions in challenging and dangerous logistical situations. Muravev et al., (2020) examined China Railway Express's (CR Express) international logistics centers' location selection issue in response to the EU's constantly increasing trade volume with China. To assess potential logistics center locations and determine the best choices, the authors created an integrated DEMATEL–MAIRCA-based MCDM framework. To increase operational effectiveness and better handle growing container flows along the China–Europe railway corridor, their findings emphasized the need of dynamically choosing logistics center sites. Zhang et al., (2021) evaluated 38 potential cities within the Belt and Road Initiative in order to study the choice of Chinese international container intermodal hubs. The study determined the best hub locations using an integrated GARA–TOPSIS-based MCDM framework, and sensitivity and comparison analyses were used to confirm the findings. Boakai and Samanlioglu (2023) utilized the fuzzy Best-Worst Method (BWM) to examine the third-party logistics (3PL) provider selection issue in the textile sector. Based on the evaluations of three decision-makers, the study assessed six different 3PL suppliers using fifteen selection criteria. The results showed that, in comparison to conventional fuzzy AHP-based methods, fuzzy BWM efficiently captures uncertainty in management judgments while needing fewer pairwise comparisons and yielding more consistent outcomes. Keleş and Pekkaya (2023) utilized the selection of logistics center locations in Türkiye using an integrated MCDM approach. Criterion weights were obtained through the Entropy and CRITIC methods, while alternative locations were evaluated and ranked using PROMETHEE. The stability of the findings was further assessed through sensitivity analysis and sustainability-oriented scenarios. Wang et al., (2025) examined the pre-pandemic, pandemic, and post-pandemic performance of Vietnam's publicly traded logistics firms. The authors assessed organizations' operational performance and financial resilience between 2019 and 2023 by combining the CRITIC, TOPSIS, and EDAS techniques with 10 financial variables. The results showed significant disparities in business performance, emphasizing both the resilience of companies severely impacted by the COVID-19 epidemic and the stability of top organizations. Le and Pham (2026) explored the performance of logistics firms operating in Vietnam by proposing an integrated evaluation framework that combines Data Envelopment Analysis (DEA) with fuzzy multi-criteria decision-making methods. The authors assessed both the operational efficiency and sustainability performance of leading logistics companies and found that environmental and technological capabilities play a decisive role in achieving superior performance. Their findings also highlighted that firms adopting green logistics practices and robust data security measures tend to outperform their competitors. Tsai et al., (2026) investigated the resilience of Vietnam’s cross-border e-commerce supply chain under increasing operational, regulatory, and infrastructure-related challenges. The authors developed an integrated T-spherical fuzzy decision-making framework combining Delphi, DEMATEL, and COCOSO methods to identify critical resilience factors, analyses their causal relationships, and prioritize strategic interventions. Their findings highlighted the significant roles of product customization, contingency planning, trade policies, inventory safety stocks, and reconfiguration strategies in strengthening supply chain resilience. Maravić et al., (2025) exploited the potential of new digital technologies to enhance food logistics operations' sustainability, dependability, and efficiency. The authors assessed and prioritized alternative technologies, such as IoT, blockchain, Big Data analytics, automation and robotics, and cloud/edge computing, using an integrated CILOS–MOOSRA framework. The results showed that while blockchain and big data technologies are important for improving traceability, data security, and decision-making processes, automation and robots have the most promise for improving operational performance.

2. Method

In the methodological phase of the study, the Level-Based Weight Assessment (LBWA) method has utilized to derive the weights of the evaluation criteria and to identify their relative importance within the decision-making framework.

2.1. LBWA Method

The Level-Based Weight Assessment (LBWA) method was introduced by Žižović and Pamucar (2019) as a subjective weighting approach designed to determine the relative importance of evaluation criteria in multi-criteria decision-making problems. One of the distinguishing characteristics of the method is its ability to generate criterion weights with a limited number of pairwise assessments. In the case of a situation where n criteria are involved, $(n - 1)$ comparisons are needed. This greatly decreases the load of the assessment process imposed on decision-makers. Also, this technique can be implemented even if there is an increase in the number of criteria and therefore will not make the decision process overly complicated. Another unique feature of the LBWA method is its ability to allow for inconsistencies in experts' judgment without making the process of assigning weights inconsistent. Due to these features, this method has gained more attention in recent years. The implementation procedure of the LBWA method consists of the following steps (Žižović & Pamucar, 2019).

Phase 1. Identification of the Most Important Criteria: Assume that the decision problem consists of a set of criteria represented by $S = \{C_1, C_2, C_3, C_4, \dots, C_n\}$. In the first stage of the LBWA method, experts evaluate the criteria and select the one that possesses the highest level of importance with respect to the decision objective. The identified criterion is treated as the most influential criterion and subsequently acts as a benchmark against which the relative importance of all other criteria is assessed.

Phase 2. Grouping the Criteria Sets: In this step, the decision-maker classifies the criteria into different importance levels. Criteria with similar significance are placed within the same group, while the most influential criteria are assigned to the first level. A criterion belonging to level k is at least k times more important than the criteria in lower-priority levels and less than $(k + 1)$ times more important. The complete set of criteria is represented $S = S_1 \cup S_2 \cup \dots \cup S_k$ (1) where (S_i) denotes the set of criteria belonging to importance level (i) . The criteria assigned to each level are determined as follows Eq. (1);

$$S_i = \{C_{i1}, C_{i2}, \dots, C_{in}\} = \{C_j \in S: i \leq s(C_j) < i + 1\} \quad (1)$$

where $S(C_j)$ represents the importance value assigned to criteria (C_j) . As a result, all criteria are organized into distinct importance groups that reflect the judgments of the decision-maker.

Phase 3. Assigning Importance Values to the Criteria: At this stage, each criterion within the same level is assigned an integer value $I_{ip} \in \{0, 1, \dots, r\}$ according to its relative importance. The most important criterion within a given level is assigned a value of "0", the second most important criterion is assigned a value of "1", and so forth. Accordingly, if criteria C_j is considered more important than criterion $C_i = 0$ Then $I_p < I_q$ Consequently, the least important criterion within a given level is associated with the highest integer value. The parameter (r) represents the maximum integer value that can be assigned during the evaluation process and is determined according to the largest number of criteria contained in any level. The value of (r) is calculated implementing Eq. (2):

$$\max\{|S_1|, |S_2|, \dots, |S_k|\} \quad (2)$$

Step 4. Determination of the Flexibility Coefficient: Following the determination of the parameter r , a flexibility coefficient denoted by $(r_0 \in R)$ is introduced into the evaluation process. The value assigned to r_0 must exceed the previously identified r value ($r_0 > r$). The most appropriate selection for this parameter is the first integer that is greater than r . Selecting the coefficient in this manner contributes to the stability of the weighting procedure and supports a more effective differentiation among the criteria considered in the analysis.

Step 5: Calculation of the Influence Functions: At this stage, the influence function values associated with each criterion are determined. These values are computed by considering the level position (i) , the flexibility coefficient (r_0) , and the integer value assigned to each criterion (I_{ip}) . The influence function reflects the relative position of a criterion within its assigned level and serves as a basis for the subsequent weighting calculations. The influence function values are obtained employing Eq. (3):

$$f(C_{ip}) = \frac{r_0}{i \cdot r_0 + I_{ip}} \quad (3)$$

Step 6: Determination of Criterion Weights: The final stage of the LBWA procedure involves deriving the importance weights of all evaluation criteria. Initially, the weight of the highest-priority criterion is calculated, serving as the reference point for the weighting process. Once this benchmark value has been established, the weights of the remaining criteria are obtained according to their previously determined influence function values. In this way, the relative importance of each criterion is quantified while preserving the hierarchical structure defined throughout the earlier stages of the method. The weight of the most influential criterion is calculated using Eq. (4), whereas the weights of the remaining criteria are determined based on Eq. (5).

$$w_i = \frac{1}{f(C_1) + f(C_2) + \dots + f(C_i) + \dots + f(C_n)} \quad (4)$$

$$w_j = f(C_i) * w_i \quad (5)$$

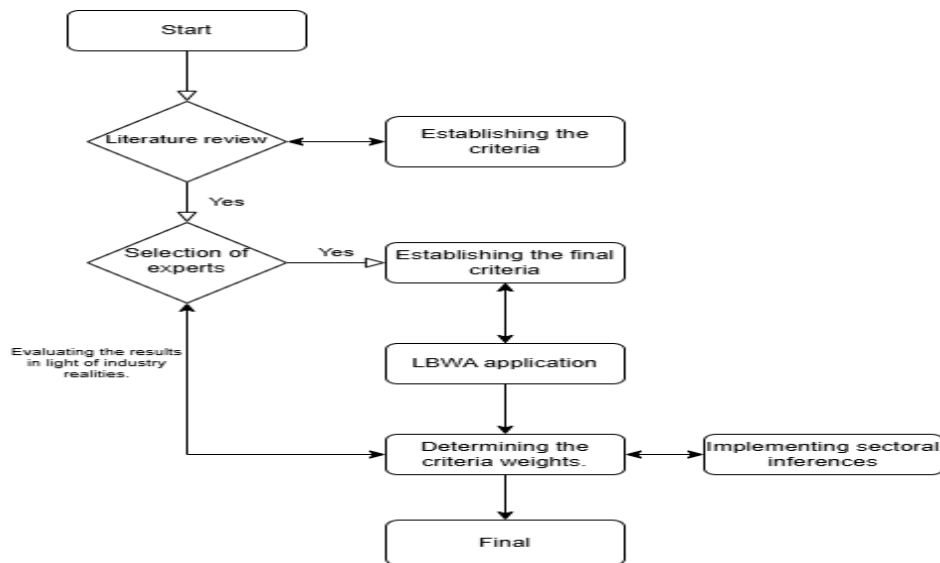
Assuming that the first criteria is identified as the most important criteria, the weights of the remaining criteria are derived relative to the weight of this reference criteria. In this framework, the weight assigned to each criteria are obtained by multiplying the influence function value of the corresponding criteria by the weight of the highest-ranked criterion. Accordingly, the weights of the other criteria are expressed as $w_j = f(C_2) * w_1, w_3(fC_3), \dots w_n(f(C_n))$.

3. Application of Study

Safe transport of roll-type cargos has emerged as a serious issue in existing intermodal logistics networks. Roll-type cargos have unique characteristics in comparison with usual pallets or containers, which include their cylindrical form, the localization of their weight, as well as their ability to shift during dynamic transport operations. This makes them especially vulnerable to shifts, resulting in damage to the cargo themselves, equipment failure, accidents at workplaces, as well as significant economic losses. The increasing popularity of multimodal transport adds importance to managing this issue.

As cargo units are transported between road, rail, marine, and terminal settings, they are subjected to variable operational conditions and external factors. Throughout the transportation process, the interplay of these variables may have a substantial impact on cargo stability. Therefore, it is now crucial to identify the most significant risk variables and comprehend their relative relevance to improve operational dependability and transportation safety. Against this backdrop, the current application aims to evaluate the risk dimensions connected with the transportation of roll-type commodities inside intermodal logistics operations. A set of risk criteria has been constructed by an exhaustive analysis of the relevant literature and conversations with industry personnel knowledgeable in cargo handling, transport operations, and logistics management. The workflow structure is presented in Figure 1.

Figure 1. Framework of the study



This study is based on the evaluations of specialists in Türkiye who are active in intermodal transportation operations within the framework of international commerce, and who assume operational responsibility, notably in the transportation of roll-type goods. Roll-type cargo requires unique safety precautions in logistics operations due to its large weight, cylindrical construction, and inclination to shift during transit. Maintaining cargo stability and successfully controlling safety concerns are crucial, especially in intermodal systems where road, rail, and marine transportation are employed in an integrated way. Thus, the purpose of this study is to ascertain the relative relevance of the basic stability and safety issues that roll-type cargo faces in intermodal logistics procedures.

In the research process, the decision-making committee comprised three specialists (DM₁, DM₂, and DM₃). The major criterion for picking the specialists was their direct experience in roll-type cargo transportation, cargo safety, and intermodal operations. Demographic information regarding the experts as follows:

Decision Maker 1 (DM1) is experienced in the field of intermodal transportation and international logistics for 24 years, working as a logistics operations manager. During his career path, he has been involved in the design, coordination, and administration of significant international freight transportation projects using road, rail, and maritime transport modalities. His experience

encompasses intermodal logistics operations management, operational coordination, cargo securing operations, and heavy cargo transportation.

Decision Maker 2 (DM2) is an operations manager experienced in the field of port and terminal operations for 19 years. During his career path, he has taken responsible positions related to cargo handling operations, cargo securing systems, terminal logistics operations and cargo safety management. He has extensive practical experience in roll-type cargo handling operations, project cargo handling operations, and other special types of heavy cargo transportation.

Decision Maker 3 (DM3) is an academic specialist with 22 years of experience in logistics and transport systems. His scientific interests are dedicated to such spheres as logistics risk management, freight transportation, transport systems, multimodal logistics, and multi-criteria decision-making approaches. Besides his academic background, he has conducted numerous scientific research studies in national and international publications and became competent in logistics-related hazards management.

The selected specialists have all the necessary knowledge and experience that will enable them to evaluate the stability and safety risks associated with transporting roll-type cargo in intermodal transport, based on their professions and many years of experience. The involvement of specialists from the operational, managerial, and academic sectors ensured different perspectives, thus enhancing the quality and reliability of the study findings.

The expert panel consisted of experts who have been selected using the purposive expert selection approach, as opposed to the statistical sampling approach. In other words, the goal of the process was not to ensure statistical representativeness of the sample with many respondents, but to get informed judgments from specialists who have considerable experience related to the problem area under consideration. Specifically, the experts chosen for the analysis have provided different viewpoints on intermodal logistics processes, port/terminal cargo handling and safety issues, and academic background in logistics risks and multi-criteria decision making. However, the small number of experts means that the generalizability of the obtained results is limited to the specific operational situation analyzed by the experts.

Table 1. Stability and Safety Risk Criteria in Intermodal Transportation of Rolled Loads

Code	Criteria	Description
C_1	Cargo Overturning Risk	Risk of cargo overturning during transport or handling.
C_2	Cargo Rolling Risk	Risk of uncontrolled rolling of cargo
C_3	Inadequate Cargo Securing Risk	Risk caused by insufficient cargo securing measures.
C_4	Intermodal Transfer Risk	Risk arising during transfers between transport modes.
C_5	Sudden Motion and Braking Risk	Risk caused by sudden acceleration or braking.
C_6	Vibration and Shock Risk	Risk resulting from vibration and impact forces.
C_7	Loading and Unloading Risk	Risk occurring during cargo handling operations.
C_8	Cargo Damage Risk	Risk of physical damage to cargo.
C_9	Personnel Safety Risk	Risk of injury to operational personnel.
C_{10}	Stability Loss at Transfer Points Risk	Risk of stability loss at terminals and logistics hubs.

Ten risk factors have been identified to assess the stability and safety threats in relation to cargo transportation via rolls within the intermodal logistics processes after a comprehensive review of the literature and expert opinions. The key factors that may influence cargo stability, handling safety, and reliability of transportation have been considered while determining these risk factors. These risk factors and their descriptions are presented in Table 1.

3.1. The Result of LBWA Method

Finding the criteria that best capture the decision problem is the first step in applying the LBWA approach. The criteria for this study were developed by a thorough analysis of the pertinent literature and improved by discussions with three specialists in logistics operations, intermodal transportation, and cargo safety. As a result, ten criteria $S = \{C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}\}$ representing the major stability and safety risks associated with the transportation of roll-type cargo.

Following the establishment of the criterion set, the decision-makers evaluated the relative importance of each criterion. Based on their collective assessments, C_3 (Inadequate Cargo Securing Risk) was identified as the most critical factor. The unique characteristics of roll-type products, which are extremely susceptible to movement, displacement, and instability when suitable securing measures are not put in place during the transportation process, are reflected in this research. By comparing each criterion with the most significant criteria, the criteria were then categorized into various importance levels. Classification of

criteria levels Criteria level classification $S_1 = \{C_3, C_1, C_{10}, C_4, C_9\}$, $S_2 = \{C_2, C_5, C_6\}$ and $S_3 = \{C_7, C_8\}$.

Integration of the assessments of DM1, DM2, and DM3 occurred by implementing a consensus-based team assessment approach. Every expert first assessed the degree of importance of the selected risk criteria; afterward, differences in the priorities of the criteria were jointly discussed. The level of importance of each criterion and the value of its importance were established once the experts reached an agreement. Consensus was considered achieved when all three experts agreed on both the importance level and the assigned value of each criterion. Consequently, the weights that have been obtained later for the LBWA procedure are not the result of individual decision makers' assessments but of the combined opinion of the expert team.

The most significant issues that directly impact cargo stability and transportation safety are included in the first group. Operational risks that might cause cargo instability during transit are included in the second category, while risks that have a comparatively less impact but could still have an impact on transportation performance and safety results are included in the third group.

Based on the consensus evaluation of the expert panel, the criteria were first classified into the corresponding importance levels and assigned relative importance values. The flexibility coefficient and influence function values were then determined according to the LBWA procedure. The influence function of each criterion was calculated using Eq. (3), the weight of the reference criterion was obtained using Eq. (4), and the remaining criterion weights were calculated using Eq. (5). For example, C3 was classified into Level 1 and assigned a consensus value of 0. Based on Eq. (3), this resulted in an influence function value of 1.000. Subsequently, applying Eqs. (4) and (5) yielded a final weight of 0.156 for (C_3). The same calculation procedure was applied to all remaining criteria. The resulting consensus-based values, influence functions, and final criteria weights are demonstrated in Table 2.

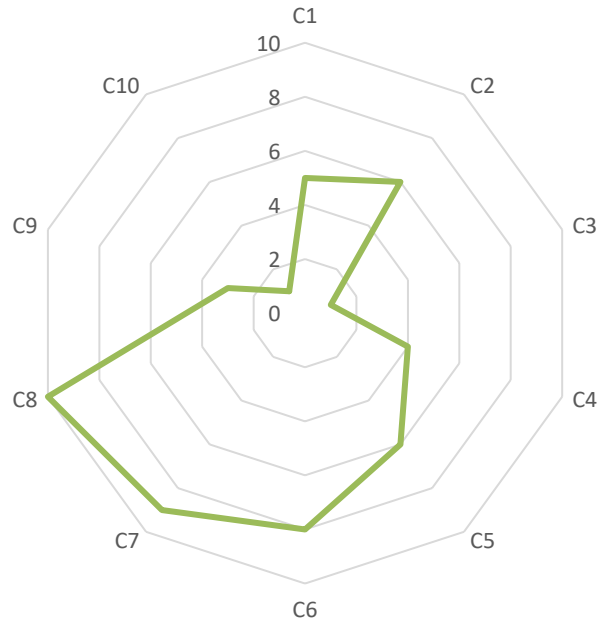
Table 2. Consensus-Based Influence Functions and Final LBWA Weights of the Criteria

Criteria	Consensus Assigned Value DMs	Influence Function	Final Weight
Level 1 (S_1)	1	$F = \frac{6}{6i + 1}$	W
C_1	3	0.666	0.104
C_3	0	1.000	0.156
C_4	2	0.750	0.117
C_9	1	0.857	0.134
C_{10}	0	1.000	0.156
Level 2 (S_2)			
C_2	0	0.500	0.078
C_5	0	0.500	0.078
C_6	1	0.461	0.072
Level 3 (S_3)			
C_7	0	0.333	0.052
C_8	1	0.315	0.049

According to Table 2, the LBWA weights have been determined by implementing a sequence of consensus-based computation procedures. The criteria have been divided into three importance classes based on the common assessment of the three decision makers and have been assigned respective consensus values. Since the largest class has five criteria, the maximum comparison scale has been set to 5, while the elasticity coefficient has been set to 6. Using these values, the influence function for each criterion has been computed. The total value of the influence has been 6.38447, which gives a reference weight of 0.15663. Finally, multiplying each influence value with the reference weight gives the normalized weights for each criteria.

The results show that the most important criteria are Inadequate Cargo Securing Risk (C_3) and Stability Loss at Transfer Points Risk (C_{10}), with the highest weights (0.156). It means that the main factors in intermodal transportation of roll-type cargo are maintaining the stability of the cargo by proper securing and ensuring stability while transferring. The third important criteria, Personnel Safety Risk (C_9), with the weight 0.134, showed the consequences of cargo instability for personnel. The criteria importance is presented in Figure 2.

Figure 2. Ranking Criteria



On the other hand, Cargo Damage Risk (C8), Loading/Unloading Risk (C7), and Vibration/Shock Risk (C6) have been assigned the smallest weights. While all these risks are quite important, it has been identified by the experts that their effects on transportation safety are more restricted when compared to the risks associated with the stability and securing of the cargo. In general, the findings prove that reducing the level of risks associated with the intermodal transportation of roll-type cargo involves increasing staff safety, stability at transfer points, and cargo securing.

3.2. Sensitivity Analysis

In the sensitivity analysis conducted to examine the robustness and stability of the risk prioritization results for roll-type cargo transportation in intermodal logistics processes, 100 different scenarios were created. For this purpose, different scenarios were generated by systematically changing the weight of each risk criterion while proportionally redistributing the resulting change among the remaining criteria. Each scenario therefore represents a different weighting condition and enables the assessment of whether variations in criterion importance substantially affect the overall priority structure of the identified stability and safety risks. The formulas employed in the sensitivity analysis are presented in Eqs. (6)– (8):

$$w_{fv}^1 = w_{pv}^1 - (w_{pv}^1 \times m_v). \quad (6)$$

The adjusted weight of the j^{th} factor, expressed as w_{fv}^1 , is determined using Eq. (7).

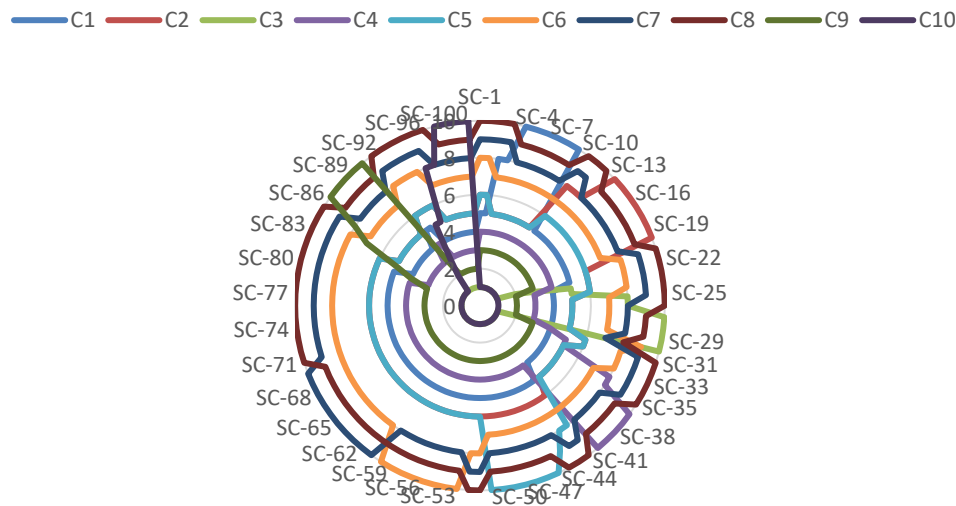
$$w_{nv}^2 = \frac{(1-w_{fv}^1)}{n-1} + w_{pv}^2. \quad (7)$$

According to Eq. (8), w_{nv}^2 matches the newly obtained values of the remaining criteria, where n is the total number of criteria, while w_{pv}^2 stands for the previous values of the remaining criteria.

$$w_{fv}^1 + \sum w_{nv}^2 = 1. \quad (8)$$

A sensitivity analysis was conducted to examine the robustness and stability of the risk criterion weights obtained for the intermodal transportation of roll-type cargo. During the sensitivity analysis, the weight of each criterion was individually increased by 10% to evaluate the potential changes in the relative importance and ranking of the identified risks under different weighting conditions. To maintain the normalization condition, the weights of the remaining criteria were proportionally adjusted so that the sum of all criterion weights remained equal to 1 in each scenario. The recalculated weights were subsequently compared with the original LBWA results to determine whether variations in criterion importance caused substantial changes in the overall risk prioritization. The results of the sensitivity analysis are presented in Figure 3.

Figure 3. Sensitivity Analysis Result



Conclusion

The Level-Based Weight Assessment (LBWA) method was implemented in this research to determine the relative importance of the stability and safety concerns associated with the transport of roll-type cargo using the multimodal system. The roll-type cargo is a unique type of cargo that needs to be handled and fixed in place due to its cylindrical shape and natural tendency to shift during transport. Three experts who have vast experience in the field of logistics operations and cargo handling assessed the relative importance of the 10 risk factors identified as a solution to this problem.

From the above results, it is evident that Inadequate Cargo Securing Risk (C3) and Stability Loss at Transfer Points Risk (C10) play a significant role in the transportation process of roll-type cargo. The two parameters have been assigned the highest weight values, indicating how significant their importance is in relation to the security of the cargo transport process. These results imply that during the process of transferring the cargo, when there is excessive handling of cargo, any small defect in the cargo securing systems can cause risks of cargo movement.

These results are generally in line with literature studies stressing that cargo securement and stability are fundamental criteria for transportation safety. Specifically, the dominance of the Inadequate Cargo Securing Risk (C3) is fully in line with findings by Singh et al. (2014), who illustrated that inadequate cargo securement and improper cargo loading increase the risk of damage to the cargo and injuries to people in truck, container, and intermodal transportation. Nevertheless, the current study provides an additional insight into the problem since it shows that inadequate securing is not just another cause of damage in operational activities, but the key risk recognized by specialists in relation to roll-type cargo in intermodal transportation. The significant importance of the Stability Loss at Transfer Points Risk (C10) is in line with Opala (2021), who showed that insufficient securing under dynamic operations significantly reduces stability and transportation safety. Although Opala (2021) was focused on the technical aspects of stability of semi-trailers carried on intermodal railway vehicles, the current results show that stability becomes especially important when transferring the roll-type cargo between transportation modes. Therefore, the results of this study mostly corroborate rather than oppose the previous literature findings but stress that securing and transfer points stability becomes the major risk dimension in the case of roll-type cargo transportation.

It can be seen from the results that the third most significant factor is the Personnel Safety Risk (C9). It reveals the fact that cargo instability is not only a technical issue but also an economic problem. There are safety hazards faced by port workers, terminal workers, warehouse employees, and loaders because of accidents related to unstable cargo. In this regard, measures related to occupational safety and cargo security should be perceived as two complementary aspects of the integrated risk management system.

Another significant finding is the relatively high importance of cargo overturning risk (C1) and intermodal transfer risk (C4). These factors reveal the necessity of ensuring the consistency of cargo security requirements for all types of transport and the vulnerability of roll-type cargo during the modal transition. The maintenance of cargo stability throughout the entire logistics chain is required to avoid disruptions and improve transportation reliability.

By contrast, the importance weight scores for Cargo Damage Risk (C8), Loading and Unloading Risk (C7), and Vibration and Shock Risk (C6) were considerably lower. Though these criteria were considered less important by the expert respondents, they certainly

cannot be regarded as minor. On the contrary, they seem to denote secondary effects of primary stability-related issues. Thus, an enhancement of cargo securing practices and stability management is likely to help reduce these secondary risks at the same time.

Practically, the study results can be useful for logistics companies, terminals, freight forwarders, and transport managers. It would be easier for the professionals involved in the industry to manage their resources and develop targeted risk reduction plans thanks to the prioritization of risk factors revealed in the study. The safety and reliability of the roll-type cargo transportation process can be greatly enhanced by means of investing in advanced securing equipment, reliable handling procedures, regular inspections, and staff training programs.

Moreover, by examining an under-researched area of freight transport, the paper contributes to the existing literature. While general freight operations and containers have been widely researched, the specific hazards of roll-type cargo have been left behind in terms of scholarly interest. In this context, the proposed framework provides an organized base for assessing the stability and safety concerns that arise in roll-type cargo transport.

However, the results must be understood in consideration of the expert-oriented research design employed in the study. Even though the three experts chosen for the research were carefully chosen according to their wide-ranging experience in the field, the small number of experts involved may limit the generalizability of the weights generated. It will be necessary to further verify the present results through studies that use larger and internationally diverse expert panels.



This research article has been licensed with Creative Commons Attribution - Non-Commercial 4.0 International License. Bu araştırma makalesi, Creative Commons Atıf - Gayri Ticari 4.0 Uluslararası Lisansı ile lisanslanmıştır.

Author Contributions

The author has not declared any other contributors.

Acknowledgments

The author(s) did not provide acknowledgment.

Funding and Support

The author(s) did not report any funding or support information.

Conflict of Interests

The author(s) did not report any conflict of interest.

Ethics Statement

The author(s) did not report ethical committee approval as the research content does not require.

References

- Alazzawi, A., & Žak, J. (2020). MCDM/A Based Design of Sustainable Logistics Corridors Combined with Suppliers Selection. The Case Study of Freight Movement to Iraq. *Transportation Research Procedia*, 47, 577–584.
- Boakai, S., & Samanlioglu, F. (2023). An MCDM approach to third party logistics provider selection. *International Journal of Logistics Systems and Management*, 44(3), 283–299.
- Caris, A., Macharis, C., & Janssens, G. K. (2013). Decision support in intermodal transport: A new research agenda. *Computers in Industry*, 64(2), 105–112.
- Crainic, T. G., & Kim, K. H. (2007). Intermodal transportation. *Handbooks in Operations Research and Management Science*, 14, 467–537.
- Di Gialleonardo, E., Melzi, S., & Trevisi, D. (2023). Freight trains for intermodal transportation: optimisation of payload distribution for reducing longitudinal coupling forces. *Vehicle System Dynamics*, 61(10), 2532–2550.
- Keleş, N., & Pekaya, M. (2023). Evaluation of logistics centers in terms of sustainability via MCDM methods. *Journal of Advances in Management Research*, 20(2), 291–309.
- Le, M.-T., & Pham, T.-D. T. (2026). Analysis and Evaluation of the Impact of Quantitative and Qualitative Factors on Vietnam's Logistics Efficiency Using the DEA-MCDM Integrated Method. *Sustainability*, 18(3), 1594.
- Malaksiano, M. O., & Melnyk, O. M. (2020). Vessel selection prospects and suitability assessment for oversized cargo transportation. *Scientific Notes of Taurida National VI Vernadsky University. Series: Technical Sciences*, 31(70), 1.
- Maravić, A., Pajić, V., & Andrejić, M. (2025). Evaluation of Digital Technologies in Food Logistics: MCDM Approach from the Perspective of Logistics Providers. *Logistics*, 10(1), 6.
- Melnyk, O., & Malaksiano, M. (2020). Effectiveness assessment of non-specialized vessel acquisition and operation projects, considering their suitability for oversized cargo transportation. *Transactions on Maritime Science*, 9(01), 23–34.
- Muravev, D., Hu, H., Zhou, H., & Pamucar, D. (2020). Location optimization of CR express international logistics centers. *Symmetry*, 12(1), 143.

- Opala, M. (2021). Analysis of safety requirements for securing the semi-trailer truck on the intermodal railway wagon. *Energies*, 14(20), 6539.
- Pencheva, V., Asenov, A., Sladkowski, A., Ivanov, B., & Georgiev, I. (2022). Current issues of multimodal and intermodal cargo transportation. *Modern Trends and Research in Intermodal Transportation*, 51–124.
- Pokrovskaya, O., Fedorenko, R., & Kizyan, N. (2020). Cargo transportation and commodity flows management. *IOP Conference Series: Materials Science and Engineering*, 918(1), 12050.
- Rodrigue, J.-P. (2020). *The geography of transport systems*. Routledge.
- Rong, C., Li, X., Zhang, G., & Wang, X. (2025). Analysis on the adjustment of transportation structure and the logistics transformation of railway freight. *Railway Sciences*, 4(1), 82–96.
- Roso, V., & Lumsden, K. (2009). The dry port concept-The case of Falköping terminal. *Maritime Transport IV*, 17–27.
- Singh, P., Singh, J., Antle, J., Topper, E., & Grewal, G. (2014). Load securement and packaging methods to reduce risk of damage and personal injury for cargo freight in truck, container and intermodal shipments. *Journal of Applied Packaging Research*, 6(1), 6.
- Snyder, W. R., Ge, C., Lee, C., & Park, J. (2026). Measurement and Analysis of Climatic and Vibrational Hazards in Cold Chain Double-Stacked Rail Transport: Effects of Mount and Stack Position. *Journal of Vibration Engineering & Technologies*, 14(2), 79.
- Tsai, J.-F., Tran, T.-H., Che, Z.-H., Lin, M.-H., & Nguyen, P.-H. (2026). A Multi-Stage T-SF MCDM Framework for Assessing Vulnerabilities in Cross-Border Logistics Chains. *Journal of Intelligent & Fuzzy Systems*, 18758967261445500.
- Wang, C.-N., Nguyen, T. T. M., Chung, Y.-C., Nguyen, T. T. T., & Nguyen, T. D. (2025). Performance evaluation of listed Vietnamese logistics companies in the pre-, during, and post-COVID-19 based on a three-layer MCDM method. *Humanities and Social Sciences Communications*, 13(1), 43.
- Zhang, D., Wang, S.-M., Tang, Y.-Y., Ni, Y.-Q., Guo, J.-W., & Peng, Q.-Y. (2024). A novel method for evaluating load restraint assemblies to ensure the safety of railway freight transportation. *Scientific Reports*, 14(1), 4612.
- Zhang, X., Lu, J., & Peng, Y. (2021). Hybrid MCDM model for location of logistics hub: A case in China under the belt and road initiative. *Ieee Access*, 9, 41227–41245.
- Žižović, M., & Pamucar, D. (2019). New model for determining criteria weights: Level Based Weight Assessment (LBWA) model. *Decision Making: Applications in Management and Engineering*, 2(2), 126–137.