NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE

THE ACADEMY OF APPLIED SCIENCE
ACADEMY OF MANAGEMENT AND ADMINISTRATION IN OPOLE

CARGO SAFETY RISKS IN LOGISTICS SYSTEMS

Academy of Applied Sciences
Academy of Management and Administration in Opole
National University of Life and
Environmental Sciences of Ukraine

CARGO SAFETY RISKS IN LOGISTICS SYSTEMS

Monograph

Opole
2026

Cargo safety risks in logistics systems. Monograph. Opole: Academy of Applied Sciences Academy of Management and Administration in Opole, 2026;
ISBN 978-83-66567-97-9 200 pp., illus., tabs., bibls.

Together with:

National University of Life and Environmental Sciences of Ukraine, Kyiv

Recommended for publication
by the Academic Council of Academy of Applied Sciences
Academy of Management and Administration in Opole
(Protocol No. 4 of May 14, 2026)

Editorial Office:
Academy of Applied Sciences Academy of
Management and Administration in Opole
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Publishing House:
Academy of Applied Sciences Academy
of Management and Administration in Opole,
45-085 Poland, Opole, ul. Niedzialkowskiego 18
tel. 77 402-19-00/01

150 copies

Authors are responsible for content of the materials

ISBN 978-83-66567-97-9

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PART 3

INTRODUCTION

The efficient functioning of logistics supply chains, covering all stages of material flows – from the supply of raw materials and semi-finished products to the delivery of finished products to the end consumer, as well as the organization of reverse logistics flows, is one of the key factors in ensuring the sustainability and competitiveness of enterprises in the modern economy. In the context of large-scale cataclysms (wars, pandemics), high volatility of the market environment, increased uncertainty and risks, tightening requirements for the quality of logistics services, the issues of reliability of transport operations and the safety of cargo movement are of particular importance.

The transport component of the logistics chain significantly affects both the overall level of logistics costs and the quality of customer service. At the same time, transportation costs are formed not only due to the direct performance of transportation, but also include costs associated with violation of delivery deadlines, downtime of vehicles, additional transshipment operations, as well as losses from damage, damage or complete loss of cargo. A significant share in this structure is occupied by the costs caused by the implementation of transport risks, in particular the risks of non-safety of goods. Road transport occupies a leading place in freight transportation due to its versatility, mobility and the ability to provide door-to-door delivery. At the same time, road transportation is characterized by increased sensitivity to the impact of a wide range of risk-forming factors (technical, organizational, technological, human and related to the influence of the external environment). This leads to a fairly high prevalence of cases of non-safety of goods in the process of transportation, which negatively affects the economic results of carriers' activities, the level of customer satisfaction and the efficiency of logistics systems in general.

Cargo safety is one of the basic characteristics of the quality of transport services and the main contractual responsibility of the carrier. Non-safety of goods belongs to the transport risks of a man-made nature and manifests itself in the form of mechanical damage, deformation, damage, loss of commercial properties or complete loss of cargo. The formation of such risks has a complex multifactorial nature and is the result of the interaction of transportation conditions, cargo characteristics, technical condition of vehicles, quality of packaging and fastening, the level of organization of the transport process and personnel actions.

Despite the application in practice of a wide range of organizational and technical measures to ensure the safety of goods – the use of specialized rolling stock, modern means of fastening, traffic monitoring and control systems, improvement of transportation routes – the level of non-safety remains significant. This indicates the limitations of fragmented measures and the need to move to systematic risk management based on quantitative assessment, modeling and forecasting. The analysis of scientific research in this area shows that most of the works are devoted to certain aspects of the problem: the study of the causes of damage to specific types of cargo, the analysis of technical solutions or regulatory requirements for transportation. At the same time, the issues of formalization of the process of formation of risks of non-safety of goods, determination of their structure, hierarchy and interconnections, as well as the construction of integrated risk indicators suitable for use in the practice of logistics process management remain insufficiently developed.

In this regard, the development of a methodological approach to assessing the risks of non-safety of goods, which is based on:

– systematic analysis of risk factors, taking into account their internal and external nature;

– application of methods of multi-criteria assessment and decision-making theory;

– the use of mathematical modeling to quantify the level of risk;

– formation of integrated risk indices as a tool to support management decisions.

It is this approach that allows us to move from a descriptive analysis of individual cases of non-safety of goods to a comprehensive risk assessment at the level of the logistics chain and the transport process as a whole. This creates the basis for an informed choice of risk mitigation measures, optimization of technological solutions and increase the reliability of road transportation.

In this context, this monograph is aimed at forming a holistic system of methods and models for assessing the risks of non-safety of goods in the process of road transportation. The logic of presenting the material provides for a consistent transition from the identification and classification of risk factors to the development of quantitative methods for their assessment, the construction of mathematical models and integrated risk indicators, as well as the formation of practical recommendations for managing the risks of cargo non-safety in modern logistics systems.

Part 1

THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF CARGO SAFETY DURING ROAD TRANSPORTATION

1.1 Basic provisions in the field of cargo safety in transport

Freight transportation is an integral part of supply chains, as it ensures that raw materials, semi-finished products or finished products are delivered to customers in the right place, at the right time, in the right quality and at the right price. In today's interconnected world of trade, the importance of cargo security cannot be overstated.

Trade routes span continents, and the movement of goods comes with risks, ranging from theft and damage to non-compliance with international standards. Cargo security plays a crucial role in reducing these risks, protecting valuable goods, and ensuring the reliability of supply chains.

Thus, the World Bank, in its Guide to Supply Chain Security[1], considers supply chain security as programs, systems, procedures, technologies and solutions used to counter supply chain threats and the resulting threats to the economic, social and physical well-being of citizens and society.

In recent decades, the global road freight market has been growing steadily and has been considered one of the major markets in the world. The COVID-19 pandemic, and then the war in Ukraine, significantly changed the road freight market, and further affected consumer behavior and logistics operations, forcing the former to caution and, accordingly, complicating the latter. Hostilities, economic sanctions, high commodity prices, and supply chain constraints have negatively impacted the road freight market.

[1] Donner M,. Kruk C. Supply Chain Security Guide; World Bank: Washington, DC, USA, 2009; URL.: http://hdl.handle.net/10986/28128

However, despite these challenges, the market is projected to grow steadily, reaching USD 127.27 billion by 2027 at a CAGR of 6.5%[2].

Every day, billions of euros in cargo will be transported through the trans-European road network, making it critical for the European Union's economy. At the same time, the growth of the share of road freight transportation revealed serious problems in ensuring the safety and efficiency of road freight transportation. Road transport faces numerous risks that can lead to damage or loss of cargo, including accidents, theft, improper packaging, vibrations and environmental impacts. These risks not only compromise the quality and integrity of goods, but also lead to economic losses and reduced efficiency of global supply chains. Thus, the annual losses of the European Union from cargo theft, according to estimates by J. Kubanova and I. Kubasakova, amount to about 8.2 billion euros, which corresponds to an average of 6.7 euros per transport operation[3].

It should be noted that in the transport sector it is impossible to guarantee one hundred percent high-quality service "a priori" in advance – this is one of the specific characteristics of the transport industry, associated with the multifactorial impact on the cargo during its transportation and the risks arising as a result of these influences. Even the nature of risks based on hazards and threats is fundamentally different, which leads to different difficulties in analyzing them at the same level. S. Fan and Z. Yang[4], reviewing the literature on the safety of transport systems, distinguish different terms within the framework of a joint analysis of cargo safety and protection (Table 1.1).

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[2] GlobeNewswire. Road Freight Transport Global Market Report. 2023. URL. https://www.globenewswire.com

[3] Kubanova J., Kubasakova I. Security Risks in the Trucking Sector, Transportation Research Procedia, Volume 44, 2020, 234-239

[4] Fan S., Yang Z. Safety and security co-analysis in transport systems: Current state and regulatory development, Transportation Research Part A: Policy and Practice, Volume 166, 2022, 369-388.

Table 1.1 Terminology of Joint Analysis of Cargo Safety and Protection

Term	Definition	References
Accident	An unplanned event or series of events resulting in damage to or loss of equipment or property, as well as damage to the environment."	Ericson (2015)
Incident	Intentional event or series of events that caused damage or loss of equipment or property, or damage to the environment	Ericson (2015)
Loss	It's about something of value to stakeholders, including property damage, environmental pollution, mission disruption, loss of reputation, loss or leakage of confidential information, and any other loss that is unacceptable to stakeholders	Leveson, John (2018).
Danger	Any actual or potential condition that could result in damage to or loss of system, equipment, or property; or causing damage to the environment.	Ericson (2015)
Thunderstorm	The object most vulnerable to damage. This is the result of the event and the expected indirect damage and loss.	Ericson (2015)
Losing scenario	The loss scenario describes causal factors that can lead to dangerous control measures and hazards	Leveson, John (2018)

Source: compiled by the authors based onFan S., Yang Z., Safety and security co-analysis in transport systems: Current state and regulatory development, Transportation Research Part A: Policy and Practice, Volume 166, 2022, 369-388.

Therefore, when planning transportation, the cargo owner must adequately assess the possible risks of poor quality service and, if there are alternatives, choose the one that meets the set conditions, including in terms of the risk of non-safety of the cargo.

The well-known "six rules of logistics" emphasize the necessity: to deliver the goods, at the specified time, to the right place, of the required quality, in the right quantity, at the right price. Everything that contradicts this postulate is poor-quality logistics service, which can be the basis for risk research within logistics operations.

Transportation is only a part of logistics processes, so it can be assumed that non-compliance with part of the rules of logistics due to transportation is poor-quality transport service.

After all, the transportation of goods is a business process, the purpose of which is the safe delivery of goods to their destination. Therefore, guaranteeing safety – that is, the absence of losses during transportation – is the key task of transport and logistics companies. And if we also take into account that during transportation three rules – "goods", "place", "price" are usually observed, then the risk of loss of profit due to poor-quality transport services is caused by: untimely delivery, deterioration of the quality of goods in the process of delivery and reduction of its quantity. Decrease in the quantity and deterioration of the quality of the transported goods is the result of non-preservation of the cargo during transportation. Moreover, we note that cases of non-preservation of cargo are not isolated, they are quite common and have an adverse economic impact both for the carrier and negatively affect the interests of customers.

If we consider the concept of cargo, it should be noted that all cargoes have physical and chemical characteristics, volumetric and weight parameters and the degree of danger inherent only to them, which determine the technical conditions of their transportation. In combination with the parameters of containers and packaging, these specific properties form the concept of "transport characteristics of cargo".

Transport characteristics of cargo is a set of properties and parameters of cargo that determine the conditions of its transportation, transshipment and storage, as well as requirements for technical means of performing relevant operations. This concept is used in solving the problems of rationalization of the transport process: choosing the type of rolling stock, loading and unloading mechanisms and devices, warehouse equipment, means of packaging goods, as well as in the development of conditions for their transportation.

The transport characteristics of the cargo directly affect:

– selection of the optimal carrying capacity of the car;

– balance between the volumes of acceptance and shipment in the warehouse;

– formation of "bottlenecks" in warehouse areas;

– economic indicators (transport and warehouse costs), etc.

Transport characteristics of cargo are a key system-forming factor of logistics systems. It determines not only the parameters of transportation, but also the logic of the warehouse functioning, the level of resource utilization and the economic efficiency of the logistics chain.

A set of specific qualitative and quantitative indicators of the transport characteristic forms the transport condition of the cargo. Moreover, the safety of the cargo and the safety of its transportation are ensured only if it is presented for transportation in a transportable state[5].

Therefore, the greatest importance in the transportation of cargo is given to the characteristic of transportability, which is

[5] Panjee, P.; Kaewchueaknang, V.; Amornsawadwatana, S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https://doi.org/10.3390/safety11010020

defined as the degree of readiness (suitability) of the cargo for transportation.

Transportability requirements provide for the possibility of transporting cargo without damage and loss, efficient use of vehicles, as well as proper organization of loading and unloading, warehousing and other operations related to its movement from the sender to the recipient.

Cargo is considered transportable if:

– is in a conditioning state;

– meets the requirements of standards and conditions of transportation;

– has serviceable containers, packaging, seals, locks, control tapes and proper marking;

– reliably protected from the negative effects of the external environment;

– has no signs of damage or spoilage.

The transportability of cargo is influenced by a complex of physical, technical and organizational factors, namely:

1. Weight and dimensions: exceeding the permitted norms for weight or dimensions may require special conditions or prohibitions by traffic rules.

2. Packaging and packaging: strength, tightness, vibration resistance; the presence of a standard pallet or container.

3. Quality of cargo: freshness or preservation (for food - humidity, temperature). It is believed that the quality of cargo is one of the main indicators of its transportability (the better the cargo is stored, the more transportable it is).

4. Transportation conditions: temperature and humidity in the body, vibration, shocks, climatic factors, etc.

5. Impact of Transportation Operations:

– correct load;

– fasteners;

– marking;

– timely execution of accompanying documents.

There are both legislative and technical documents regulating transportability criteria. In particular, these are international ISO standards that regulate certain aspects of transportability:

– ISO 780 (Packaging: Graphic labelling for the handling of goods) specifies international symbols (labels) on packaging ("fragile", "hold vertically", etc.), which guarantee the correct handling of the cargo during transport.

– ISO 4178 (Transport containers, complete, loaded. Operational test.) describes test methods for packaging structures for resistance to loads during stacking, vibration and shock during transportation.

– ISO 22982 (Temperature-controlled transport packaging for parcel delivery) is developed for the cold chain (temperature controlled) – is a standard for the packaging of food and medicines to be stored in the refrigerator.

– ISO 668 (Series 1 Cargo Containers: Classification, Dimensions and Nominal Characteristics) establishes the basic sizes and maximum loads of sea containers, providing uniform rules around the world.

There are also international requirements for supply chain safety (e.g. ISO 28000 Supply Chain Security Management Systems) and veterinary and phytosanitary regulations for wooden packaging (ISPM 15 standard, which requires the treatment of wooden pallets to prevent pests. during which the cargo retains its quality).

In addition to this, any cargo has a property of preservation, which is determined by the ability of the transported objects to maintain a serviceable and efficient condition during transportation and after it[6]. To increase the level of cargo safety, special measures and methods[7], are used to guarantee a reliable supply of serviceable and undamaged goods anywhere in the world.

In contrast to the term "cargo safety", the term "cargo safety", although it has key convergences, is broader and characterizes the possibility of delivering cargo from the sender to the recipient without deterioration in quality and in the amount specified in the transportation documents (taking into account the norms of natural shrinkage and loss)[8].

The presence and variety of characteristics, terms and concepts (Table 1.2) regarding the safety of cargo and the safety of its transportation indicate that the problem of non-safety of goods remains one of the priorities for both logistics operators and their customers.

An analysis of academic sources[9] indicates that one of the key quality criteria for truck freight transport is ensuring the safety of the cargo. Accordingly, meeting this criterion requires eliminating any form of cargo damage.

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[6] Feng X., Wang Z., Wang Y., Yin W., Chao Y., Ye G. Improving resilience in an intermodal transport network via bulk cargo transport coordination and empty container repositioning, Ocean & Coastal Management, Volume 248, 2024, 106970

[7] Kumar A., Shrivastav S.K., Shrivastava A.K,. Panigrahi R.R., Mardani A., Cavallaro F. Sustainable Supply Chain Management, Performance Measurement, and Management: A Review. Sustainability 2023, 15, 5290. https://doi.org/10.3390/su15065290

[8] Mora Lozano P.E., Montoya-Torres J.R. Global Supply Chains Made Visible through Logistics Security Management. Logistics 2024, 8, 6. https://doi.org/10.3390/logistics8010006

[9] Alvarez Gallo S., Maheut J. Multi-Criteria Analysis for the Evaluation of Urban Freight Logistics Solutions: A Systematic Literature Review. Mathematics 2023, 11, 4089. https://doi.org/10.3390/math11194089.; Bayguzhina G., Sagatbekova A. The main indicators of ensuring the quality of cargo transportation by road. Vestnik of M. Kozybayev North Kazakhstan University. 2023. 81-86. 10.54596/2958-0048-2023-1-81-86.; Nkesah S.K. Making road freight transport more Sustainable: Insights from a systematic literature review, Transportation Research Interdisciplinary Perspectives, Volume 22, 2023, 100967.; Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https://doi.org/10.3390/safety11010020

Table 1.2 Key concepts of cargo transportation and safety

Concepts	Definition	Main aspects
Transport characteristics of the cargo	A set of physical and chemical properties, volumetric and weight parameters, degree of danger, as well as features of containers and packaging	Determines the modes of transportation, transshipment, storage; requirements for transport, warehouse equipment
Transport condition of the cargo	Specific qualitative and quantitative indicators of transport characteristics	Indicators that indicate the readiness of the cargo for transportation
Transportability of cargo	The ability of the cargo to maintain integrity and quality during transportation	Requirements: condition, compliance with standards, serviceable containers and packaging, labeling, protection from external influences
Conservation cargo	The ability of the cargo to maintain good and working condition during and after transportation	Provided with special protection measures
Safety of goods	Property of delivery of cargo without loss and deterioration of quality (taking into account the norms of natural loss from the sender to the recipient	The key problem of the transport industry is the risk of non-preservation

Source: compiled by the authors on the basis of scientific sources

In the context of road transport, defects should be understood to include events such as damage, spoilage, loss, or shortage of cargo. At the same time, the safety of cargo during transport is not only an obligation of the carrier arising from the contract of carriage but also a fundamental condition for the transport process, since without preserving its quality, integrity, and quantity, transport loses its meaning.

This entails not only the physical custody of the cargo but also protection against spoilage, loss, and theft, as well as ensuring the conformity of the goods' consumer properties, which forms the basis of cargo logistics in general.

At the same time, studies of the problem of the quality of transport services indicate the presence of a number of factors that cause differences in the perception of quality between consumers and service providers. One of the key factors is the incorrect interpretation of customer expectations[10]. After all, the management of transport organizations does not always adequately understand what characteristics of the service are a priority for consumers and how they evaluate its components. Thus, the carrier may proceed from the assumption that the main criterion for customers is the timeliness of delivery, while in practice, in many cases, the safety of the cargo is of decisive importance for customers.

Usually, the carrier carries out its activities on the basis of a cargo transportation agreement. Such an agreement is the legal basis for the emergence and regulation of relations between the carrier and the customer (consignor or client). When concluding an agreement, the parties assume mutual obligations to carry out transportation. According to the terms of the cargo transportation agreement:

[10] Hajduk I., Poliak M., Gašparík J. Quality of transport services and customer satisfaction measurement. The Archives of Automotive Engineering - Archiwum Motoryzacji. 2022. 96. 51-76. 10.14669/AM/151707.

– the carrier undertakes to deliver the cargo entrusted to it to the designated destination point and issue it to an authorized person;

– the sender (client), in turn, undertakes to pay the established carriage fee for transportation.

The carrier's activities are regulated by regulatory legal acts. Depending on the type of transportation, the following are applied: national regulations for domestic transportation by road or the Convention on the Contract for the International Carriage of Goods by Road (CMR) for international transportation.

In all cases, the carrier's liability is imperative and presumed under national law. Thus, according to the Civil Code of Ukraine, the carrier is responsible for the safety of the cargo from the moment of its acceptance for transportation and until the moment of delivery to the recipient. And according to him, he is responsible for damages caused by his actions or inaction, which led to the non-safety of the cargo.

Such actions/omissions include:

– technical malfunction of the vehicle;

– a malfunction of the body, which allowed access to the sealed cargo without breaking the seal;

– equipment malfunction;

– violation of traffic rules by the driver, which could cause damage to cargo or containers;

– damage to the sender's seal;

– signs of theft;

– violation of sanitary rules in the body or transportation of incompatible goods.

In case of loss, shortage or damage to the cargo, the carrier is obliged to reimburse its cost:

– in case of loss or shortage of cargo – in the amount of the value of the cargo that is lost or missing;

– in case of damage to the cargo – in the amount of the amount by which its value has decreased;

– in case of loss of cargo handed over for transportation with a declaration of its value – in the amount of the declared value, unless it is proved that it is lower than the actual value of the cargo.

The CMR Convention (Geneva, 1956) also regulates contractual relations in the international carriage of goods by road. The carrier's liability is defined in Chapter IV of the Convention and the Additional Protocol. According to it: the maximum amount of the carrier's liability for the loss of cargo is limited to 8.33 IMF Special Drawing Rights (SDR)[11] for each kilogram of cargo. In addition, transportation charges, duties and other expenses related to transportation are reimbursed. Therefore, the most important criterion of the carrier's responsibility is the safety of the cargo during transportation, i.e. its delivery without changing the quantitative and qualitative characteristics to the consignee. After all, the cargo has a material value, which is of considerable interest to the customer (many companies invest in cargo transportation insurance to receive significant monetary compensation, but higher costs lead to an increase in insurance payments, which, in turn, increases future insurance premiums)[12]. Instead, the carrier (as mentioned above) is not directly interested in the cargo itself, as the bearer of a special obligation, is solely responsible for its condition. Therefore, many shipper companies do not outsource decisions about the choice of transportation methods to logistics service providers, but determine every aspect of cargo movement in order to maintain final control

[11] The value of the SDR is calculated based on a basket of five leading world currencies: the US dollar, the euro, the yuan, the yen, and the pound sterling.

[12] Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https:/doi.org/10.3390/safety11010020

over how their goods are transported[13]. An important reason for this is the perceived risk of loss of control and transparency if shippers completely outsource the transport function.

1.2 The concept of unsaved cargo

Cargo non-safety is a diverse category in both theoretical and practical aspects. According to the terminology of Ukrainian legislation, the term "unpreserved cargo" means theft of cargo, loss, shortage of pieces and weight of cargo, damage and damage to cargo, which occurred in the process of transportation or during storage in station warehouses and other common places[14].

In scientific publications, non-preservation of cargo is understood as loss, shortage, damage and spoilage of cargo, which is characterized by the loss of its quantitative (except natural losses) and qualitative characteristics by cargo[15].

That is, it is a state or phenomenon in which the cargo loses its original properties, quantitative or qualitative characteristics, or integrity in the process of transportation from the sender to the recipient. Non-preservation of cargo includes all cases when the cargo has not been preserved in the condition in which it was transferred for transportation and can manifest itself in the following forms of Fig. 1.1.

[13] Khakdaman M., Rezaei J., Tavasszy L.A., Shippers' willingness to delegate modal control in freight transportation, Transportation Research Part E: Logistics and Transportation Review, Volume 141, 2020, 102027, https://doi.org/10.1016/j.tre.2020.102027

[14] On Approval of the Instruction on the Procedure for Interaction between the Internal Affairs Bodies, the Railways of Ukraine, and Railway Transport Enterprises in the Detection of Cargo Theft and the Response to Statements and Reports of Such Offenses
Ministry of Internal Affairs of Ukraine, Ministry of Transport and Communications of Ukraine, 2010, No. 404/624

[15] Ciok P. The carrier's liability for damage to cargo in multimodal transport with special focus on the Rotterdam Rules. Studia Iuridica Toruniensia. Online. 18 March 2017. Vol. 19, 23-51. https:/10.12775/SIT.2016.014

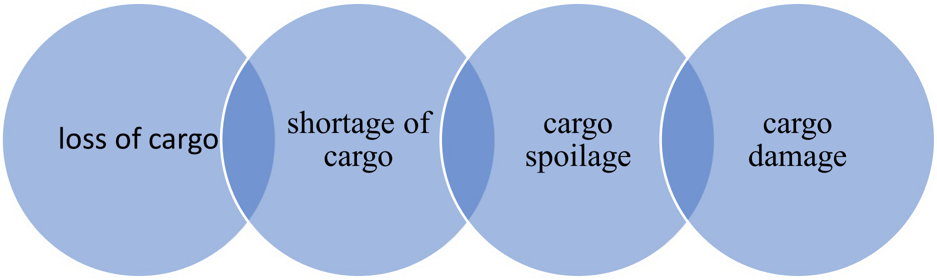

Fig. 1.1 Forms of cargo non-preservation

Source: compiled by the authors

Let's consider them in more detail.

1. Loss of cargo is a complete loss, theft or erroneous delivery of cargo to another recipient. Most often, this is the result of the physical destruction of cargo as a result of an accident, catastrophe, natural disaster, etc.

This also includes the theft of property that makes up the cargo, that is, the unlawful possession of it by another person. In transportation relations, the loss of cargo is not only its actual absence, loss is considered to be any inability for the carrier to deliver the cargo to its recipient within the established regulatory terms.

2. Shortage of cargo – cases when the cargo is transferred to the recipient in a smaller quantity or weight than indicated in the consignment notes. Cargo shortage is understood as a partial loss of the object of transportation, i.e. a decrease in its quantitative parameters - weight, volume, number of cargo pieces, etc. At the same time, the actual reduction of the cargo is not always a disadvantage if the difference between the weight at dispatch and receipt does not exceed the permissible weighing error (marginal discrepancy). The mass is considered correct if this deviation is within the technical standards (natural losses), which is important for determining the carrier's liability.

The norms of natural losses (loss) of cargo are the maximum permissible values of reducing the mass of products due to physical and chemical properties (drying, sawing, etc.) during transportation. For example, when transporting by road, the loss rate for grain is 0.07%, and for wet cargoes - up to 2% of the net weight.

3. Cargo spoilage is a complete or partial loss of the value of the cargo in the process of transportation. Damage means irreversible changes in the qualitative and/or quantitative characteristics of the cargo that cannot be restored, including:

– decrease in chemical, physical or biological properties;

– deterioration of appearance;

– mechanical damage.

4. Cargo damage – changes in the qualitative and/or quantitative characteristics or appearance of the cargo that can be restored. Damage is most often interpreted as a malfunction or malfunction of a mechanism or device that does not affect the performance of their main functions, this is a violation of the physical integrity of the cargo.

The main sign of non-preservation is a quantitative shortage relative to the data specified in the waybill, or damage and other signs of a decrease in the quality of the cargo or its complete unsuitability for its intended use. The main reasons for the non-safety of cargoes: various violations of technology and rules for performing commercial operations, leading to the loss or damage of cargo, as well as unsatisfactory organization of its protection, which contributes to theft[16].

The variety of cases and forms of non-preservation of cargo and their connection with the quality of transportation necessitate the systematization of the causes of adverse events. Thus, in scientific

[16] Economic Code of Ukraine. Bulletin of the Verkhovna Rada of Ukraine, 2003, No. 18, No. 19–20, No. 21–22, Art. 144. URL: https://zakon.rada.gov.ua/laws/show/436-15#Text

research[17], the following main classes of reasons for the non-preservation of cargo are distinguished (Table 1.3).

Table 1.3 Classification of the causes of non-safety of cargo

№	Label	Категорії	Characteristics
1	For character	Force majeure events that developed without the carrier's ability to predict or prevent them; Not force majeure events that depended on the carrier and could be eliminated by it.	Determines the extent of the carrier's influence on the occurrence of the event.
2	Behind the view	Damage – damage caused without the possibility of restoration (repair, replacement are impossible); Damage – damages that can be repaired or restored; Loss (shortage) – a decrease in the amount of cargo.	Characterizes the consequence of the event for the cargo.
3	Subjective	Transportation participant (driver, dispatcher, etc.) – an event related to the actions of persons directly involved in transportation; Third party – an event involving persons not related to transportation; Without the participation of persons – the event occurred without the participation of subjects.	Determines the degree of the human factor.

[17] Md Hanafiah R., Abu Talib N. A., Mohd Zaideen I. M., Tarudin N. F., Othman M. K. Mitigating cargo damage in containerised shipping: a hybrid assessment of risk factors and strategic interventions. Journal of Maritime Logistics, 2025. *5*(1), 66–81. https://doi.org/10.46754/jml.2025.08.005; Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. *Safety* 2025, 11, 20. https://doi.org/10.3390/safety11010020; Tunçel A. L., Erdem P., Turan, O. Estimation of Human Errors During Cargo Unloading Operations on Bulk Carriers Using SLIM and Interval Type 2 Fuzzy Sets. JEMS Maritime Sci, 2023. 11(3), 198-208. https://doi.org/10.4274/jems.2023.92260.

Continuation of Table 1.3

4	By source of occurrence	External – the source is the external environment (natural, mechanical, social, political, road influence); Internal – the source is a vehicle, driver or cargo.	Reflects the place of origin of the risk factor.
5	By procedural determinantм	At the stage of loading and unloading operations – the reason arises outside the transportation process itself; At the stage of transportation, the reason is directly related to the transportation process.	Shows at what stage of the logistics process the event took place.
6	Behind the type	Simple – the event occurred due to one reason Complex – the event is caused by a combination of several reasons.	Reflects the complexity of causation.

Source: compiled by the authors on the basis of scientific sources

And they note that the correct choice of classification features is of both scientific and practical importance. For road transportation, cargo non-safety is a complex phenomenon characterized by partial or complete loss by cargo of its quantitative and/or qualitative characteristics, physical integrity or commercial value during transportation. It is directly identified with a violation of the safety of transportation and is interpreted as a result of certain special effects on the cargo.

In the scientific literature[18], there are three groups of influences on the cargo: mechanical, climatic and biological (Table 1.4).

[18] Abbood K., Meszaros F. Social impacts of freight transportation industry: a global methodological review and synthesis. 10.23717/LOGEVK.2024.11. https://10.23717/LOGEVK.2024.11; Hoagland-Grey, H. Climate Change Risk Management Options for the Transportation Sector. 2015 https://doi.org/10.18235/0005997; Fatorachian H., Pawar K. The interplay between Industry 4.0 and their impact on freight transportation sustainability. European Journal of Innovation Management,

Table 1.4 Main types of impacts on cargo, their manifestations and causes during road transportation

Influences	Manifestations of influence	Causes of occurrence
Climatic	Precipitation, gas composition, temperature, humidity, dustiness of the air, the presence of microbiological forms in its composition, light	atmospheric precipitation that causes moisture or wetting of containers and cargo; temperature fluctuations, which can cause moisture condensation inside the container; increased or decreased air temperature, which changes the physical and chemical properties of materials, spoils food, destroys packaging. lack of thermal insulation in the vehicle or warehouse; non-compliance with the temperature regime; lack of ventilation or its excessive intensity, which favors drying or accumulation of condensation. increased content of gases (ozone, sulfur dioxide, exhaust gases) that interact with the surface of the cargo or its packaging; dustiness of the air, which causes pollution, abrasion of surfaces, and a decrease in the presentation of products.

2025; Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/EJIM-05-2024-0506: Melkonyan A., Hollmann R. Tim Gruchmann, Denis Daus, Climate mitigation and adaptation strategies in the transport sector: An empirical investigation in Germany, Transportation Research Interdisciplinary Perspectives, Volume 25, 2024, 10110; Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. *Safety* 2025, 11, 20. https://doi.org/10.3390/safety11010020; Rajesh D., Gupta S. K., Ilinich S., Singh N. An assessment of challenges and factor influencing the freight forwarding business in the logistics industry. Economics, Finance and Management Review, 2023, (2), 4–23. https://doi.org/10.36690/2674-5208-2023-2-4-23

Continuation of Table 1.4

Mechanical	Shocks, jerks, vibration, static loads, friction arising during transportation, handling operations, overloading, storage, etc.	malfunction of rolling stock bodies; breakdowns of mechanisms and machines for loading/unloading; unreliable or improperly used lifting devices; violation of cargo placement technology; disruption of technological delivery processes.
Biological	Vital activity of microorganisms, insects, rodents, etc.	infection with microorganisms during storage or transportation (mold spores, bacteria, yeast); contact of cargo with already infected surfaces of containers, pallets, walls of the body or warehouse. lack of disinfection of warehouses and transport premises; the presence of rodents or insects that damage the container and product; no sealing of the body or packaging, which allows the penetration of biological pests. creating a favorable environment for the development of mold, fungi and bacteria; acceleration of decay, fermentation or spoilage of organic materials (grain, vegetables, fruits, food). use of equipment without sanitization; damage to the packaging that gives access to insects and rodents.

Source: compiled by the authors on the basis of scientific sources

It is also worth noting that the influence of the source on the safety of the cargo takes place at all stages of the transportation process. By itself, this impact cannot be eliminated completely, but only compensated by special organizational measures at the technological, technical and organizational levels - both at the stage of transportation planning and during its implementation.

In practice, all cases of non-safety of cargo have a dual nature of impact, which is manifested in man-made and economic consequences for the production activities of the enterprise. At the same time, the leading factor is the man-made impact, because it directly creates the prerequisites for further economic losses. The man-made origin of non-safety of goods is associated with the physical, technological and operational parameters of the transport process, the state of infrastructure, equipment, environmental conditions and the characteristics of the object of transportation itself.

It is these factors that determine the likelihood of damage, damage or loss of cargo, forming a further chain of economic consequences that negatively affect the activities of the enterprise, reduce its efficiency and increase overall logistics costs.

Taking into account the above, it is necessary to clearly define the objectivity of the cargo, i.e. to establish its characteristics, properties and sensitivity to external influences (Fig. 1.2).

Such identification allows you to correctly describe the mechanism of formation of man-made impact and, accordingly, to assess the associated economic risk of non-safety of cargo. After all, cargo is at the same time a material object and an object of property legal relations.

From an economic point of view, the safety of cargo is determined in value equivalent. In the event of events related to its non-preservation, the cargo as a physical object undergoes changes in quantitative or qualitative characteristics.

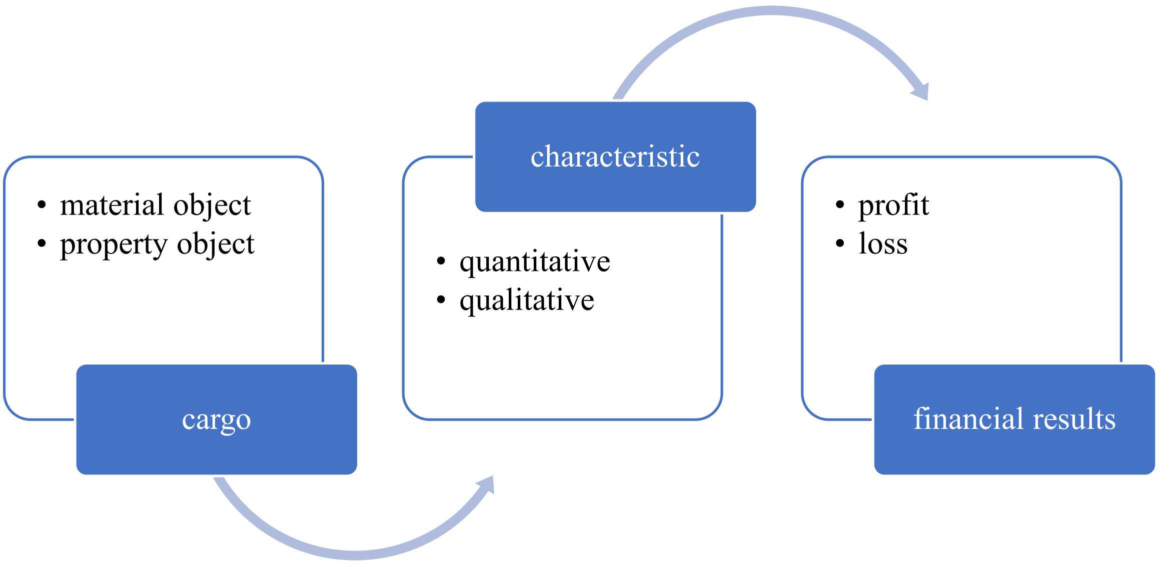

Fig.1.2 Objectivity of cargo

Source: compiled by the authors

This manifests itself in the form of damage, spoilage, partial or complete loss of consumer properties. As a result of such changes, the cargo, as an object of property value, loses its value or part of it. Accordingly, the person who is responsible for ensuring its preservation is obliged to compensate for the damages caused. This compensation covers the difference between the initial value of the cargo and its value after the occurrence of the event of non-preservation, i.e. it compensates for the economic consequences of man-made impact on it.

However, the perception of cargo only through cost indicators is irrational, since it is necessary to take into account the substantive essence of the cargo taking into account different approaches (Table 1.5).

Table 1.5 The concept of "cargo" in different approaches

Approach	The essence of the concept
Economic approach	Cargo is a product that is in the process of transportation. It has a value equivalent and is an object of economic circulation.
Legal approach	Cargo is an object of transportation accepted by the carrier in accordance with the established procedure. It has defined rights and obligations of the parties.
Technical approach	Cargo is a physical object or a set of objects that have certain mass-dimensional, physical-mechanical, structural and operational characteristics that affect the conditions of their movement, storage and handling.
Logistics approach	Cargo is a material object that has quantitative, qualitative and financial characteristics and moves in space in order to meet the needs of the consumer.

Source: compiled by the authors on the basis of scientific sources

According to these approaches, we can state that cargo can exist in any state of aggregation and size, and as an object, it can have commercial value or not have it at all. The only fundamental statement remains that a load is an object that moves in space. Moreover, this movement is somehow associated with the risk of its non-preservation during transportation, but with the risk of supplies (transport risk).

The formation of cases of cargo non-safety usually occurs in the open driver-vehicle-cargo system (VD–AZ–Vn).

However, according to the practice of investigating cases of non-preservation of goods, the external environment has a tremendous impact on this system, spreading to all its elements. One of the manifestations of the action of the external environment is the so-called force majeure circumstances, which are described as situations that the subject could not foresee or prevent. The simplest manifestation of the external environment as a force majeure factor is climatic influences.

Therefore, we believe that the non-safety of goods in modern supply chains is a systemic consequence of an insufficient level of management, fragmented and outdated legal regulation, a low level of technical and organizational culture of transportation, high accident rates and weak state control and force majeure.

Moreover, it has another characteristic feature - determining the source of the event of its occurrence, namely the cargo itself. In this regard, in our opinion, the driver-vehicle-cargo-external environment system (VD–AZ–Vn-ZS) should be considered as internal and external from the point of view of the source of the event of cargo non-safety (Fig. 1.3).

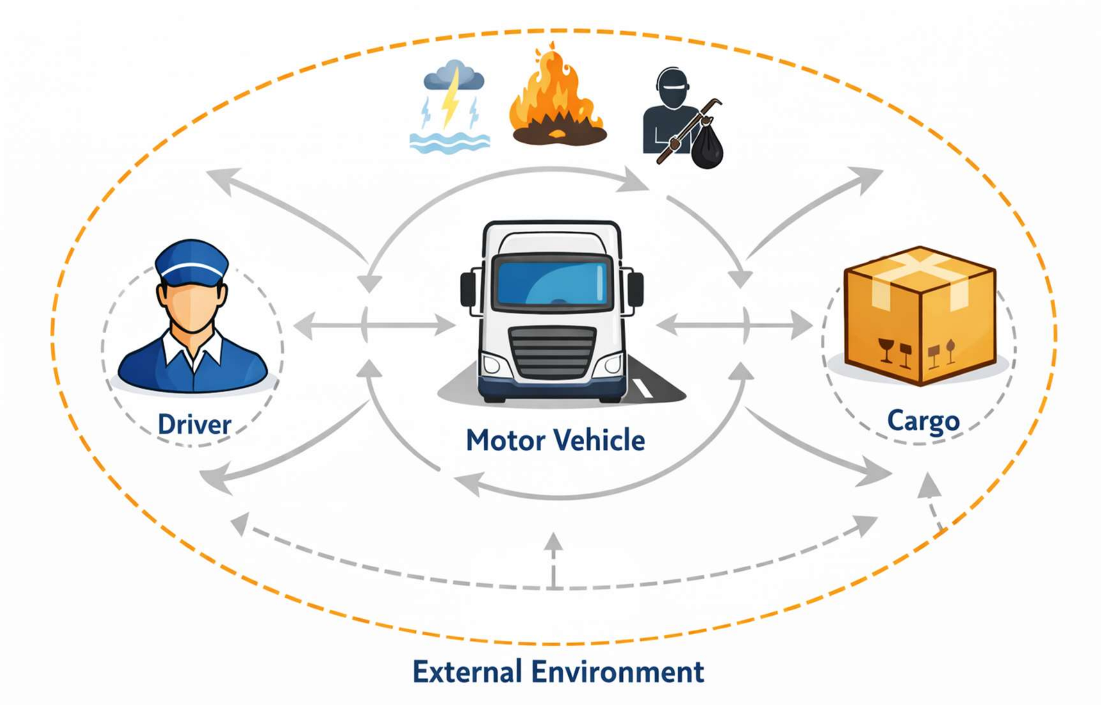

Fig. 1.3 System "driver - motor vehicle - cargo - external environment"

Source: Source: Generated by the authors using ChatGPT

In addition, taking into account the interconnections in this system, it can be argued that there can be several sources of influence, but the one whose intensity of influence is the highest compared to others is considered relevant. The influence of the source on the level of cargo safety is manifested in the form of certain factors that form the cause-and-effect complex of the events that have occurred.

1.3 Factors affecting the safety of goods

Cargo security includes policies, procedures, and technologies designed to protect goods in transit. Its purpose is to prevent theft, damage and other threats to the integrity of the cargo. At its core, cargo safety is the protection of goods from various risks, ensuring their delivery to the destination safely, safely and on time. Moreover, such risks are defined as "the probability, in quantitative terms, of the occurrence of a certain danger.

They combine "the probability of the occurrence of the main event (or events) with the measure of the consequences of this event (these events)"[19].

Researchers and practitioners identify a number of factors for the occurrence of such risks. Thus, Drewry specialists in the report for 2009 offer a list of risk factors associated with logistics operations. Among the main ones are: errors in documentation, booking and invoicing, errors in compliance with customs and security regulations, strikes and traffic congestion, theft and loss or damage to cargo, piracy and terrorist acts[20].

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[19] Chia-Hsun Chang, Jingjing Xu, Dong-Ping Song, An analysis of safety and security risks in container shipping operations: A case study of Taiwan, Safety Science, Volume 63, 2014, 168-178

[20] Risk Management in International Transport and Logistics, Drewry Shipping Consultants, London. 2009.

For further rational conduct of the study and the achievement of its goal, we need to determine the nature of the non-safety of the cargo through the formulation of factors affecting its preservation and their further structuring. Understanding the factors of cargo non-safety helps to develop effective measures for cargo safety, such as choosing reliable transport, proper packaging, insurance and monitoring of transportation.

It is worth noting that the factors affecting the safety of the cargo, in most cases, are also risk factors for non-safety of the cargo. They can be both internal, depending on the economic entity (Table 1.6)

Table 1.6 Internal factors of non-safety of goods

№	Factor	Structure factory	Properties	The need to take into accounti
1	Cargo packaging	– type of packaging; – correctness of execution – correctness of execution	Protection of cargo from constituent elements of the environment and external influences	Ensuring the protective function of the cargo
2	Cargo marking	– correct execution	Informing about possible cargo operations	Determination of permitted or prohibited actions with cargo
3	Loading cargo	– loading method; – loading tools used; –accuracy of execution	Direct impact on the cargo in the process of its movement	Manipulation of cargo for its further movement

Continuation of Table 1.6

4	Placement of cargo in the body of a vehicle	–Cargo placement scheme	Ensuring the optimal action of inertial forces	Impact of cargo on its individual components during transportation
5	Securing cargo in the vehicle body	- used fasteners; – fastening method; – Fastening quality	Ensuring the neutralization of inertial forces	Fixing the load in the vehicle
6	Driver	–qualification; – motivation; – health status	Efficiency, quality and safety of driving a vehicle	Direct process of driving a vehicle with cargo
7	Attitude to the technical condition o f the vehicle	–timeliness of reporting malfunctions; – willingness to conduct basic checks	Impermanence; depends on the personal qualities of employees	Minimizes the risks of technical failures that can cause an accident or damage to cargo
8	Communi-cation between participants in the process	Interaction between the driver, logisticians, loaders; Efficiency of information exchange	Depends on the human factor; possible failures or misunderstand-dings	Avoids errors when loading, unloading, and routing

Source: compiled by the authors

and external, which do not depend on him and on which he has an indirect influence (Table 1.7)

Table 1.7 External factors of non-safety of goods

№	Factor	Structure of the factor	Properties	The need to take into account
1	Road traffic conditions	– condition of the road surface; – the presence of potholes; – infrastructure; – traffic intensity	Instability; depends on weather and seasonal conditions	Determines the risk of damage to the load due to vibrations, shocks, sudden maneuvers
2	Weather conditions	– temperature; - humidity; – precipitation; – sudden changes in the weather	High variability; Inability to have full control	Important for loads sensitive to temperature, moisture, slippery roads
3	Criminogenic risks	– crime rate on the route; – risk of theft; – actions of third parties	Unpredictability; Dependence on the region and time of day	Allows you to take into account the risk of loss of cargo due to outside interference
4	Route risks	– length of the route; – number of stops; – complexity of the terrain; – the presence of dangerous areas	Heterogeneity; depends on the terrain and the state of the infrastructure	Affects the duration of transportation, and the likelihood of traffic incidents
5	Status of loading/ unloading infrastructure	– availability of equipment; – organization of the territory; – queues; – storage facilities	Variability; depends on partner enterprises	Reduces the risk of mechanical damage during operations

Continuation of Table 1.7

6	Regulatory and regulatory constraints	– customs procedures; – environmental requirements; –мovement restrictions	Frequent changes; Country and region dependency	Important to avoid delays, fines, and the risk of damage due to downtime
7	Technical risks of third-party objects	– actions of other drivers; – the state of their transport; – behavior of road users	Low predictability; strong influence of the human factor of other persons	Affects the risk of accidents, which can cause damage to the cargo
8	Economic and market conditions	– fluctuations in fuel prices; – logistical load; – lack of resources	High instability; depends on global factors	Important for estimating delays, rerouting, and overall costs
9	Socio-political situation	– protests; – roadblocks; – hostilities; – mobilization restrictions	Unpredictability; High danger	Makes transportation risky, requires route changes and insurance
10	Seasonal fluctuations in demand for logistics	– carriers' workload; – peak periods; – shortage of warehouses	Regularity but significant variability	Affects transportation time, storage and planning risks

Source: compiled by the authors

The process of moving an object of material value (cargo) within the framework of a transportation agreement consists of two stages: organizational and transport.

However, regardless of the stage of transportation, the factors affecting the safety of the cargo may or may not be subject to the influence of the participants in the transportation.

The factors subject to influence include organizational measures and technological processes aimed at the object of transportation and which directly affect the condition of the cargo. Among these factors:

– transportability of the cargo, which is determined by the condition and properties of the cargo;

– manipulative actions with cargo, such as packing, labeling, loading and unloading.

These actions are part of the group of organizational and technological factors, which are the preparatory processes for the implementation of transportation.

Organizational and technological factors also include:

– technical condition of the vehicle carrying out cargo transportation;

– driver's qualifications, including his psychophysiological and personal qualities;

– placement of cargo in the body and its fastening;

– driving culture, i.e. the driver's manner of driving a vehicle.

A separate group consists of factors with a clearly defined number of alternatives that remain unchanged during transportation, for example: the choice of vehicle or transportation route.

These factors in themselves do not cause cases of non-safety of cargo, but they significantly affect its safety due to derivative factors that depend on them.

Factors beyond the control of the participants in transportation affect mainly at the stage of transportation. The source of such factors is the external environment.

They can be divided into:

1. Road and climatic:

– natural and climatic conditions;

– condition of the road surface;

2. Socio-political:

– political influences;

– accident rate;

– criminal actions;

– hostilities;

– administrative influences (this factor is not risky, since by itself cannot be the cause of non-safety of cargo).

External factors also include:

– the condition of the cargo and accompanying documents, i.e. the information received about the cargo and its properties, which is a social factor coming from the sender or recipient;

– the culture of driving road users, which, when interacting with other factors, acts as a social external factor;

– the technical condition of the vehicle, which, in interaction with other factors, acquires a random character and is also considered as a factor of the external environment.

It should be noted that depending on the distance of transportation, with its increase, the risk of unsafety of the cargo increases. Therefore, intercity transportation is more susceptible to the risks of cargo non-safety.

According to the generally accepted classification of goods and current regulatory legal acts, general cargoes remain the least regulated in terms of cargo safety.

Due to the wide range of general cargoes, special attention should be paid to cargoes that have the least safety.

In long-distance traffic, the safety of cargo is strongly influenced by:

– weather and road conditions;

– the complexity of calculating the exact delivery time;

– force majeure;

– other internal and external factors.

From the list of factors influencing the safety of cargo in intercity transportation of general cargo, internal factors that can be the reasons for non-safety of goods are especially distinguished.

Let's consider them in more detail.

1. Packing of cargo. Packaging plays a key role in ensuring safety, as it is the outer shell of the cargo, protecting the object from the external environment and the influence of its constituent parts. It provides:

– protection of products from damage and loss;

– protection from environmental influences and pollution;

– convenience of product circulation.

The safety of cargo during transportation is largely ensured by proper preparation of cargo and rational packaging. According to the standards, cargoes are divided into three groups depending on the type of packaging:

– transported in containers;

– transported without containers with partial protection of individual elements;

– transported without containers.

Transportability of cargo is achieved through proper packaging. The term "packaging" has a double meaning: according to the first packaging, it includes any materials and aids used for packaging, in combination with or without packaging[21].

[21] Pascall M.A., Chapter 6 - The role and importance of packaging and labeling in assuring food safety, quality & compliance with regulations I: Packaging basics, Editor(s): André Gordon, Food Safety and Quality Systems in Developing Countries, Academic Press, 2020, 261-283.

According to the second, packaging is the final product of a packaging operation intended for transportation, consisting of both containers and cargo contained in it[22].

Our research focuses on the processes of cargo safety during transportation, so transport packaging is a key element of consideration. It is the correctly selected containers and packaging that ensure the integrity and safety of goods both in the process of transportation and during loading and unloading operations. Thus, the International Insurance company in the field of transport and logistics TT Club states that two-thirds of cargo damage cases are caused by improper packaging of goods in containers. This negligence in the supply chain results in economic losses of more than $6 billion[23].

In addition, packaging performs an important function in the formation of cargo units by weight and dimensions, which greatly simplifies the control, accounting and tracking of quantitative indicators of goods when they are sent and received. According to this criterion, transport packaging is also divided into four groups (Table 1.8).

The main types of transport containers and packaging include: boxes; boxes; barrels; eurocubes (IBC cubes); canisters; boxes; drums; bags; balloons; kegs; kipps; pallets; crate; stretch film; shrink film; containers.

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[22] Matyi H., Tamás P. Operational Concept of an Innovative Management Framework for Choosing the Optimal Packaging System for Supply Chains. Sustainability 2023, 15, 3432. https://doi.org/10.3390/su15043432; Melkonyan A., Hollmann R. Tim Gruchmann, Denis Daus, Climate mitigation and adaptation strategies in the transport sector: An empirical investigation in Germany, Transportation Research Interdisciplinary Perspectives, Volume 25, 2024, 10110; Rajesh D., Gupta S. K., Ilinich S., Singh N. An assessment of challenges and factor influencing the freight forwarding business in the logistics industry. Economics, Finance and Management Review, 2023, (2), 4–23. https://doi.org/10.36690/2674-5208-2023-2-4-23.

[23] TTClub, Shippers urged to take more responsibility for supply chain safety [WWW Document] https://www.ttclub.com/news-and-resources/news/press-releases/2021/shippers-urged-to-take-more-responsibility-for-supply-chain-safety/ 2021 accessed 2.21.23

Table 1.8 Classification of packaging of goods

Class	Name	Characteristics	Role in ensuring the safety of cargo
I	Pervinne	Is in direct contact with the product; forms a consumer unit; provides basic protection against external influences	Prevents spoilage, contamination, loss of physical and chemical properties of the product
II	Tuesday	Combines several primary packaging units; contains markings and information	Reduces the risk of mechanical damage, facilitates identification and accounting
III	Tretinné	Designed for forming cargo packages and packages; provides strength during transportation and handling	Protects cargo from shocks, vibrations, and shifts during transportation
IV	Quaternary (logistics)	Means of cargo consolidation: pallets, containers, multi-turn modules	Reduces the risks of non-safety by stabilizing cargo and optimizing logistics operations

Source: compiled by the authors

Among all types of containers, pallets occupy the largest share in supply chains. At the same time, containers are also actively used: according to the results of the survey, 25% of respondents use 20-foot containers, 31% use 40-foot containers, and 25% use high-capacity containers of the High Cube type[24] (Fig. 1.5).

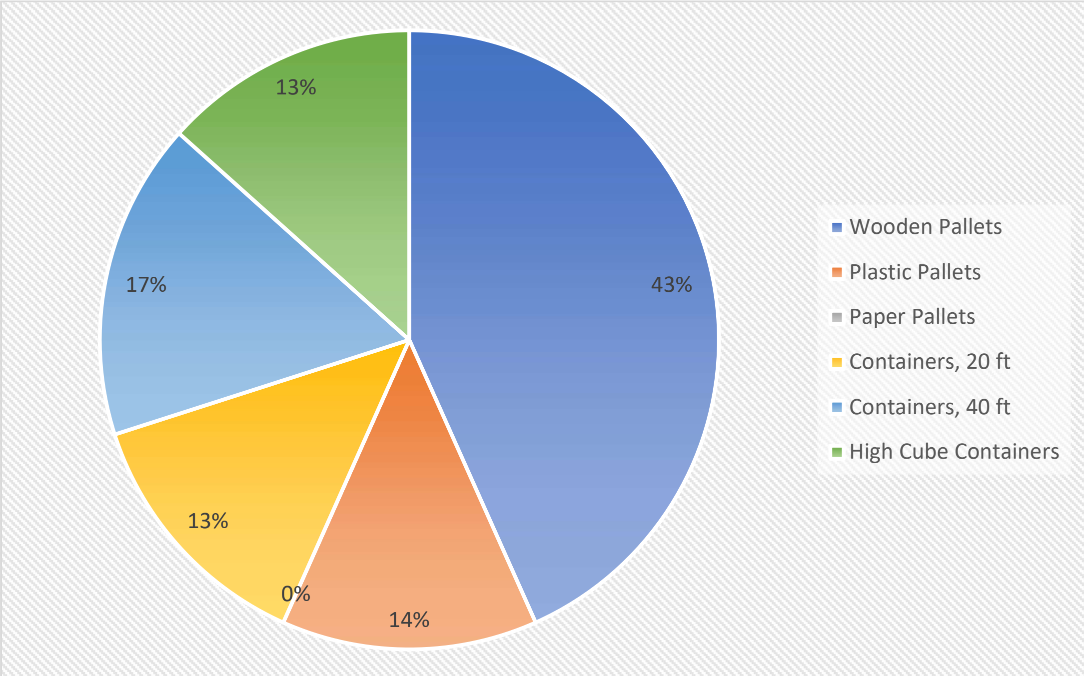

Fig. 1.5 Type of transport containers used by enterprises

Source: Packaging and storage of goods. Logistics in Ukraine https://logistics-ukraine.com/2018/02/15/пакування-і-зберігання-вантажів-стан

The main issues that Ukrainian enterprises solve in their economic activities include tracking the movement of containers (50%) and the costs of its purchase and maintenance of containers (43.8%). The problem of container disposal is currently not relevant for most of them, but the transition of European countries to environmental standards will necessitate the introduction of similar practices by domestic business entities. So far, work with transport containers in Ukraine is mainly focused on the efficiency of its maintenance and circulation.

One of the modern approaches to solving these issues is pooling – a system of sharing reusable containers aimed at optimizing

[24] Packing and storage of cargo. Logistics in Ukraine URL. https://logistics-ukraine.com/2018/02/15/packaging-and-storage-of-cargo-condition

logistics costs in the process of delivering products from the manufacturer to the end consumer. Within the pooling system, transport containers circulate between a limited circle of participants who are part of the pool. Each participant has a certain amount of packaging at his disposal for a certain time, after which he transfers it to the next user[25].

The mechanism of operation of pooling is that a specialized pooling company provides customer enterprises with reusable containers on a lease basis (Fig. 1.6).

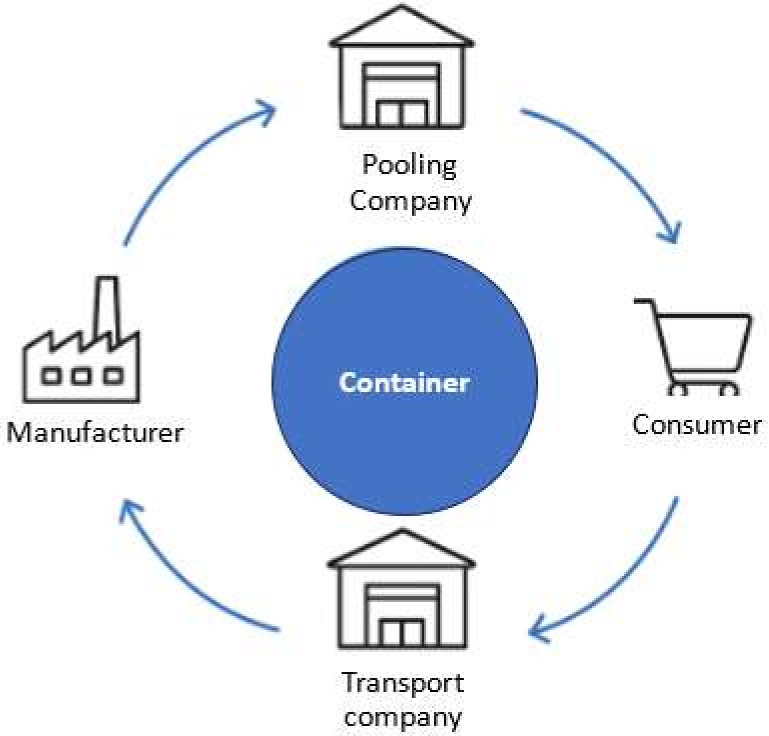

Fig. 1.6 General scheme of the pooling system for the circulation of transport containers

Source: compiled by the authors

By using this approach, the company avoids capital investments in circulating containers and in the creation of reserve stocks to cover weekly or seasonal peak loads. When pooling, the company pays a

[25] Coelho P.M., Corona B., ten Klooster R., Worrell E. Sustainability of reusable packaging–Current situation and trends, Resources, Conservation & Recycling: X, Volume 6, 2020, 100037

fixed rent only for actually used containers and does not incur costs associated with replenishment or replacement of containers that have fallen out of circulation.

It should be noted that the approach itself is not new. It is known that during the Second World War, the US Army delivered a huge amount of cargo to Australia on a similar principle to ensure military operations in the Pacific region against Japan[26], but under modern conditions, especially from the point of view of sustainable economic development, it is quite effective.

2. Cargo marking. Labeling is called inscriptions, images, signs and symbols that are applied directly to a cargo piece (product, packaging or container) or to attached, pasted or sewn labels (labels). Its purpose is to ensure the identification of cargo, speed up its handling, as well as provide information on how to handle cargo during transportation, storage and performance of loading and unloading operations[27].

The main task of marking is to provide the most complete, reliable and unambiguous characteristics of the load, which makes it possible to identify its name, determine the main physicochemical and operational properties, as well as check the completeness and integrity of the delivery. Marking is one of the information elements of the transport process, ensuring the correct organization of loading and unloading operations, the selection of appropriate conditions for transportation, storage and warehousing. Transport marking must be registered manipulation signs that inform the participants of the logistics chain about the permissible ways of handling the cargo, preventing its damage or loss of consumer authorities.

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[26] McCloskey, Joseph F. U.S. Operations Research in World War II. Operations Research 35, no. 6 (1987): 910-25. http://www.jstor.org/stable/171441.

[27] Orozonova A., Gapurbaeva S., Kydykov A., Prokopenko O., Prause G., Lytvynenko S. Application of smart logistics technologies in the organization of multimodal cargo delivery, Transportation Research Procedia, Volume 63, 2022, 1192-1198.

In addition, it includes the main inscriptions (name of the cargo, sender and consignee, destination), additional inscriptions (batch number, weight, number of pieces) and information inscriptions corresponding to the information of a technical, reference or preliminary nature. The combination of these elements ensures the safety of cargo, successful reliability of the transport process and reduces the risks of errors and losses in supply chains.

Marking of goods is regulated by the relevant state standards, which define the rules, options, means of application and types of manipulation signs, inscriptions and images (see Table 1.9 and Fig. 1.7).

Table 1.9 Types of markings, their content and examples of application

Type of marking	Purpose / content	Examples of notations	Norms / standards
Identification/ Commodity Labeling	Indicates the name of the product, manufacturer, model, serial number, country of manufacture	For example, barcode, manufacturer's name, model, serial number, country code "Made in ..."	Labeling requirements for goods in the EU (regulated by directives / egulations)
Weight/volume/ net/gross/ ℮-label marking	Indicates the weight of the packaged goods or volume, with tolerances	℮ – stimated" symbol (shows that the average amount of product in the package corresponds to the specified one)	Directive 76/211/EEC (and its amendments) – rules on packaging and content

Continuation of Table 1.9

CE marking (Conformité Européenne)	Guarantee that the product meets EU safety, health, environmental requirements	The letters "CE" (on the product or packaging)	EU Internal Market Regulation, Directives, Uniform Standards
Labeling for packaging (ecological / recycling / producer responsibility)	Indicates that the packaging is recyclable, whether the manufacturer participates in recycling schemes	The "Green Dot" symbol shows that the manufacturer is involved in a packaging collection and recycling scheme	Directive 94/62/EC on packaging and packaging waste; New European Packaging Regulation (PPWR)
Manipulation / instructional symbols (cargo handling)	Show how to handle cargo during storage, transportation, loading/unloading	For example: "Side up" (up arrows), "Do not throw", "Caution / Fragile", "Do not wet / Keep dry", temperature limits, etc.	ISO symbols (e.g. ISO 780)
Labeling of hazardous substances / chemical classification (risk pictograms)	Indicates potential physical or environmental risks of the substance or mixture	GHS/CLP Classification Pictograms: Fire, Corrosion, Toxicity, Environmental Hazard, etc.	CLP Regulation (EC) No 1272/2008 – classification packaging and labelling of substances and mixtures in the EU

Continuation of Table 1.9

Container labeling (international container coding)	Unique identifier of the container, its parameters (size, type)	Codes according to ISO 6346	ISO 6346 Standard (Container Labeling)

Source: compiled by the authors on the basis of DSTU 2887-94 Packaging and labeling. Terms and definitions

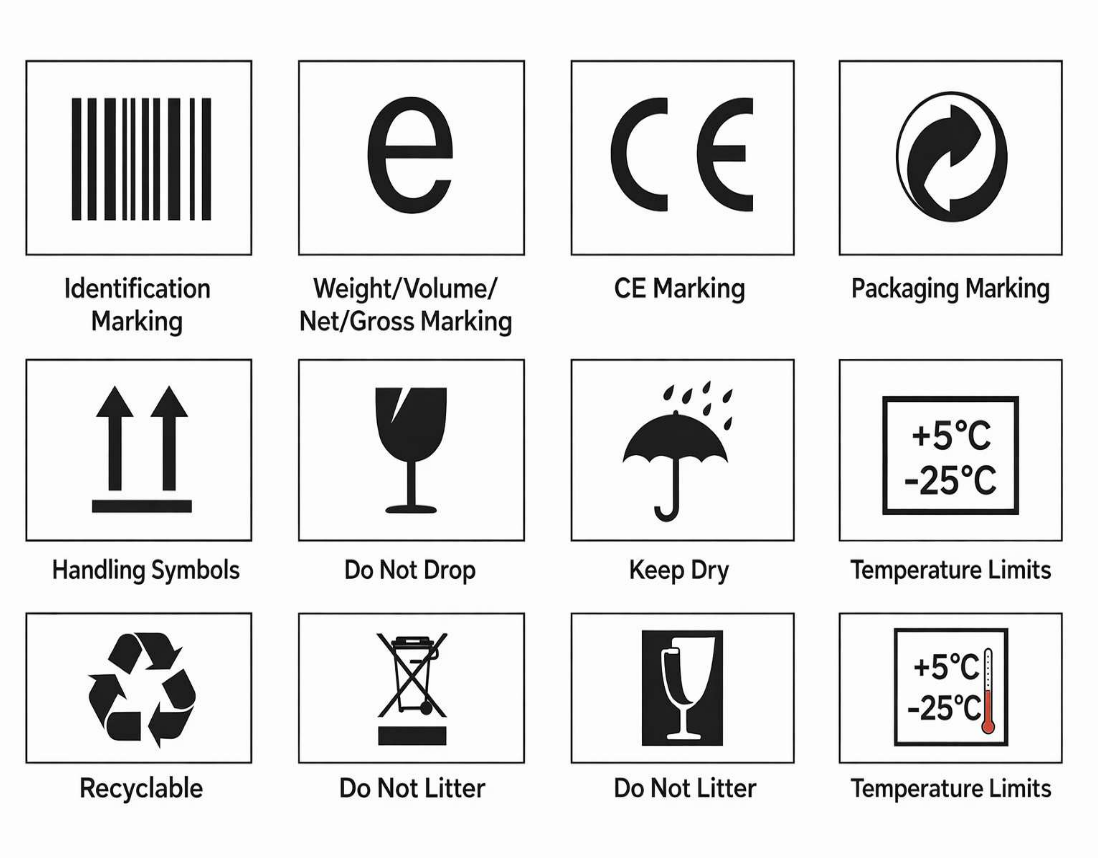

Fig. 1.7 Examples of cargo markings in the EU

Source: compiled by the authors based on Labels and markings https://europa.eu/youreurope/business/product-requirements/labels-markings/index_en.htm

Marking plays an important role during further manipulations with cargo - it ensures the correct placement, fixing, loading and unloading, contributing to the preservation of the integrity of the cargo and the safety of the transport process.

3. Placement of cargo in the body of the vehicle. Cargo placement is the distribution of cargo in the body of the vehicle in accordance with the marking and ensuring its safety by rationally securing it[28]. When placing cargo on vehicles and in containers, it is necessary to avoid damage to cargo, containers, packaging, vehicles and containers.

The rational scheme of cargo placement is chosen in each case, depending on the type of cargo, the size of the container (packaging) and the dimensions of the body. So, when transporting goods in small batches from small distributors or return points, it is advisable to calculate the amount of cargo that can be transported in the back of a car in one trip.

At the same time, it is worth considering the number of pallets that can be placed in the body and the number of stacks in which goods can be stacked for their safe transportation. For example, car parts are most often transported in medium-sized plastic containers (0.80 x 0.40 x 0.35), which can only be transported horizontally and stacked in no more than 4 pieces, so they should be placed in the car body in only two ways, shown in Table 1.10.

Table 1.10 Example of options for placing cargo in the body car

Placement option in the back of ATZ	Number of cargo pieces along the body	Number of cargo pieces by width	Number of cargo pieces by height	Total number of cargo pieces that can be accommodated
L/l; B/b; H/h.	2	3	4	24
L/b; B/l; H/h.	5	1	4	20

Source: compiled by the authors

From Table 1.10 we can see that the first one will be the best option for placing the cargo, and as a result of certain simple

[28] Jäck C., Gönsch J. How to load your auto carrier. A hybrid packing approach for the auto-carrier loading problem, European Journal of Operational esearch, Volume 315, Issue 3, 2024, 1167-1181.

calculations, it is possible to determine the volume of cargo placed in the body, it is 2.69 m^3 out of the total volume of the cargo compartment of 3.96 m^3.

4. Securing the cargo. The cargo securing procedure is aimed at reducing the inertial forces that arise during the movement of the vehicle and ensuring the inviolability of the cargo[29].

Goods transported by road must be secured in the body regardless of the distance of transportation. The choice of the type of fastening depends on the type and composition of the cargo (Table 1.11).

Table 1.11 Comparative characteristics of cargo fixation methods and risks of non-preservation

Fixation method	Key Benefits	Main disadvantages	Risks of non-safety of cargo	Manifestation of risks in supply chains
The method of imprinting	Ease of implementation; low cost; versatility for different types of cargo	Low efficiency under dynamic loads; needs a large number of belts; dependence on the coefficient of friction	Load displacement during braking and turning; partial damage to the packaging; Local deformities	Increasing the likelihood of damage during road transportation over medium and long distances; increase in the cost of claims and insurance payments

[29] Dolzhenko, N., Imasheva, G., Berkesheva, A. ., Garmash, O., & Beketov, T. (2025). Development of Innovative Cargo Safety Systems for Vehicles. Journal of Studies in Science and Engineering, 5(2), 124-143. https://doi.org/10.53898/josse2025536; Macioszek, E. Essential techniques for fastening loads in road transport. Scientific Journal of Silesian University of Technology. Series Transport. 2021. 110. 97-104. 10.20858/sjsutst.2021.110.8.; Nieoczym A., Caban J., Vrabel J. The problem of proper cargo securing in road transport – case study, Transportation Research Procedia, Volume 40, 2019, 1510-1517.

Continuation of Table 1.11

Stretch mark method	High rigidity of fixation; effective protection against shear and rollover; fewer fasteners	High requirements for the strength and quality of belts; Need for certified attachment points	Overloading of fasteners; local damage to the cargo at the points of contact; Risk of belt breakage	Critical for international transportation; Risks of downtime, delivery delays, and disruption of schedules due to emergencies
Blocking method	Effective limitation of horizontal movement; rational use of body space; reducing the need for belts	Does not protect against vertical vibrations; depends on the geometry of the cargo; Requires additional materials	Vibration damage; landslide when the road is uneven; deformation of fragile loads	Increased risks at the stages of multimodal transportation and overloading; loss of quality of goods during long-term transportation

Source: compiled by the authors

In the context of supply chains, the choice of cargo fixation method directly affects the level of operational, technical and financial risks of non-compliance. The clamping method is characterized by an increased risk of cargo displacement and is used mainly for short routes. The stretch mark method provides the highest level of safety, but requires strict control of the technical condition of the fasteners. The blocking method is an effective auxiliary solution, especially in the conditions of transportation of heterogeneous goods, but requires combination with other methods.

At the same time, the existing provisions on securing goods in road transport are of a general nature and do not specify how exactly it should be fastened[30], therefore, a theoretically correctly developed and practically applied fastening scheme should ensure the stability and immobility of the cargo in the car body. This is achieved by evenly distributing the load, using appropriate fasteners (belts, cables) and anti-slip mats, as well as ensuring that it cannot be moved in any direction. In addition to the fastening procedure, in order to ensure the safety of the cargo, it is necessary to control the technical condition of the mechanisms and fasteners during transportation.

5. Loading cargo. Loading is the process of filling a vehicle with cargo, placing or storing cargo in the body. Loading affects the method of securing the cargo, since the choice of fastening method depends on the scheme of its placement. If we consider loading as a factor affecting the safety of cargo, then it is of practical importance for ensuring the safety of transportation. Any transportation necessarily includes the loading procedure, so it is an important stage that directly affects the safety of the cargo. A modern tool for the safety of cargo during its loading, placement or storage is the CTU Code (Code of Practice for Packaging Goods in Transport Units). This is a reference guide on all aspects of loading and securing loads in intermodal transport units. Applying the rules of the CTU Code to the processes of loading and transporting goods can increase the level of security of transport operations, as well as improve business processes and competitiveness. The results of research by G. Bruno and colleagues show that the use of the CTU Code provides increased safety with a drastic reduction in loading accidents and damage to

[30] Dolzhenko N., Imasheva G., Berkesheva A., Garmash O., Beketov T. Development of Innovative Cargo Safety Systems for Vehicles. Journal of Studies in Science and Engineering, 2025, *5*(2), 124-143. https://doi.org/10.53898/josse2025536.;Nieoczym A., Caban J., Vrabel J. The problem of proper cargo securing in road transport – case study, Transportation Research Procedia, Volume 40, 2019, 1510-1517.

cargo, as well as significant benefits in terms of costs, increased efficiency, corporate image and reduced environmental impact[31].

6. Unloading cargo. Unloading (unloading) is the process of emptying vehicles transporting materials, products or structures. The unloading factor plays an important role in transshipment of goods or delivery to several recipients, when there is a need for reloading, and therefore for new placement and securing of cargo.

In modern logistics systems, the unloading process is more often performed using mechanized, automated and automated means, which reduces the labor intensity of operations, increases the speed of loading processing and damages the risks of their damage.

Mobile and overhead cranes, vacuum grippers, magnetic systems, as well as specialized traverses are used for cargo handling. A separate group is created by digital and intelligent tools to support the unloading process, including warehouse management systems (WMS)[32], loading and tilt sensors[33], RFID tags[34], machine viewing systems and digital twins of logistics processes[35]. Their use provides the control position of the cargo, identification of the unit of transportation and prompt detection of deviations from the established safety parameters.

7. Driver qualification. The driver, as a subject of the transportation process and an element of the previously determined

[31] Bruno C., Guerrini G., Caballini C. The use of the CTU Code to increase freight transport safety and business competitiveness: An empirical analysis of a sample of Italian companies, Transportation Research Interdisciplinary Perspectives, Volume 19, 2023, 100826

[32] Kalinowski M., Hering M., Brejtfus A., Bernal T., -Rompa A., Weichbroth P. Pinquark Warehouse Management System (WMS): Moving from process-ased to activity-oriented management, Procedia Computer Science, Volume 246, 2024, 4741-4750.

[33] Coiret A., Fontaine M., Cesbron J., Betaille D. Wheel load estimation for autonomous vehicle by using a fiber optical sensor, Transportation Research Procedia, Volume 69, 2023, 131-138.

[34] Casella, Giorgia & Bigliardi, Barbara & Bottani, Eleonora. The evolution of RFID technology in the logistics field: a review. Procedia Computer Science. 2022. 200. 1582-1592. 10.1016/j.procs.2022.01.359.

[35] Le T., Fan R. Digital twins for logistics and supply chain systems: Literature review, conceptual framework, research potential, and practical challenges, Computers & Industrial Engineering, Volume 187, 2024, 109768

system, has a set of psychophysiological, professional and personal qualities.

Table 1.12 Influence of driver qualities on the risks of non-safety of goods

Driver quality	Impact on the transportation process	Risks of non-safety of goods Sudden maneuvers or delayed actions lead to displacement of the load, violation of fastening, damage
Psychomotor reaction speed	Provides timely response to changes in traffic conditions and emergency situations	Omission of dangerous factors causes emergency braking, impacts, rollovers, etc.
Concentration and distribution of attention	Maintains stable control of traffic, vehicle condition and cargo behavior	Skipping dangerous factors causes emergency braking, shocks, rollovers, etc.
Stress resistance	Allows you to maintain control in difficult road and logistical conditions	Driving errors in stressful situations increase the likelihood of mechanical damage to cargo
Fatigue resistance	Ensures compliance with the optimal driving regime on long routes	Overwork leads to loss of vigilance, emergencies and hidden damage to cargo
Professional training	Forms the ability to correctly assess the transport characteristics of the cargo	Incorrect selection of speed or route causes damage to products
Risk appetite	Affects driving style and choice of driving modes	Aggressive driving increases dynamic loads and the likelihood of damage to cargo

Source: compiled by the authors

As noted by B.S. Rashmi and S. Marisamynathan, "The concept of driving behavior is difficult to define because it involves many factors, such as personality traits, cognitive distortions, and the ability to perceive the world around us."[36]

Accordingly, any actions while driving that significantly go beyond the norms of safe driving and directly affect other road users are risky. And since it is the driver who is the operator of transportation and directly manages the stage of transportation, he should be appointed rationally – taking into account the specifics of organized transportation, because most of the factors that affect the cargo at the same time affect the driver himself.

8. Attitude to the technical condition. The attitude to the technical condition of the vehicle characterizes the level of responsibility of the carrier, fleet owner and service personnel for timely technical inspection, preventive maintenance and repair of vehicles. Insufficient attention to the technical condition of the vehicle is carried out by the risk of damage, loss or complete danger of the cargo at all stages of transportation.

Improper technical condition of the vehicle causes uncontrolled dynamic influences (vibrations, shocks, distortions) that exceed the permissible transport loads for a specific type of cargo[37]. This is especially critical for fragile, dangerous, bulk and perishable cargo. In addition, technical malfunctions increase the likelihood of traffic accidents, which is an extreme manifestation of the risk of complete loss of cargo.

9. Communication between participants in the transport process includes information between the sender, carrier, driver,

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[36] Rashmi B.S., Marisamynathan S., Factors affecting truck driver behavior on a road safety context: A critical systematic review of the evidence, Journal of Traffic and Transportation Engineering (English Edition), Volume 10, Issue 5, 2023, 835-865

[37] Obst, Maciej & Glowinski, Sebastian & Kurpisz, Dariusz. (2024). Analysis of Technical Condition of Cars in Western Poland: A Study Based on Selected Indicators. Applied Sciences. 14. 10.3390/app14020645.

freight forwarder, logistics operator, warehouse personnel, control services and the consignee. Insufficiently established or fragmented communication is the reason for the inconsistency of the actions of participants, violation of transportation technology and increased risks of damage, loss or damage to the cargo[38].

Communication disruption creates information gaps, due to which individual participants in the transport process act on the basis of incomplete or outdated data. This can lead to the wrong choice of packing and fixing method, temperature violations, failure to take into account route restrictions or transshipment features. As a result, the likelihood of mechanical damage, damage or loss of cargo increases.

However, we emphasize once again that the safety of cargo during any stage of product delivery depends on the organization of the entire logistics process. Therefore, the main reasons for the loss of safety are statistical and dynamic forces, the source of which is the cargo itself, as well as poor-quality performance of work at the previous stage (fixing, loading, unloading, packing). In most cases, it is the shortcomings of these operations that become the main cause of damage or loss of cargo while driving.

An important role in ensuring the safety of cargo during transportation is played by constant factors, which cannot be completely eliminated. These include:

– correct placement of cargo;

– its reliable fastening;

– technological organization of loading and unloading operations.

All these factors are determined both by the influence of the external environment and by the subjective actions of the participants in the transportation process (Fig. 1.8).

[38] Jachimowski R., Zieliński T., Jóźwiak A. The issue of transport documentation circulation between logistic processes participants. WUT Journal of Transportation Engineering. 2022. 135. 55-72. 10.5604/01.3001.0018.8426.

External Environmental Influences

- Road-Climatic
- Road-Infrastructure
- Socio-Political
- Technological

Subjective Actions of Transport Participants

- Organizational-Operational
- Technical-Operational
- Behavioral
- Psychophysiological
- CommunicationMoral-Volitional and Motivational

Fig. 1.8 Main factors affecting the safety of cargo

Source: compiled by the authors

The essence of the influence of the external environment on the safety of cargo is determined by a set of factors that are not subject to direct control by the participants in the transportation process, but significantly affect its course (Table 1.13).

The external environment is an uncontrollable variable that directly or indirectly affects the safety of cargo transportation. Along with this, subjectively directed actions of the participants in the transportation process (driver, freight forwarder, loaders, dispatchers) determine the level of adaptation of the transportation system to environmental influences.

Table 1.13 Main groups of environmental influence

Category	Examples of actions	Possible consequences
Road and climatic	Temperature, humidity, precipitation, wind, condition of the road surface, terrain	High temperatures can lead to deformation of containers or damage to heat-sensitive goods. Excessive humidity causes corrosion of metal containers, swelling or destruction of cardboard packaging. Weather conditions such as rain, snow or ice increase the risk of accidents, which indirectly affects the safety of the cargo.
Socio-political	The quality of the pavement, the presence of slopes, turnovers, bridges, tunnels, the condition of roadsides and road signs	Insufficient road quality causes vibration and shock loads that are transmitted to the cargo. Frequent changes in speed and direction of movement increase the dynamic effects on the load fastening.
Socio-political	administrative restrictions, customs controls, strikes, blocking of transport routes, hostilities or threats	May cause transport delays, rerouting, or increased risk of lost and damaged cargo.
Man-made	accidents on transport communications	technical malfunctions of vehicles, failures in energy supply, in the operation of loading and unloading equipment

Source: compiled by the authors

Errors, negligence or poor professional training of personnel can significantly increase the risk of unsafe cargo.

Such actions are formed under the influence of individual characteristics of a person and directly affect the quality, safety and efficiency of the transportation process (Table 1.14).

Table 1.14 Main groups of subjectively directed actions

Category	Examples of actions	Possible consequences
Organizational and operational	Incorrect route planning, inaccurate execution of transport documents, violation of the traffic schedule	Delays, overspending, violation of contractual obligations
Technical and operational	Negligent maintenance of the vehicle, improper loading or securing of cargo	Damage to cargo or transport, emergencies
Behavioral	Traffic violations, speeding, using a phone while driving	Accidents, delays, threat to life
Psychophysiological	Fatigue, inattention, stress, low concentration	Increased risk of errors or accidents
Communication	Misunderstandings between the driver and the dispatcher, misinterpretation of instructions	Errors in route or load
Moral, volitional and motivational	Insufficient responsibility, low work discipline, underestimation of risks	Violation of transportation technology, reduced productivity

Source: compiled by the authors

Thus, the efficiency of the transportation process depends on the coordination of actions of all its participants, which should ensure the rational organization of transportation, taking into account external factors that cannot be eliminated, but can be partially neutralized thanks to the right management and technical decisions[39]. Accordingly, the safety of the cargo at the stage of transportation is derived from the organizational measures carried out at the previous stages[40].

In addition, when organizing transportation, key parameters are determined - the choice of route, vehicle, driver, as well as means and methods of loading and unloading operations. All these decisions directly affect the level of cargo safety in transit.

1.4 World practice of organization of control in the field of cargo transportation

World practice demonstrates different approaches to the organization of control in the field of cargo transportation. In some countries, the key role belongs to the ministries of transport, in others – to specialized agencies or independent supervisory bodies. Despite the differences, a common feature is the growing attention to the issues of cargo safety, compliance with international standards and increasing the transparency of logistics processes.

Approaches of different countries of the world to ensure the safety and safety of goods are shown in Table 1.15.

Table 1.15 Experience of the countries of the world in the field of ensuring the safety and safety of goods

[39] Dolzhenko N., Imasheva G., Berkesheva A., Garmash O., Beketov T. Development of Innovative Cargo Safety Systems for Vehicles. Journal of Studies in Science and Engineering, 2025, 5(2), 124-143.

[40] Kubanova J., Kubasakova I. Security Risks in the Trucking Sector, Transportation Research Procedia, Volume 44, 2020, 234-239.

Country	Control and regulatory bodies	Main areas of activity	Features and priorities
USA	Department of Transportation, Transportation Security Administration	Control of compliance with safety rules, risk monitoring	Prevention of loss and damage; Active use of monitoring technologies
Canada	Transport Canada Agency, Department of Transport	Carrier regulation, licensing, incident monitoring	Developed reporting system and transparency of carriers' activities
United Kingdom	Ministry of Transport	Compliance with national and international standards; control over carriers	The priority is the safety of road transportation, the safety of goods
Germany	Federal Ministry of Transport and Federal Freight Service	Legislative regulation and control of carriers; Conducting inspections	Safety and safety of goods; Official statistics of violations
France	Ministry of Ecology, Sustainable Development and Transport	Implementation of European regulations, transportation control	Focus on EU integration, environmental friendliness and safety
Sweden	Sweden Transport Agency	Road traffic safety control, violation statistics	High level of automation, emphasis on sustainability

Continuation of Table 1.15

Netherlands	Ministry of Infrastructure and Water Management	Regulation of transport processes, digital control systems	Leader in the implementation of "green" logistics standards
Poland	Road Transport Inspectorate, Ministry of Infrastructure	Control over compliance with EU rules in the field of transport	Enhanced control of international carriers; integration with EU regulations
Ukraine	Ministry of Communities, Territories and Infrastructure Development of Ukraine (Ministry of Infrastructure); State Service of Ukraine for Transport Safety	Control of compliance with legislation in the field of transportation, licensing, inspection of vehicles, ensuring the safety of cargo	Orientation towards harmonization with EU legislation; implementation of digital tools (e-queue, GPS-m)
South Africa	National Department of Transportation	Regulatory regulation of road transportation; control of the technical condition of vehicles;	Priority of physical security of goods; the impact of infrastructure and security factors; adaptation of international standards to national conditions

Continuation of Table 1.15

Egypt	Ministry of Transport of Egypt; General Directorate of Land Transport; Customs and port administrations	State regulation of automobile and multimodal customs and border control;	Priority of physical security of goods; the significant role of ports and transit corridors; implementation of international security standards
Australia	Federal Department of Infrastructure and Transport;	Regulation of carriers; control; Licensing and Auditing	Risk-based approach; active use of digital monitoring systems;
Japan	Ministry of Land, Infrastructure, Transport and Tourism	Control of transportation standards, implementation of innovative solutions	Strict security controls and integration of smart technologies
China	Ministry of Transport of the People's Republic of China	Licensing, inspections, Digital control	Active development of digital corridors and tracking systems
India	Ministry of Road Transport and Highways;	State regulation of road transportation; licensing; control of the technical condition of transport	Minimization of losses and damage to cargo; implementation of digital control systems and international security standards

Continuation of Table 1.15

Kazakhstan	Ministry of Transport of the Republic of Kazakhstan; Transport Committee; Customs and border services	State regulation of road and transit transportation; control of cargo safety requirements; Customs support	Priority of transit flow control; influence of climatic and territorial factors; gradual harmonization of norms with international standards
Uzbekistan	Ministry of Transport; Road and River Transport Agency; Customs authorities	Regulation of carriers' activities; control of cargo safety conditions; licensing; Customs and border control	Development of transport infrastructure; Increasing focus on security standards and digitalization of control

Source: compiled by the authors based onCargo security measures https://www.cathaycargo.com/en-us/help-and-support/security-and-compliance/cargo-security-measures.html; Kubanova J., Kubasakova I. Security Risks in the Trucking Sector, Transportation Research Procedia, Volume 44, 2020, 234-239.; Saienko V. Transport and logistics security: implementation of eu and us rights. 2023. 12. 52-57.

Generalized comparisons of approaches of countries of the world to ensure the safety of goods are given in Table 1.16. In it shows contrasting models of institutional cargo safety: on the one hand, developed countries of the world – as an example of a mature risk-based system: the EU – focuses on the unification of rules and environmental friendliness; The USA/Canada/Australia – on risk management and transport security, Asian countries – on innovative digital technologies and "smart logistics", on the other hand – African countries – as a system in the phase of institutional and regulatory development dominated by environmental factors, or the countries of South and Central Asia, representing a transit-oriented model of cargo security, in which the key are the control of infrastructure nodes (ports, corridors) and minimizing the risks of non-safety at the junctions of logistics systems.

Ukraine is at a crossroads – combining the European course of harmonization of the institutional environment with its own initiatives of digitalization and increased control over the safety of goods.

Table 1.16 Generalized comparison of approaches to ensuring the safety and safety of goods

Group of countries	Key control bodies	Main areas of activity	Priorities and features
EU (Germany, France, Poland, Netherlands, Sweden, United Kingdom)	Ministries of Transport, Specialized Transport Agencies	Regulation of carriers; implementation of EU norms; inspections and statistical accounting of violations	Unified regulatory framework (EU regulations), emphasis on harmonization of rules, environmental friendliness and cargo safety
USA/Canada	U.S. Department of Transportation (DOT), TSA; Transport Agency of Canada	Security control and licensing; risk monitoring; inspections of goods and vehicles	Focus on security and countering threats (loss, damage, terrorism); active use of monitoring and reporting systems

Continuation of Table 1.16

Asia (Japan, China)	Ministry of Transport (MLIT in Japan, Ministry of Transport of the People's Republic of China)	Transportation control, digital technologies, innovation	Digitalization of control systems; development of logistics corridors; emphasis on innovation and high discipline
South Asian countries (India, Pakistan, Bangladesh)	National Ministries of Transport; railway and automobile regulators; Customs and border services	Regulation of road and multimodal transportation; licensing of carriers; control of the technical condition of transport; Customs and fiscal control	Fragmentation of the transportation market; increased risks of damage and loss; gradual digitalization and implementation of international security standards
African countries (South Africa, Kenya, Nigeria, Egypt, Morocco, etc.)	Ministry of Transport; national road and customs administrations; Regional transport agencies	Regulatory regulation of road transportation; control of the technical condition of transport; customs and border control; supervision over compliance with the conditions of cargo transportation	Fragmented regulatory framework; significant impact of infrastructure and security factors; priority of physical security of cargo and counteraction to losses; gradual harmonization of standards within regional economic communities

Continuation of Table 1.16

Australia and Oceania	Federal and state ministries of transport; Road Safety Agencies	Regulation of carriers' activities; control of compliance with transportation safety standards; licensing; audit of logistics chains; Incident analysis	Risk-based approach to security; strict responsibility of all participants in the supply chain; high level of digital monitoring and preventive control
Central Asian countries (Kazakhstan, Uzbekistan, Kyrgyzstan)	Ministry of Transport; transport committees; Customs and border authorities	State regulation of road and transit transportation; control of cargo safety; customs support; Supervision of international transport corridors	Transit orientation; significant influence of geographical and climatic factors; priority of transit flow control; gradual harmonization of norms with international standards
Ukraine	Ministry of Communities, Territories and Infrastructure Development; Ukrtrans-bezpeka	Control of compliance with legislation, licensing, inspections, implementation of digital tools	Orientation towards harmonization with the EU; strengthening traffic safety control and cargo safety; development of e-tools (e-queue, GPS monitoring)

Source: compiled by the authors

However, despite the experience gained and modern approaches of the countries of the world to ensure the safety and safety of cargo, scientific studies[41] show that the problem of the last 2-3 years is the rapid growth of organized theft of cargo, insider schemes and cyber fraud (criminals disguise themselves as legal carriers or forge documents in order to appropriate cargo). Thus, Proofpoint has recorded almost two dozen cases since mid-2025, during which transport and logistics companies were hacked to commit theft of goods.

Criminals do not choose victims – they use every opportunity to attack carriers of all sizes, from small family businesses to large transport companies[42].

This especially affected the high-cost categories (electronics, cosmetics, alcohol). The increase in incidents in recent years is confirmed by open sources-analysts, the summarized data of which are presented in Fig. 1.9.

In particular, a report by the American Institute for Transportation Research (ATRI) notes that the number of strategic thefts – deception, fraud and cybercrime aimed at forcing shippers, brokers and carriers to hand over goods to thieves instead of legitimate recipients – has increased by 1500% since 2022. Accordingly, the total losses of carriers amounted to more than 520,000 US dollars per year, and for companies providing logistics services more than 1.84 million US dollars per year.

Annual losses from cargo theft for the industry reach $6.6 billion, or more than $18 million per day[43].

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[41] Burns R., Crawford C. Moving Forward in the Study of Cargo Theft: Data Collection, Extent, and Crime Control Theater. Journal of Applied Security Research. 2025. 20. 1-25. 10.1080/19361610.2025.2472072.; Clavijo Mesa M.V., Patino-Rodriguez C.E., Guevara Carazas F.J. Cybersecurity at Sea: A Literature Review of Cyber-Attack Impacts and Defenses in Maritime Supply Chains. Information 2024, 15, 710. https://doi.org/10.3390/info15110710; Klopott M., Urbanyi-Popiołek Cargo Theft as a Systemic Risk in Global Supply Chains: Data, Modus Operandi and Emerging Trends (2019-2025). European research studies journal. XXVIII. 2025. 1298-1313. 10.35808/ersj/4219.; Liang X., Fan S., Lucy J., Yang Z., Risk analysis of cargo theft from freight supply chains using a data-driven Bayesian network, Reliability Engineering & System Safety, Volume 226, 2022,108702

[42] Cyber Cargo Theft Surge – 7 Insights on the Growing Threat (2025) by TankTransport · November 19, 2025 URL. https://tanktransport.com/2025/11/cyber-cargo-theft-surge/

[43] New research confirms the high costs of cargo theft to industry. The American Transportation Research Institute URL. https://www.iru.org/news-resources/newsroom/new-research-confirms-high-costs-cargo-theft-industry

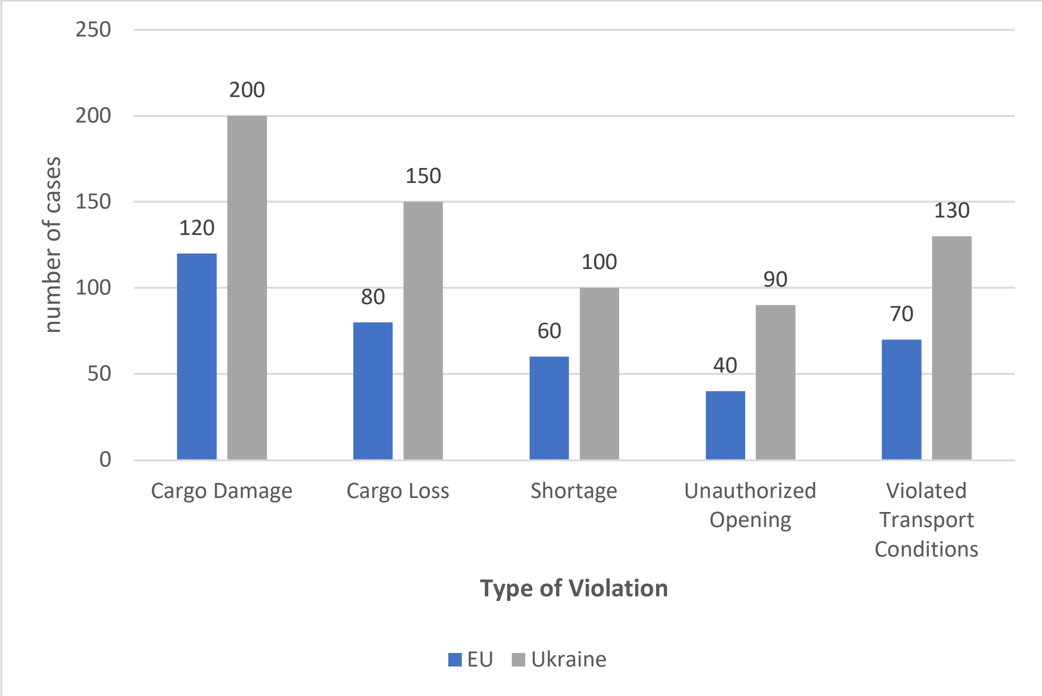

Fig. 1.9 Diagram of violations of cargo safety in the EU and Ukraine by type

*Source:*High-value shipments at risk: The growing threat of strategic cargo theft URL. https://www.wtwco.com/en-us/insights/2024/12/high-value-shipments-at-risk-the-growing-threat-of-strategic-cargo-theft?utm_source=chatgpt.com; Cargo Theft Surges to Record Levels in 2024, Verisk CargoNet Analysis Reveals URL.https://www.wtwco.com/en-us/insights/2024/12/high-value-shipments-at-risk-the-growing-threat-of-strategic-cargo-theft?utm_source=chatgpt.com; 1,843 Recorded Cargo Crimes in Sweden Up 164% in 2 Years URL. https://tapaemea.org/intelligence/1843-recorded-cargo-crimes-in-sweden-up-164-in-2-years/?utm_source=chatgpt.com; In 2024, 729 acts were drawn up in Kyiv due to violations in the field of freight transportation https://cfts.org.ua/news/2025/01/13/u_2024_rotsi_v_kievi_skladeno_729_akti v_cherez_porushennya_u_sferi_vantazhnikh_perevezen_81652?utm_source=cha tgpt.com

The results of the study conducted by Y. Kubanova and I. Kubasakova showed that the most critical factors of non-safety of goods are:

– category of cargo (especially tobacco products, foodstuffs, cargoes with high liquidity);

– type of location (transportation "en route", unguarded parking lots, objects of departure and destination);

– year and region of transportation, reflecting the dynamic change in criminal risks;

– the method of committing theft (modus operandi), in particular breaking and stealing from vehicles[44].

The largest number of crimes occurs:

– during the parking of trucks;

– on unguarded parking lots;

– at night and during mandatory breaks for drivers.

Cargo theft is becoming a global problem that needs to be effectively addressed to avoid financial losses and supply chain disruptions. When a single case of cargo theft occurs, the costs of the entire supply chain are six times the cost of the cargo, as this leads to increased costs for product replacement, settlement of the consequences of the accident, increased insurance premiums, loss of sales and negative impact on the reputation of the business[45]. In addition to financial costs, cargo theft can also lead to injury/death and violence against vehicle drivers[46], which in turn worsens working conditions and their attractiveness, especially for women, increasing labor shortages as well as gender inequality. In addition, the criminal organizations behind attacks on the transport sector are growing in power, scale and impact on society, which has obvious consequences for business, namely: reduced economic growth and unfair market competition[47].

[44] Kubanova J., Kubasakova I. Security Risks in the Trucking Sector, Transportation Research Procedia, Volume 44, 2020, 234-239

[45] Burges D. Cargo Theft, Loss Prevention, and Supply Chain Security | ScienceDirect 2022. 366. URL. https://www.sciencedirect.com/book/9780124160071/cargo-theft-loss-prevention-and-supply-chain-security

[46] Klopott M., Urbanyi-Popiołek Cargo Theft as a Systemic Risk in Global Supply Chains: Data, Modus Operandi and Emerging Trends (2019-2025). European research studies journal. XXVIII. 2025. 1298-1313. 10.35808/ersj/4219.; Liang X., Fan S., Lucy J., Yang Z., Risk analysis of cargo theft from freight supply chains using a data-driven Bayesian network, Reliability Engineering & System Safety, Volume 226, 2022,108702

[47] Urciuoli L. What are the causes of transport insecurity? Results from a survey with transport operators, Transport Policy, Volume 47, 2016, 189-202

Therefore, the complication of logistics operations, high dynamics of demand and an increase in transportation volumes create new challenges for participants in the transport process, which requires the introduction of more effective approaches to managing the risks of cargo non-safety.

In recent years, breakthrough achievements in the field of digital technologies have opened up fundamentally new opportunities to improve safety and reduce the risks of unsafe goods during road transportation[48]. Predictive analytics, intelligent real-time monitoring systems, as well as innovative technologies for packing and securing goods significantly expand the tools of modern logistics management. For example, digital sensors and IoT devices make it possible to constantly monitor the state of the environment, vibration and temperature fluctuations, the technical performance of vehicles and the actual safety of cargo. Real-time data provides a rapid response and sets the stage for preventing potential incidents before they can cause losses.

In parallel, methodologies based on big data and machine learning algorithms offer reliable tools for in-depth analysis of patterns, forecasting potential risks, choosing optimal routes, and improving the efficiency of transportation operations. Intelligent systems can assess risk in real time, taking into account both historical data and current traffic circumstances, which strengthens the capabilities of proactive management of logistics processes.

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[48] [48] Bayguzhina G., Sagatbekova A. The main indicators of ensuring the quality of cargo transportation by road. Vestnik of M. Kozybayev North Kazakhstan University. 2023. 81-86. 10.54596/2958-0048-2023-1-81-86.; Kayikci Y., Subramanian N., kuppusamy S. Exploring Digitalization, Resilience, and Sustainability Challenges in the Cargo Transportation and Logistics Industry through Topic Modelling and Empirical Evidence in the Aftermath of COVID-19. IEEE Transactions on Engineering Management, .2024. 1-62.

Part II

RISKS OF NON-SAFETY OF GOODS DURING ROAD RANSPORTATION AND DIRECTIONS OF THEIR MANAGEMENT

2.1. Risks of non-safety of cargo arising during transportation by road

Based on the analysis of the state of the issue and the provisions of the system analysis, we have identified a system within the framework of the study of the risks of non-safety of cargo: "car - driver - cargo - external environment", in which the characteristics of each element are the source of the formation of risks of non-safety of goods during transportation. Moreover, the nature of the risk is due to the presence of uncertainty, which, if it occurs, will affect the achievement of one or more goals. transportation process, in particular, ensuring traffic safety, cargo safety, compliance with delivery deadlines and minimizing logistics costs. Uncertainty can be both internal in nature, related to the human factor, the technical condition of the vehicle and the organization of transportation, and external - due to road, weather, infrastructure and regulatory conditions.

Usually, uncertainty is defined as a fundamental characteristic of the insufficient provision of the process of economic decision-making with knowledge regarding a certain problem situation[49].

Taking into account the characteristics provided, it can be interpreted and detailed as:

– unreliability (haze effect) – a distorted reflection of the real state of an object or process as a result of erroneous, outdated or deliberately distorted data;

– ambiguity (the effect of "fuzziness", "vagueness") – the possibility of multiple interpretations of information through fuzzy formulations, lack of unambiguous criteria or context;

[49] Ahiadu A.A., Abidoye R.B., Yiu T.W. Decision-Making Amid Economic Uncertainty: Exploring the Key Considerations of Commercial Property Investors. Buildings 2024, 14, 3315. https://doi.org/10.3390/buildings14103315; Gheddar R. Decision-making criteria under uncertainty and risk in the agricultural sector. Journal of Innovations and Sustainability. 2023. 7. 06. 10.51599/is.2023.07.04.06.; Sniazhko S. Uncertainty in decision-making: A review of the international business literature. Cogent Business & Management. 2019. 6. 10.1080/23311975.2019.1650692

– "unknown" (the effect of "knowledge void" or "information gap") – the absence or fundamental inaccessibility of data on the state, parameters or behavior of the object, which makes it impossible to make informed decisions.

They, in turn, can also be detailed (see Fig. 2.1.).

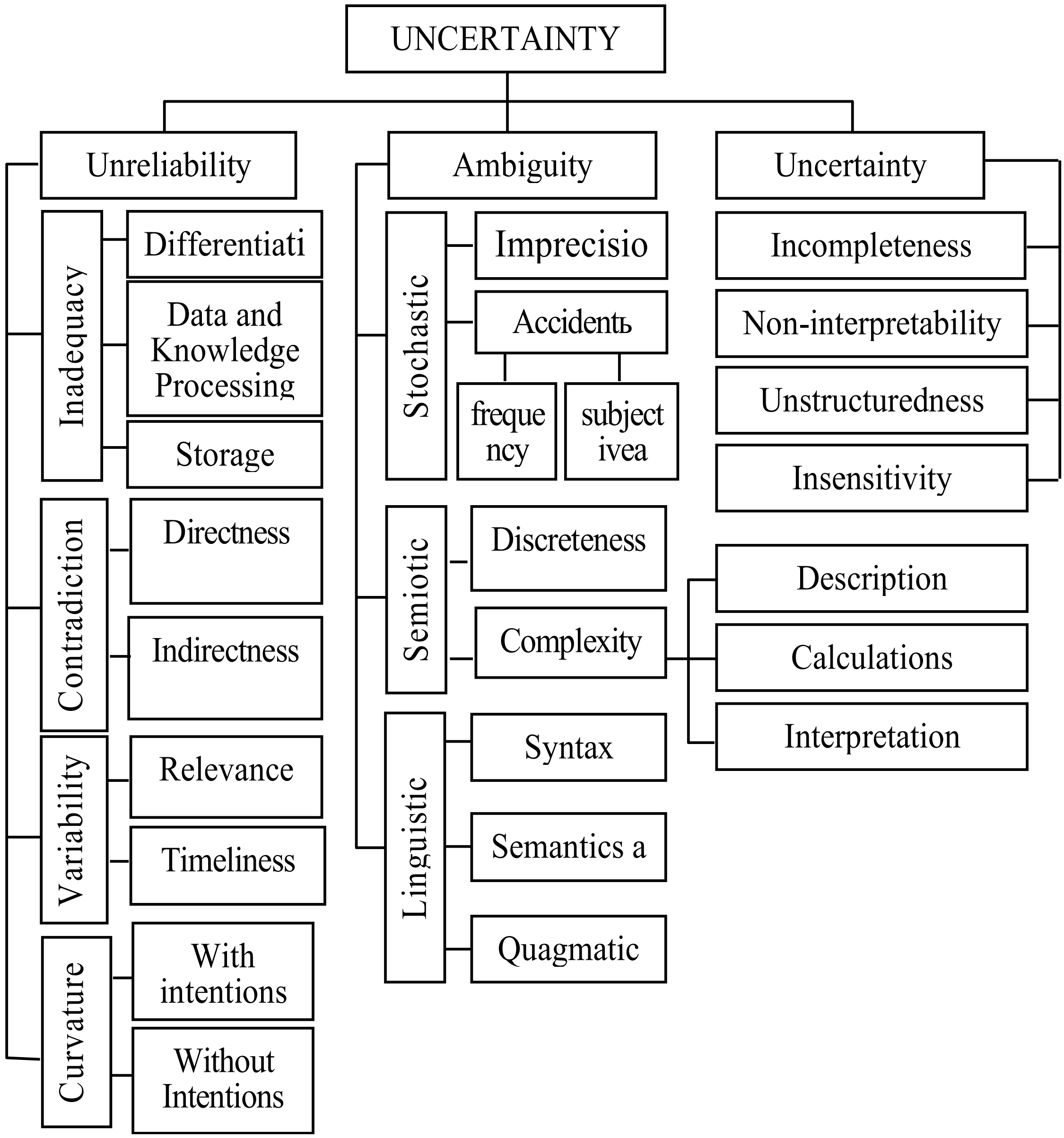

Fig. 2.1. Hierarchy of types of uncertainty

Source: compiled by the authors

Uncertainty implies the presence of factors in which the results of actions are not deterministic, and the degree of influence of each factor on the results is unknown. Moreover, if in risk situations objective values of probabilities can be used for statistical forecasting, then in situations with uncertainty, according to Y. Xu and colleagues, only probability is used as a subjective assessment of possible consequences[50]. Risk and uncertainty play an important role in the activities of logistics enterprises, containing the contradiction between the real and the planned. It is impossible to eliminate uncertainty, since it is an element of objective reality.

Accordingly, we understand uncertainty as an incomplete or inaccurate idea of the meaning of various parameters of logistics processes in the future, which arises as a result of incompleteness and (or) inaccuracy of information on the conditions for the implementation of a management decision. In the context of cargo non-safety risk management, uncertainty is manifested in the variability of traffic parameters, dynamic loads, environmental conditions and behavior of participants in the transport process. It is this variability that makes it impossible to completely deterministic description of transportation and necessitates the use of probabilistic, expert and multi-criteria approaches to assessing the risks of non-safety of goods.

Uncertainty factors introduce a large number of random events affecting all aspects of supply chain operations, and also make risk and vulnerability a serious problem for organizations and logistics operators[51]. Risks and uncertainty factors have a direct impact on both customer satisfaction and costs associated with non-safety of goods.

Considering the concept of risk, we can note that the word "risk" itself comes from the ancient Italian "risicare", which means to dare. In this sense, risk is more of a choice than fate, that is, actions that we are willing to take, which in turn implies that we have freedom of choice. Etymologically, the word "risk" in different languages is associated

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[50] Xu Y. Reniers G., Yang M., i Yuan S., Chao Chen Uncertainties and their treatment in the quantitative risk assessment of domino effects: Classification and review, Process Safety and Environmental Protection, 2023, Volume 172, 971-985.

[51] Yu Y, Xiong W., Cao Y. A Conceptual Model of Supply Chain Risk Mitigation: The Role of Supply Chain Integration and Organizational Risk Propensity, Journal of Coastal Research 73(sp1), 95-98, (1 January 2015). https://doi.org/10.2112/SI73-017.1

primarily with the appearance of uncertainty and danger in various spheres of economic and socio-economic existence.

There are many different definitions of risk. Most often, risk is defined as a combination of the possibility of damage and its severity. However, there is still no consensus on the interpretation of the concept of "risk" due to the variety of its aspects. Thus, the Oxford English Dictionary defines risk as the probability of danger, bad consequences, losses, etc[52]. The Webster Dictionary interprets the concept of "risk" as the possibility of loss, damage, damage or destruction[53]. The ISO 31000 standard, published by the International Organization for Standardization (ISO), describes risk as "the impact of uncertainty on objectives"[54].

According to this definition, an impact is an impact or consequence of what is expected, whether positive, negative, or both; uncertainty is a state, even partial, of lack of information related to understanding or knowledge of an event, its consequences or the probability of its occurrence; and the objectives represent the different levels of organization, products and processes.

The Supply Chain Risk Management Board[55] defines "supply chain risk" as the probability and consequences of events at any point in the end-to-end supply chain, from raw material sources to end-use by consumers, and "supply chain risk management (SCRM)" as the coordination of supply chain management actions. Peck and Christopher[56] identify four categories of risks faced by global chains: supply risks, demand risks, operational risks, and security risks. The latter is represented by the distribution of results related to adverse events that threaten human resources, the integrity of operations and information systems.

Accordingly, supply chain risk management brings together several initiatives, including those related to business continuity and

[52] Oxford English Dictionary. Oxford University Press: Oxford University, 2006. 896.
[53] New Webster Dictionary and thesaurus. – New York, Lexicon Pub, 1993. 1220.
[54] ISO 31000:2018; Risk Management Guidelines. International Standard Organization: Geneva, Switzerland, 2018. URL. https://www.iso.org/obp/ui#iso:std:iso:31000:ed-2:v1:en
[55] Supply Chain Risk Leadership Council. URL. http://www.scrlc.com/articles /Supply_Chain_Risk_Management_ A_Compilation_of_Best_Practices_final%5B1%5D.pdf
[56] Peck H., Christopher M. Building the resilient Supply Chain. Int. J. Logist. Manag. 2004, 15, 1-14

supply chain security[57]. Moreover, experts note that the vulnerability of the supply chain is transmitted to the transport network. It depends on the simple fact that transport and freight operations physically link the objects of the supply chain[58].

Therefore, risks, uncertainties and vulnerabilities in the supply chain and transport network affect each other, contribute to each other and neutralize each other. Supply chain security is designed to protect the supply chain (in this sense, transport and freight operations) from various antagonistic threats and thereby reduce the vulnerability of modern global trade.

In different disciplines, modern directions of risk research, covering a variety of definitions, goals, sets of problems, methodologies and paradigms, manifest themselves in different ways. Some focus on risk assessment and modeling[59], others focus on financial risk mitigation mechanisms[60], and others focus on behavioral and cognitive aspects of risk and their implications for strategic decisions[61].

In the literature on the theories of optimal management, risk is considered as an attributive general sociological characteristic of any type of expedient human activity, carried out in conditions of limited resources and the presence of restrictions on the choice of the optimal way to achieve conscious goals in conditions of information uncertainty[62].

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[57] Mora Lozano P.E., Montoya-Torres J.R. Global Supply Chains Made Visible through Logistics Security Management. Logistics 2024, 8, 6. https://doi.org/10.3390/logistics8010006

[58] Hintsa J., Uronen K. Common Assessment and Analysis of Risk in Global Supply Chains. Technical Report Project: FP7-CASSANDRA. 2012 URL. https://www.researchgate.net/publication /282845713_Common_Assessment_and_ Analysis_of_Risk_in_Global_Supply_Chains

[59] [59] Madan D.B., King W. Keeping Risk Alive. Risk Sciences. 2025: 100023.; Wang S. et al. Data-driven Decision Making for Social Influence Risk Management. Risk Sciences 2025: 100019.

[60] Denuit M., Robert C.Y. Equal compensations under actuarially fair contributions in endowment contingency funds. Risk Sciences 1 (2025): 100005.; Zagurskiy O., Yukhymenko P., Sokolska T., Paska I, Lobunets V., Zhytnyk T., Zharikova O. Management Models and Evaluation of Reputation Risks International Journal of Recent Technology and Engineering, 2019. Volume 8 Issue-3S3. 136-141.

[61] Eling M., Jung K. Optimism bias and its impact on cyber risk management decisions. Risk Sciences 1 (2025): 100001.; Загурський О.М. Сутність репутаційних ризиків та особливості управління ними у банківському секторі. Фінансово-кредитна діяльність: проблеми теорії та практики : зб. наук. праць. 2017 Том 2 № 23. 38-44.

[62] Aven T. On how to define, understand and describe risk, Reliability Engineering & System Safety, Volume 95, Issue 6, 2010, 623-631; Cohen A.V. Overview and definition of risk: Its assessment and management, Environment International, Volume 10, Issues 5–6, 1984, 359-366; Feng R. What are risk sciences?, Risk Sciences, Volume 1, 2025, 100029.; Kollmann T., Kayser I., Stoeckmann C. What

It means that it is impossible to determine the time and nature of the occurrence of losses, as well as to predict their consequences. Risks are usually unpredictable, and even if there are certain signs of a risk situation, people can ignore them. Their occurrence is threatening, uncertain, urgent and occurs without warning, therefore, precautionary measures should be taken in advance (or warning) of the probable situation of the occurrence of adverse events.

As for supply risk, it is defined as adverse events in incoming supplies that affect the ability of a key firm to meet customer demand[63]. It is closely related to three concepts:

1) Uncertainty. It arises due to a lack of information, respectively, the greater the exchange of information, the lower the risk.

2) Variability. Co-creation of knowledge and exchange of experience reduces variability and risks.

3) Trust. Lack of trust breeds opportunism and disputes, and vice versa, mutual investment and coordination of goals drastically reduce the risk of supply.

Moreover, in the process of cargo transportation, the risk is present at any stage and is associated with:

– non-compliance with the rules of preparation and packaging of cargo;

– discrepancy between the technical characteristics and condition of the vehicle, as well as the special equipment of the cargo compartment;

– lack of application of labeling rules and standards by the enterprise;

– loading, placement and securing of cargo in a truck, etc[64].

Supply risks are pure risks and refer to man-made risks that arise within transport systems. In addition, they may include technical, political and commercial risks[65], which is due to the active use of transport and the need to conduct a risk assessment based on their weighing procedures.

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matters most? Investigating the role of perceived risk and trust in the acceptance of social networks for political communication. Electronic Government, an International Journal. 2015. 11. 306. 10.1504/EG.2015.071410.

[63] Chen J., Sohal A.S., Prajogo D.I. Supply risk mitigation: a multi-theoretical perspective. Production Planning and Control, 2016. 27 (10). 853-863.

[64] Madai H. Risk Sources and Risk Management Strategies Applied by the Hungarian Sheep Producers. Fascicula : Ecotoxicologie, Zootehnie si Tehnologii de Industrie Alimentara. 2008. Vol. 7. No 7. 298-307.

[65] Choi T., Chiu C., Chan H. Risk management of logistics systems, Transportation Research Part E: Logistics and Transportation Review, Volume 90, 2016, 1-6

Table 2.1 Transport risks at the main stages of cargo transportation

Transportation phase	Sources of risk	Risk factors
Packing and preparation of cargo	Failure to comply with the rules of packaging and preparation; insufficient staff experience; lack of consolidated transportation practices	Absence or inconsistency of containers; the use of equipment that does not meet technical and sanitary requirements; inattention of the carrier to the characteristics of the vehicle
Loading and securing cargo	Violation of labeling, placement and fastening standards; lack of technical means; Errors in shipping documentation	Subjective risk assessment by the driver; insufficient download quality control; Staff dishonesty
Cargo transportation	Traffic accidents; theft of cargo; delays due to weather and road conditions; damage to cargo	Adverse weather and road conditions; technical malfunctions of the vehicle; low awareness or insufficient driver experience
Temporary storage	Lack or weak effectiveness of the warehouse security system; Unfavorable socio-economic situation of the region	Deficiencies in the organizational and technical components of security; violation of the requirements for packaging, placement and labeling of cargo
Unloading and acceptance of cargo	Negligent performance of loading and unloading operations; technical malfunction of equipment; human factor	Insufficient control by the driver; malfunction of weighing and auxiliary equipment; possible abuse of the recipient's personnel

Source: compiled by the authors

One of the most well-known and used classifications of supply risks is set out in the "International Commercial Conditions – Incoterms" (Table 2.2).

Table 2.2 Classification of supply risks according to the "International Commercial Conditions" – "Incoterms".

Group	Degree of responsibility
Group E	All risks associated with the storage of the goods are imposed on the supplier until the moment of its acceptance by the buyer (even if the money for the goods has already been received).
Group F	Depending on the specifics of the moment of transfer of goods from the seller to the buyer: – FCA (Free Carrier A – name of the place) – the risk and responsibility of the seller are transferred to the buyer at the time of handing over the goods at a pre-established place; – FAS (Free Along Side Ship) – the seller's risk and responsibility for the goods are transferred to the buyer at the time of handing over the goods in a pre-established port; – FOB (Free on Board) – the seller's risk and responsibility for the goods are transferred to the buyer at the time of shipment of the goods from the ship.
Group C	Covers situations when the seller and buyer enter into an agreement for the transportation of goods, but do not take any risk. This group includes the following subgroups: – CFR (Cost and Freight) – the seller pays the cost of transportation to the port of arrival, but the risk and responsibility for the safety and integrity of the goods and additional costs are borne by the buyer; the transfer of responsibility and risks occurs at the time of loading the ship; – CIF (Cost, Insurance and Freight) – provides that, in addition to CFR, the seller must additionally provide and pay for risk insurance during transportation; – CPT (Carrier Paid Maintenance) – the seller and the buyer distribute risks and responsibilities between themselves, not necessarily in equal shares; – Carriage and Insurance Paid To – risks are transferred from the seller to the buyer at a certain intermediate point of transportation, while the seller provides and pays the cost of insurance of the goods.

Continuation of Table 2.2

Group D	Covers situations when all risks associated with the transportation of goods are assumed by the seller: – DAF (Delivered At Frontier) – the seller assumes risks up to a certain state border, after which they are transferred to the buyer; – DES (DAF (Delivered Ex Ship) – the transfer of risks from the seller to the buyer takes place on board the ship; – DEQ (Delivered Ex Quay) – the transfer of risks from the seller to the buyer occurs at the time of arrival of the goods at the port of loading; – DDU (Delivered Duty Unpaid) – the seller assumes all risks associated with transportation until the goods are shipped to the buyer's warehouse; – DAF (Delivered Duty Paid) – the seller is responsible for the risks up to the specified (stipulated in the contract) place on the buyer's territory, but the latter pays for their insurance.

Source: Incoterms® 2020 Rules A Short Summary of Key Changes, Advantages and Disadvantages https://www.unitedairseafreight.com/docs/Incoterms-2020-Rules.pdf

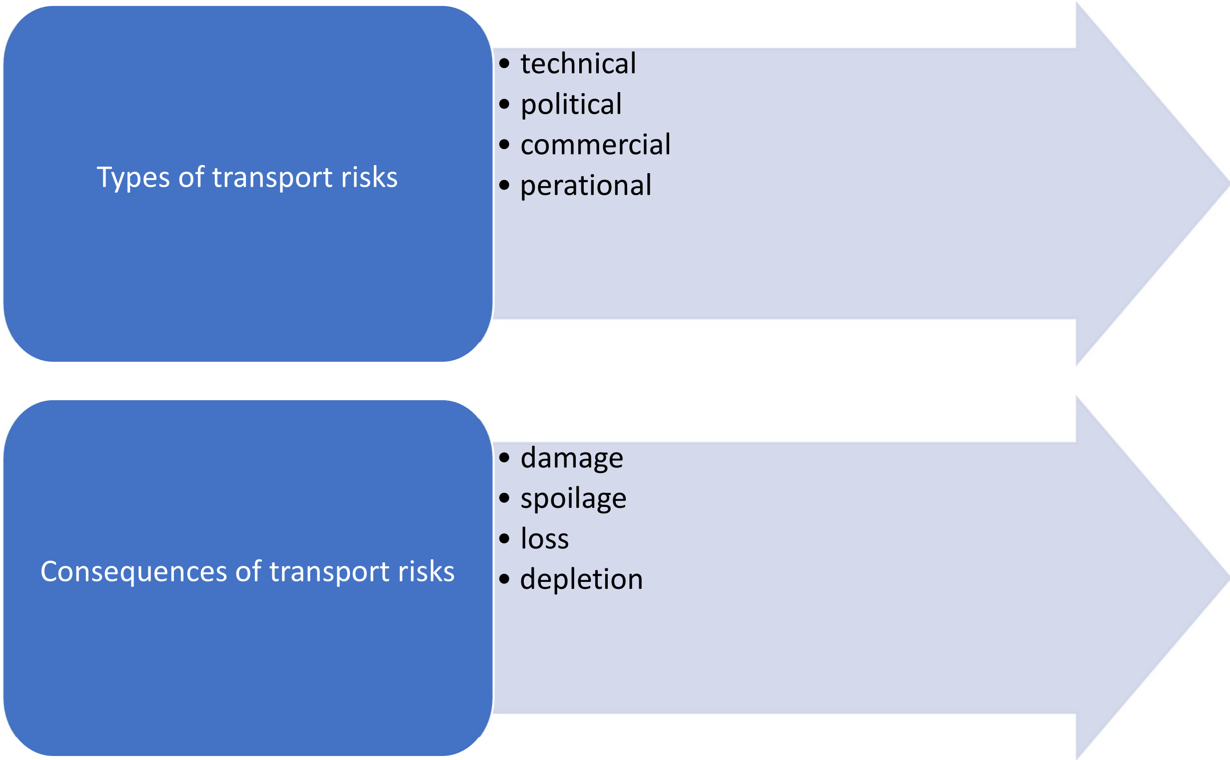
It defines the responsibilities and risks of the seller and buyer in the logistics supply chain. According to this standard, all supply risks are divided into four groups E, F, C and D according to the degree of responsibility of the seller and the buyer in international sales contracts that entered into force on January 1, 2011.

As for transport risks, this is a narrower category that determines the probability of adverse events occurring directly in the process of cargo transportation by various modes of transport[66].

This type of risk is inherent in almost all types and all stages of entrepreneurial activity (see Fig. 2.2)

Transport risks are closely related to supply, sales and other risks. The level of transport risks is not always predictable due to the possibility of force majeure. Reduction of transport risks is achieved primarily by choosing the right carrier, taking into account the specifics of the transported goods.

[66] Nedeliaková E., Ližbetinová L., Hranický M.P., Valla M. Risk Management in Transport Planning, Transportation Research Procedia, Volume 77, 2024, Pages 187-192.



Pis. 2.2 Transport risks
Source: compiled by the authors

In our study, the main focus is on the risks of cargo non-safety, which are associated with damage, damage, loss or loss of cargo during transportation by road.

They directly depend on the distance of transportation: the longer the distance, the higher the likelihood of damage or loss of cargo. Intercity transportation is considered to be especially susceptible to the risk of cargo non-safety.

Taking into account the above, the "risk of non-safety of goods" in road transportation can be defined as the probability of partial or complete loss of commodity, physical or economic properties of the cargo due to managerial, technical, personnel, legal and external factors in the process of transportation.

And its key sources are: imperfect legal field, low risk management culture, savings on safety, weak control and supervision, and a high level of accidents.

Table 2.3 Main sources of risk of non-safety of goods during transportation by road

Source of risk	Characteristics
Unguarded parking lots	65-74% of attacks occur at such sites
Long international routes	Increasing the exposure time of cargo to criminal encroachments
High cost or liquidity of goods	Involvement of organized criminal groups
Lack of secure infrastructure	Lack of alternatives for safe rest for drivers
Human Factor	Fatigue, fear and limited ability of drivers to affect safety

Source: compiled by the authors on the basis ofKubáňová J., Kubasáková I., Poliak, M.. Risks of the insurance in road transport. IOP Conference Series: Materials Science and Engineering. 2022. 1247. 012002. 10.1088/1757-899X/1247/1/012002.; Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https://doi.org/10.3390/safety11010020; Ting N. Risk Prediction of Container Cargo Loss and Damage Based on Machine Learning. In Proceedings of the 2024 International Conference on Big Data Mining and Information Processing (BDMIP '24). Association for Computing Machinery, New York, NY, USA, 2025.168–172. https://doi.org/10.1145/3735014.3735893

According to the generally accepted classification of goods and current regulations, the transportation of general cargo remains less regulated in terms of cargo safety. Due to the impressive range of such cargoes, in our opinion, special attention should be paid to the most vulnerable categories (fragile, expensive, perishable), because cases of their non-safety occur quite often and arise for various reasons and circumstances. In practice, the resolution of such issues is mostly carried out by the claim procedure, without resorting to the judicial authorities. As for the classification of risks that directly form the non-safety of goods, L. Yankovska and I. Petryk propose the following distribution:

1. Management risks:

– absence or incompleteness of accompanying documents;
– incorrect marking of the cargo;
– insufficient information about the cargo;

– incorrect determination of the moment of transfer of responsibility;

– inconsistent delivery routes and schedules.

2. Personnel risks:

– low qualification of personnel;

– improper performance of official duties;

– damage to the cargo due to the fault of employees.

3. Technical risks:

– malfunction of vehicles;

– discrepancies in the indicators of cargo weight (overload).

4. Unplanned risks:

– theft of cargo;

– traffic accidents;

– damage or complete loss of cargo as a result of accidents or overloading[67].

For road transportation, P. Panjee, V. Kaewchueaknang, S. Amornsawadwatana[68] classify all cargo non-safety risks into five main domains: man, method, machine, materials, and environment.

1. Risks associated with humans (the influence of the human factor on the transport process). Arise due to the actions or behavior of drivers and staff:

– driver fatigue, which reduces reaction speed and attentiveness;

– insufficient training and experience of staff;

– dangerous behavior on the road, including the use of a mobile phone while driving.

2. Risks associated with the method (organization of the transport process). They arise due to improper organization of work with cargo:

– improper fastening of the cargo;

– rough handling of cargo during loading and unloading;

– use of incorrect packaging methods;

[67] Yankovska L., Petryk I. Safety of Cargo Transportation in the Ukrainian Supply Chain: Risk Management and Legal Issues. Law, Business & Sustainability Herald. 2022. Vol. 2, Issue 1. P. 50–55. DOI: http://doi.org/10.46489/lbsh.2022-2-1-5

[68] Panjee, P.; Kaewchueaknang, V.; Amornsawadwatana, S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. *Safety* **2025**, *11*, 20. https://doi.org/10.3390/safety11010020

– unstable stacking or overloading;

– incompatibility with the standards and requirements for securing cargo.

3. Risks associated with machinery (vehicles and equipment). Factors related to the design and operational features of the vehicle:

– dynamic loads on the load when braking or cornering;

– insufficient strength of fasteners;

– equipment failures (locks, fasteners, shock-absorbing systems);

– design defects of vehicles and fastening systems.

4. Risks associated with materials. The main risks arise due to the characteristics of the cargo itself and packaging:

– fragile or insufficiently durable packaging, which increases the likelihood of damage;

– insufficient resistance of goods to vibration, shock or change of position during transportation.

5. Environmental risks (external environment). Factors related to operating conditions and external threats:

– poor road conditions and weather factors (ice, rain, snow);

– traffic accidents;

– risks of theft, theft or damage to the cargo by third parties.

This classification will be used in our study, because it allows us to systematically analyze the causes of losses and develop comprehensive measures to prevent them. All of these risks are interrelated and can amplify each other's effects. Accordingly, effective reduction of cargo losses requires an integrated approach: personnel training, standardization of fastening and packaging methods, vehicle maintenance, use of reliable packaging materials and taking into account external factors when planning the route, etc.

For a deeper understanding of the nature of such cases, we analyzed 50 cases of non-safety of cargo that arose in the process of road transportation of 3 logistics companies of Ukraine: "Ally Logistic LLC", "Aurora Trans", LLC "Agrarian Logistics Partnership"), taking into account the circumstances of their occurrence. The results of the analysis are shown in Fig. 2.2

As can be seen from Fig. 2.3 The lion's share of the risks of non-safety of goods is associated with improper or insufficient securing of cargo (60% of cases), environmental influences (20% of cases) and improper packaging (10% of cases).

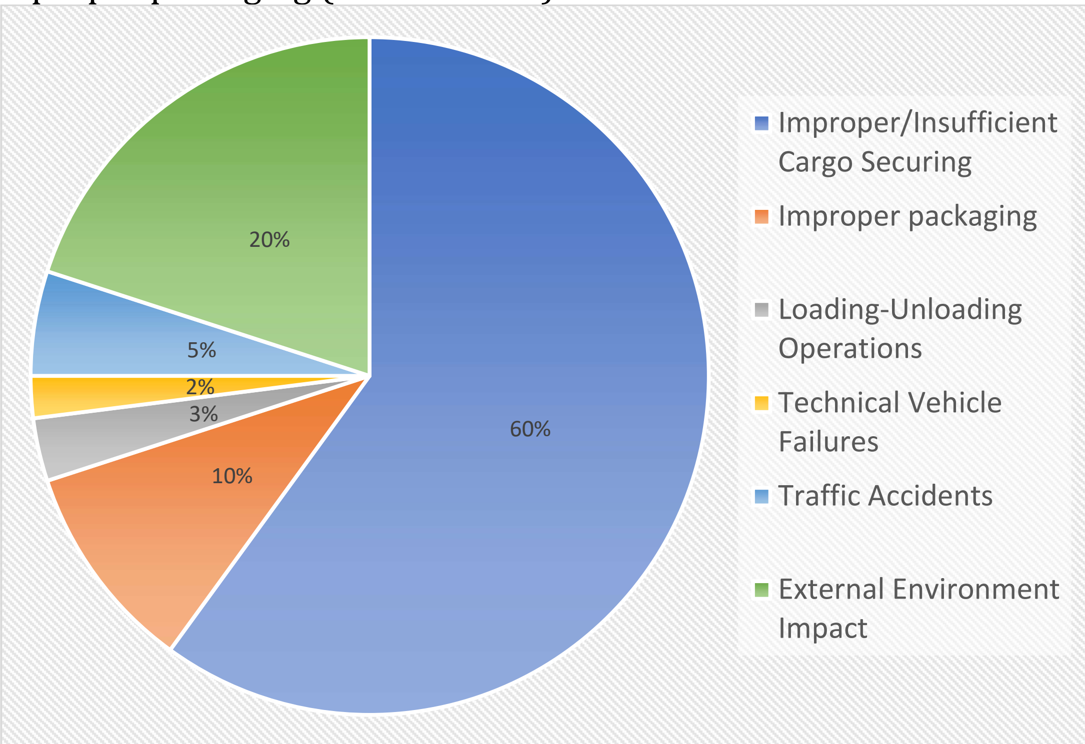


Fig. 2.3 Distribution of cases of cargo non-preservation

Source: compiled by the authors on the basis of the study

The data obtained allow not only to identify the main risk factors, but also to determine the directions for improving organizational and technical measures to ensure the safety of goods during road transportation. The main conditions for ensuring the safety of cargo during transportation are: knowledge of the properties of the transported cargo and compliance with the rules for accepting goods for transportation and their issuance by the sender and carrier. Therefore, there are many factors due to which there may be a risk of non-safety of cargo in the process of its transportation by road. To prevent or reduce the likelihood of such situations, an analysis is necessary, for which we propose to choose 4 main parameters:

1. Events that may occur and adversely affect transportation.
2. The consequences that these events can cause.
3. The probability of events.

4. Assessment of the level of risk of consequences (and whether it is necessary to apply any measures to reduce the probability of an event).

The analysis of these parameters is carried out by different methods or a set of methods, which subsequently lead to one thing – assessment of the impact of a particular situation on the level of risk and the possibility of its prevention of consequences (Table 2.4).

Table. 2.4.Analysis of the risks of non-safety of goods in different phases of the road transportation process

Phase of the process	Risk	Consequences (manifestations of non-preservation)	Minimization measures
Preparation for transportation and route planning	Passage of criminogenic regions; lack of information about risks on the route	Increased likelihood of cargo theft, attack on vehicles, fraudulent possession	Use of incident databases (TAPA IIS); Preliminary analysis of routes by safety level
Loading and leaving the point of departure	Insufficient control of access to the vehicle; lack of filling	Partial or complete loss of cargo; Difficulty in identifying the moment of loss	Access control; use of seals and fixing devices of the intervention
Vehicle movement	Seizures while moving; Stops at unspecified locations	Theft from a moving vehicle; forcible seizure of cargo	Restriction of unauthorized stops; adherence to safe routes
Driver parking / rest (key critical phase)	Parking in unguarded areas; lack of lighting and security	Up to 65–74% of all thefts; body breaking, cargo theft, packaging damage	Use of safe and guarded parking lots; Classification of parking lots by security levels
Overnight parking	Long uncontrolled downtime	Total or partial loss of cargo; significant insurance losses	Scheduling night stops only in certified parking lots

Continuation of Table 2.4

Border and transit zones	Illegal entry of unauthorized persons into the vehicle	Violation of the integrity of the cargo; Secondary losses, fines	Increased control; Selection of safe waiting areas
Access to the destination	Fraudulent pickup	Complete loss of cargo without physical damage to the vehicle	Verification of recipients; Documentary control
The entire transport process	Driver fatigue, psychological pressure, lack of safe infrastructure	Increasing the likelihood of risky decisions leading to unsafe cargo	Improvement of working conditions; integration of cargo safety with drivers' social conditions

Source: compiled by the authors

The analysis of the risks of non-safety of goods in different phases of the road transportation process shows that uncertainty manifests itself in the form of incompleteness or inaccuracy of the implementation of the transportation process, provided that it is invariant.

The existence of risk is directly related to the presence of uncertainty, since the spontaneity of the manifestation of risk factors for non-safety of cargo and the randomness of the occurrence of events caused by this risk determine different results of the transport process even with identical parameters of transportation organization.

At the same time, it should be noted that modern supply chains are characterized by the growing role of urban freight transportation, which is associated with the development of e-commerce, service economy and the concept of "last mile" delivery. Under these conditions, the risks of non-safety of goods are significantly influenced by the level of road safety in urban space.

Accordingly, traffic accidents involving freight vehicles should be considered as one of the key external sources of risks of non-safety of goods.

After all, accidents lead not only to physical damage to vehicles, but also entail mechanical deformations of the cargo, violation of the integrity of packaging, internal quality of the goods or complete loss of the batch.

In logistical terms, this translates into direct material losses, disruption of delivery deadlines, and violation of contractual obligations in supply chains. Especially vulnerable from the standpoint of cargo safety is the "last mile" phase, which is characterized by a high concentration of transport, organizational and spatial risks. Thus, in a study by the US Center for Secure and Sustainable Systems, the last mile is defined as:

– the most emergency-hazardous;
– the least standardized;
– the most vulnerable in terms of cargo safety[69].

The use of heavy trucks in dense urban environments is accompanied by an increase in the severity of the consequences of traffic accidents, which, in turn, leads to larger-scale cargo losses. On the other hand, the use of small and medium-sized commercial vehicles, as well as alternative delivery formats, although it increases the number of vehicles involved, reduces both the accident rate and the level of unsaved cargo due to better maneuverability and less kinetic energy during a collision.

However, frequent stops, maneuvering in dense city traffic, limited visibility and interaction with vulnerable road users (pedestrians, cyclists) significantly increase the likelihood of accidents.

In addition, in serious accidents, sudden braking and constant maneuvering create an additional dynamic load on the load, which can be critical for fragile, unstable or high-value products.

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[69] Urban Freight and Road Safety: Trends and Innovative Strategies. Center for Secure and Resilient Systems.Washington, DC, 2021. URL. https://www.roadsafety.unc.edu/wp-content/uploads/2021/12/CSCRS_urban-Freight_Report_12_9_21_508C.pdf

Table 2.5 Risk factors for non-safety of goods during transportation by road in the urban environment

Factor	Impact on road safety	Consequences for the safety of cargo
Increasing intensity of urban freight transport	Increase in accidents in the urban environment, increase in the number of accidents involving commercial vehicles	Increased likelihood of mechanical damage to cargo, loss of batches, violation of delivery terms
Vehicle type (heavy-duty vehicles)	Higher severity of the consequences of an accident, a larger area of damage	Significant damage to the cargo, destruction of packaging, complete loss of marketability
Use of small and medium-sized commercial vehicles (vans, light trucks)	Reduced severity of accidents, better maneuverability in heavy traffic	Reduced dynamic loads on the load, lower level of damage
The "last mile" phase	Frequent maneuvers, parking in uncertain places, conflicts with vulnerable road users	Increased risk of local damage, theft, violation of storage conditions
Interaction with vulnerable road users (pedestrians, cyclists)	Increase the likelihood of accidents in residential and commercial areas	Emergency stops and shocks result in damage to fragile and unstable loads
Speed Modes and Driving Environment	Higher speeds - more severe consequences of an accident	A sharp increase in the level of deformations and losses of cargo in collisions
Urban conditions (dense buildings, narrow streets)	Limited visibility, difficult maneuvering conditions	Partial damage to the load during maneuvers, collisions, pressing

Source: compiled by authorson the basis of Urban Freight and Road Safety: Trends and Innovative Strategies. Center for Secure and Resilient Systems.Washington, DC, 2021.

Thus, it is advisable to consider the safety of urban freight transportation as a component of the risk management system for non-safety of goods. Reducing the accident rate and increasing the level of traffic management create prerequisites for minimizing freight costs, increasing the stability of supply chains and ensuring their functional reliability in an urbanized environment.

2.2 Methods for reducing the risks of non-safety of goods

In today's international economic realities, security management is a complex task in any area, including supply chains. Therefore, the international trading community has developed general technical requirements for the design of containers and cargo compartments of vehicles, which ensure the safety of goods and cargo transported and at the same time exclude the possibility of unauthorized access to them. Thus, according to the TIR Convention of 1975[70], a motor vehicle and a container transporting goods in international traffic must be admitted by customs authorities to these transportations. Vehicles may be allowed to transport goods under customs control, the cargo compartments of which are designed in such a way that:

– the goods could not be removed from the sealed part of the vehicle, or loaded there without leaving visible traces of burglary or damage to customs seals and seals;

– seals and seals were applied in a simple and reliable way;

– there were no secret places for hiding cargo in the cargo spaces;

– all places where goods can be placed were available for customs control.

That is, at the legislative level, certain requirements are put forward for transport security, as a system for preventing, counteracting and stopping crimes, including piracy and terrorism, prevention of natural and man-made emergencies in the transport sector in order to minimize material and moral damage.

[70] Customs Convention on the international transport of goods under cover of TIR carnets (TIR Convention) 1975. https://eur-lex.europa.eu/EN/legal-content/summary/customs-convention-on-the-international-transport-of-goods-under-cover-of-tir-carnets-tir-convention.html

Various methods are used to ensure the safety of goods. Depending on the scope of application, they can be divided into:

– universal, with the help of which, along with the reduction of losses, other tasks related to the improvement of transportation technology[71] or improvement of vehicles are solved[72];

– specific – measures of narrower purpose, which are used only to ensure the safety of transported goods and to settle cases of their damage or loss[73].

The latter, in turn, are divided into technical, technological, legal, organizational and economic (see Fig. 2.4).

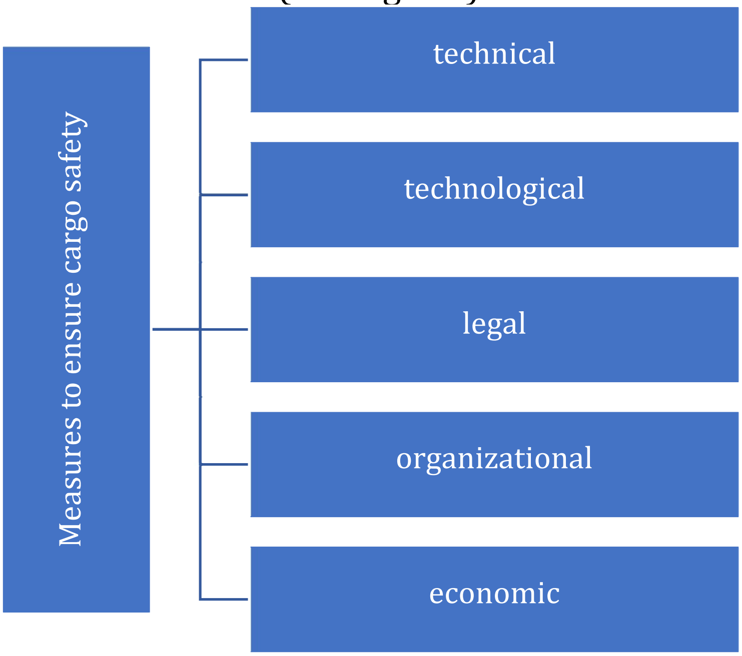


Fig. 2.4 Specific measures to ensure the safety of cargo

Source: compiled by the authors

[71] Tonhauser M., Ristvej J. Implementation of New Technologies to Improve Safety of Road Transport, Transportation Research Procedia, 2021, Volume 55, 1599-1604.; Son H., Jang, J., Park J., Balog A., Ballantyne P., Kwon H.R., Singleton A., Hwang J. Leveraging Advanced Technologies for (Smart) Transportation Planning: A Systematic Review. Sustainability 2025,17, 2245. https://doi.org/10.3390/su17052245

[72] Braidy A., Pokharel S., ElMekkawy T.Y. Research Perspectives on Innovation in the Automotive Sector. Sustainability 2025, 17, 2795. https://doi.org/10.3390/su17072795; Liang X., Wang P., Cao X., Wan X., Chao P., Zhao X., Yu A., Chuan Liu, Jiale Li, Research on improving the safety of new energy vehicles exploits vehicle operating data, Safety Science, Volume 181, 2025, 10668

[73] Yankovska L., Petryk I. Safety of Cargo Transportation in the Ukrainian Supply Chain: Risk Management and Legal Issues. Law, Business & Sustainability Herald. 2022. Vol. 2, Issue 1. P. 50–55. DOI: http://doi.org/10.46489/lbsh.2022-2-1-5

The use of such measures does not guarantee the absolute safety of the cargo, but significantly increases the level of its provision.

They are an integral part of the cargo safety system and contribute to reducing risks and increasing the efficiency of transportation processes.

Let's consider them in more detail.

1. Technical measures to ensure the safety of cargo are aimed at increasing the level of cargo safety through the use of special technical means. They are divided into:

a) security:

– adaptive vehicle bodies (specially designed bodies that can change their characteristics depending on the type of cargo, providing optimal conditions for transportation);

– pneumatic airbags (used to absorb shocks and vibrations that occur during movement, reducing the risk of damage to the cargo);

– fastening and packaging means (use of special materials and devices for reliable securing of the cargo, preventing its movement and damage).

b) control:

– electronic seals (systems that allow you to track the condition of cargo and detect unauthorized opening of containers).

– systems for monitoring the movement and technical condition of the vehicle: (include GPS navigation and sensors that allow you to track the location and condition of the vehicle in real time.

Figure 2.5 shows an example of the use of a complex of equipment for control and security of a truck and a van (semi-trailer). The system consists of the following main elements:

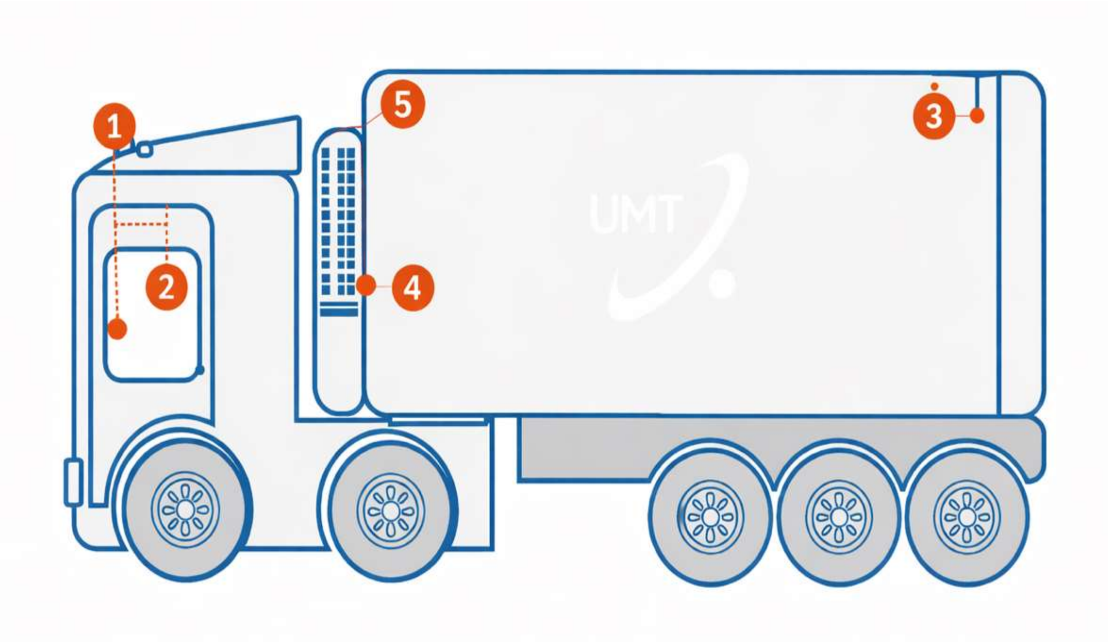
a) SmartBox GPS terminal (on a tractor) – connected to the car's CAN bus (provides data on the vehicle's condition and location).

b) Alarm key fob – used as an authorization element for the driver (transmits a signal to open/close the tractor door).

c) Door opening sensor – installed on the rear door of the van (records the opening/closing of the van door.

d) The SmartBox GPS terminal (on the van/semi-trailer) is also connected to the car's CAN bus (monitors events related to the van: door opening, movement, power, etc.).

e) The siren is used in the "Security" mode (emits a sound signal when an unauthorized door is opened).



1 - SmartBox GPS terminal (on a tractor); 2 - Alarm key fob; 3 - Door opening sensor; 4 - SmartBox GPS terminal (on the van); 5– Siren.

Fig. 2.5 Configuration of the vehicle security and cargo monitoring system based on GPS terminals and door status sensors.
Source: Generated by the authors using ChatGPT

The presence of a system for monitoring and control of traffic and the technical condition of transport significantly reduces the risk of unsafe cargo.

2. Technological measures related to the improvement of processes and technologies of cargo transportation. They include:

– modernization of transportation technology by optimizing component processes (introduction of the latest technologies and methods that reduce transportation time and reduce the risks of cargo damage, choice of a controlled route, distance and time);

– mechanization and automation of loading and unloading operations (use of automated systems and robotic devices for fast and safe movement of cargo);

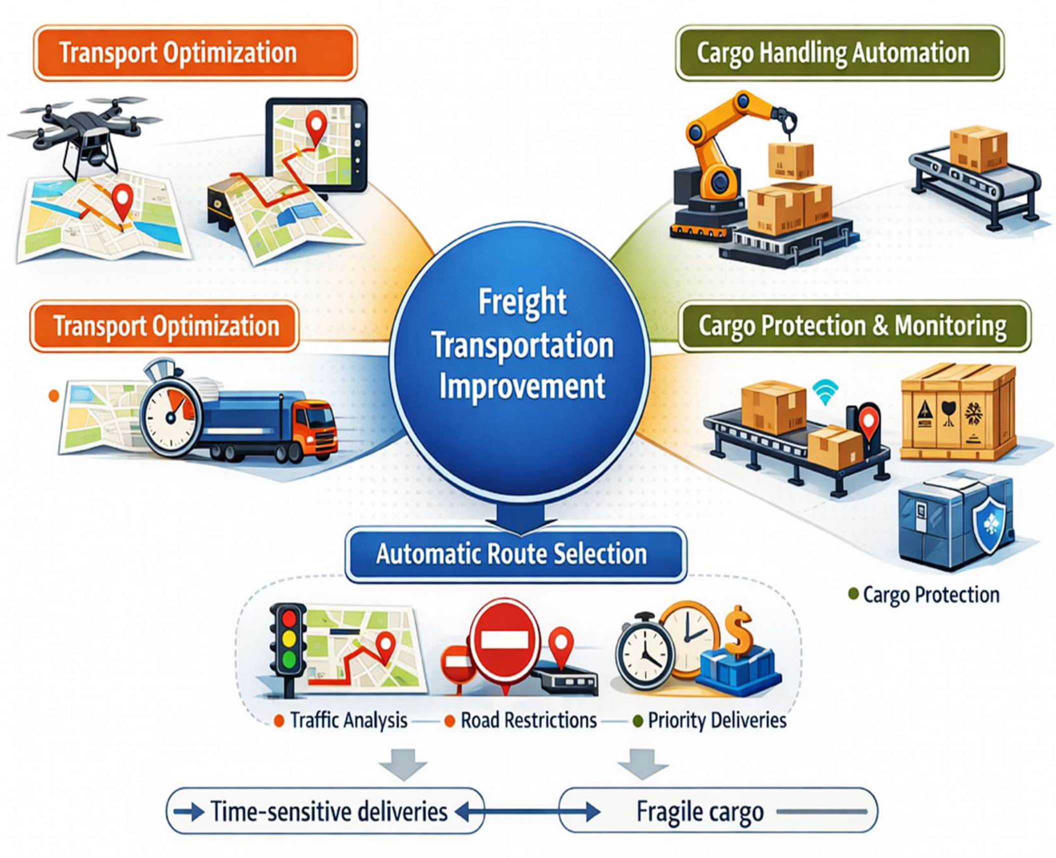


Fig. 2.6 Technological measures related to the improvement of processes and technologies of cargo transportation
Source: Generated by the authors using ChatGPT

– the use of special means of ensuring safety and control means (the use of innovative materials that provide additional protection of the cargo from the influence of external factors).

Technological measures allow you to automatically find the most efficient routes (taking into account: real traffic; traffic restrictions; priority of arrival time), determine priorities (for example: "time is more important than cost", "fragile cargo", etc.) and, depending on this, choose a set of technologies – combining solutions for maximum efficiency (Table 2.6).

Table 2.6 Latest technologies and methods that reduce transportation time, reduce the risks of cargo damage.

Technology /Method Category	Solution Name	Main function / purpose	How it reduces transportation time	How to minimize the risks of damage to cargo
Telematics and GPS monitoring	Real-time GPS systems	Vehicle Location Tracking	Provides up-to-date traffic data, avoids traffic jams	Ability to respond to stops/deviations
Touch IoT Devices	Temperature, humidity, shock sensors	Cargo Condition Monitoring (Environment/ Shocks)	Problem alert allows quick adjustments	Fix adverse conditions - reduce damage
Big Data Analytics (Big Data)	Motion History Analysis	Forecast of traffic jams, weather influences	Planning faster routes	Risk prediction of route sections
Machine learning	Predictive optimization algorithm	Automatic selection of the best route	Takes into account traffic, weather, time of day	Minimizes dangerous areas
Transport Management Systems	TMS with WMS/ERP modules	Comprehensive transportation management	Coordinates shipments and schedules	Reduces human error
Autonomous vehicles	Unmanned trucks/drones	Independent movement	Movement without the need for human breaks	Minimal human error

Continuation of Table. 2.6

Autonomous vehicles	Unmanned trucks/drones	Independent movement	Movement without the need for human breaks	Minimal human error
Drones and Last-Mile Solutions	Drone delivery	Short Distance Delivery	Avoids traffic congestion	Reduces the risk of damage to loads
V2X / C-ITS (Connected Vehicles)	Communication between cars and infrastructure	Traffic Data Sharing	Minimizes delays at traffic lights/ intersections	Increases traffic safety
Predictive Maintenance (IoT)	Forecast of the technical condition of the vehicle	Analysis of the state of the equipment	Reduces emergency failures while driving	Reduces the risk of damage to cargo due to breakdowns
Digital Twins	Modeling of logistics processes	Virtual Route Testing	Spotting bottlenecks	Damage risk modeling
5G / Fast communication networks	High-speed data exchange	Instant updates	Quick route adjustments	Real monitoring of cargo status
Computer vision	Cargo Condition Analysis Cameras	Detection of damage and improper fastening	Responds to anomalies during boot	Reduces the risks of transport damage

Source: compiled by the authors based on Álvarez P., Serrano-Hernandez A., Lerga I., Faulin J. Optimizing freight delivery routes: The time-distance dilemma, Transportation Research Part A: Policy and Practice, Volume 190, 2024,104283.; Fareed A., De Felice F., Forcina A., Petrillo ,A. Role and applications of advanced digital technologies in achieving sustainability in multimodal logistics operations: A systematic literature review, Sustainable Futures, Volume 8, 2024, 100278.

3. Legal measures are enshrined at the level of legislation and regulations that regulate the activities of road transport and provide a legal mechanism for protecting the safety of goods.

These include:

– legislative and regulatory legal acts (development and adoption of laws that determine the rules and requirements for the transportation of goods, providing legal protection for all participants in the process);

– transportation rules (establishment of standards and procedures for transportation, including requirements for the technical condition of vehicles and driver qualifications);

– contracts of carriage (conclusion of agreements that determine the conditions of cargo transportation and the responsibility of the parties).

4. Organizational measures are related to technological ones, but focus on managerial and human factors in the process of transportation. They include:

a) training and advanced training of employees of motor transport enterprises;

b) creation of motivational measures aimed at constant control and maintenance of transportation safety;

c) organization of the transportation process:

– routing (development of optimal routes for transportation, taking into account road conditions and potential risks of cargo non-safety);

– selection of rolling stock (selection of vehicles that best meet the requirements for the transportation of a specific type of cargo)

– management activities of the carrier aimed at improving the reliability and safety of the cargo (implementation of quality and safety management systems, monitoring the implementation of standards and procedures).

Accordingly, in order to preserve the cargo, the logistics department of the enterprise must weigh the degree of risk and ensure the organization of the transport process for the safety of the cargo[74].

To achieve this task, it is possible to calculate the risk potential on the route[75]. For this, based on statistical data, it is necessary to calculate the size of the coefficient of cases of non-preservation of cargo[76] for a certain period, which is an analogue of the value of the probability of a case of non-preservation of cargo.

$$К_{failure\ to\ save} = \frac{n_{nfailure\ to\ save}}{n_{total}} \qquad (2.1)$$

where $К_{failure\ to\ save}$ – the coefficient of cases of non-preservation of cargo;

$n_{failure\ to\ save}$ – number of cases of non-preservation of cargo for the period;

n_{total} – number of routes for a certain period.According to the data obtained, it is necessary to calculate the strength of the risk of not saving the cargo.

$$F_n = \frac{K_{\text{т}}}{l_s} \qquad (2.2)$$

where F_n– the strength of the risk of non-safety of the cargo;

l_s– The average length of the route for the period.

After that, it becomes possible to calculate the risk potential

$$p = F_n \times L_{\text{м}} \qquad (2.3)$$

where r – the potential for the risk of non-safety of the cargo;

$L_{\text{м}}$ – route length.

These calculations allow you to justify the use of means that ensure the safety of cargo by a certain factor. With the right approach and the necessary amount of information, the logistics operator can also form dangerous places on the route and ensure proper

[74] Dolzhenko N., Assilbekova I., Konakbay Z., Garmash O., Muratbekova G. Organization of Transport Services and Transport Process Safety, Periodica Polytechnica Transportation Engineering, 2025, 53(3), 277-291. https://doi.org/10.3311/PPtr.38137.

[75] Plass D., Hilderink H., Lehtomäki, H. *et al.* Estimating risk factor attributable burden – challenges and potential solutions when using the comparative risk assessment methodology. Arch Public Health 80, 148 (2022). https://doi.org/10.1186/s13690-022-00900-8

[76] Wu P., Chen M., Tsau C. The data-driven analytics for investigating cargo loss in logistics systems. International Journal of Physical Distribution & Logistics Management, 2017. Vol. 47 No. 1 68-83, doi: https://doi.org/10.1108/IJPDLM-02-2016-0061

organization of transportation. For example, to form, according to weather forecasts, a weather route of transportation (Fig. 2.8), which can reduce the consequences of unforeseen events for the driver.

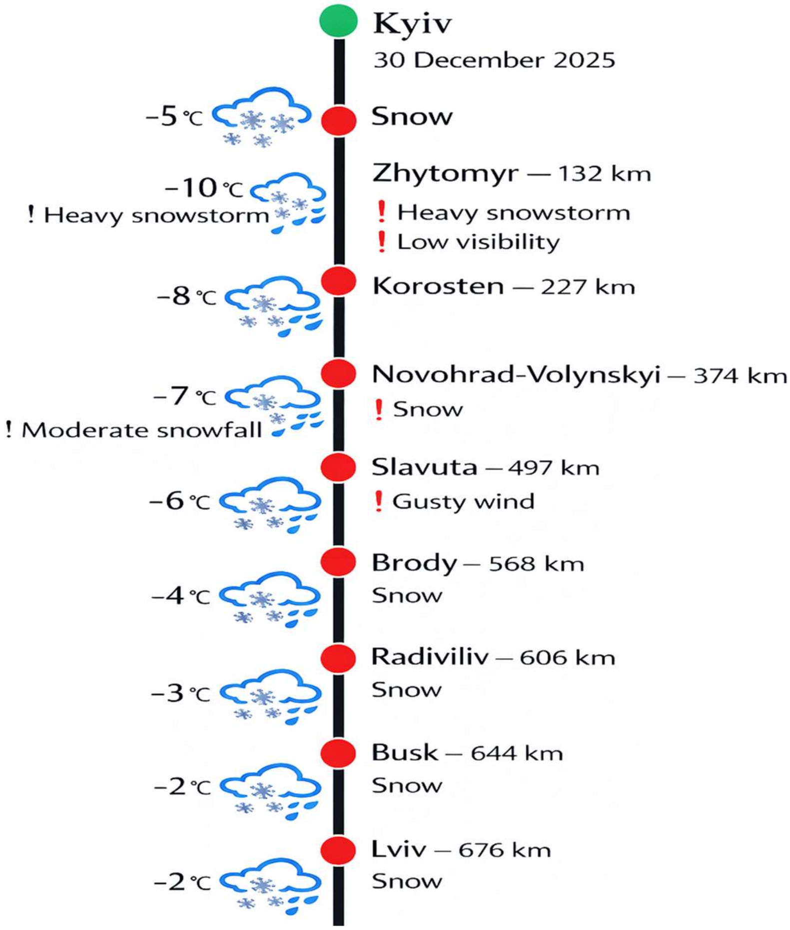


Fig. 2.8 Weather transportation route

Source: compiled by the authors

5. Economic measures are aimed not at preventing cases of non-preservation of cargo, but at their compensation. They guarantee compensation for property losses in monetary terms. Such measures include:

– cargo insurance – is a special mechanism by which the insured by paying an insurance premium of a certain amount removes the financial consequences of a possible risk, transferring them to the insurance company (conclusion of insurance contracts that provide compensation for the cost of cargo in case of its damage or loss);

– carrier's liability insurance, which is related to the determination of mechanisms and conditions for compensation for losses arising from damage or loss of cargo (coverage of financial risks associated with possible claims from customers or third parties). Insurance allows you to cancel the carrier's expenses incurred in connection with emergency situations, which has a beneficial effect on the work of transport companies and allows you to maintain the quality of services provided by the carrier. The difference between these types of insurance in terms of risks is given in Table 2.7.

Table 2.7 Comparison of Types of Insurance in the Field of Cargo Transportation

Parameter	Cargo insurance	Carrier liability insurance
Purpose	Compensation for damages in case of damage, loss or theft of cargo	Compensation for financial losses of a third party caused by the carrier
Object of insurance	The plunger itself	Carrier's liability to customers
Risks Beneficiary	Damage, Damage, Loss, Theft, Natural Disasters	Financial consequences of carrier errors or violations, accidents, damage to the client's property
	Owner or shipper of the cargo	Customer or third party
Mechanism of action	The insured pays the premium – the insurance company indemnifies the losses	The insured pays the premium – the insurance company covers liability to third parties
Nature of the event	Countervailing	Compensatory

Source: compiled by the authors based on Vignon D., Bahrami S. Safety, liability, and insurance markets in the age of automated driving, Transportation Research Part B: Methodological, Volume 191, 2025. 103115.; Suruchanu A., Kraus N., Kraus, K. innovative and digital development of the national auto insurance market in the conditions of convergence with the european market of insurance services. European Scientific Journal of Economic and Financial Innovation, 2023. *2*(12), 111-123. https://doi.org/10.32750/2023-0208.

In addition, depending on the risks covered, there are three main types of cargo insurance in the insurance market: ICC-A, ICC-B and ICC-C.

Conditions A differ from coverage on the basis of B and C in that they do not contain a list of events for the occurrence of which the cargo is insured, while B and C use a specified list of covered risks. The ICC-A basis insures transportation against any physical impact that is not excluded by the contract[77]. In other words, this type of cargo insurance is the widest and is able to provide maximum protection, regardless of the route, transport and transported cargo.

At first glance, the advantages of cargo insurance compared to civil liability insurance seem to be indisputable. However, not everything is so simple. In accordance with the general rules of cargo insurance in the EU countries and the provisions of insurance contracts, regardless of the chosen insurance model and insurance coverage conditions, the following situations that led to damage, destruction or loss of cargo, as well as financial losses related to transportation, are not recognized as insured events (see Table 2.8).

It should also be noted that the amount of the insurance premium cannot exceed the amount of the cost of the cargo, and the sum insured by analogy cannot exceed the insurance premium. In other words, in cases of damage not only to the cargo, but also to the vehicle, only the cost of the cargo will be compensated[78].

Many companies invest heavily in freight insurance both to cover losses and to receive significant monetary compensation in the event of an insured event. However, higher losses by logistics companies necessarily lead to increased insurance payments, which in turn encourages insurance companies to increase future insurance premiums[79]. This highlights the urgent need to address the problem of cargo loss in logistics systems[80].

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[77] Institute Cargo Clauses A, B, C https://www.insure24.co.uk/blog/institute-cargo-clauses-a-b-c-which-coverage-do-you-need

[78] Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. *Safety* 2025, 11, 20. https://doi.org/10.3390/safety11010020

[79] Kubanova J., Kubasakova I., Poliak M. Risks of the insurance in road transport. IOP Conference Series: Materials Science and Engineering. 2022. 1247. 012002. 10.1088/1757-899X/1247/1/012002.

[80] Wu P.J., Chen M.C., Tsau C.K. The data-driven analytics for investigating cargo loss in logistics systems. Int. J. Phys. Distrib. Logist. Manag. 2017, 47, 68-83.

Table 2.8 Exceptions of insured events for goods under EU legislation

Type of riziku	Exception description	EU regulations	Examples of situations
Military and political risks	Acts of a military nature or their consequences, including acts of terrorists, pirates, civil unrest, confiscation of cargo	Regulation (EC) No 392/2009; CMR Convention; General Conditions of Cargo Insurance (ICC)	Explosion of a bomb in a warehouse, seizure of a container by pirates, confiscation of cargo by customs
Nuclear risks	Direct or indirect effects of a nuclear explosion, radiation or radioactive contamination	Directive 2009/103/ EC; ICC	Radioactive contamination of cargo due to an accident at a nuclear power plant
Intentional actions and violations of the rules	Intentional violation of the rules of loading/unloading, transportation or storage	ICC	Damage during loading; ignoring the rules for fixing cargo
Incompatibility with infrastructural Tura	The cargo does not correspond to the dimensions or weight of the elements of the infrastructure	CMR Convention; National technical standards of TM	Damage due to exceeding the permissible height of the container on the bridge
Influence of physical and chemical properties of cargo and medium	Damage to the cargo due to temperature, humidity, natural aging or specific properties of the cargo	Directive 2009/103/ EC ICC;	Spontaneous combustion of bulk chemicals, corrosion of metal parts, etc.

Continuation of Table. 2.7

Insufficient or improper packaging	Damage due to improper packaging, styling, fastening	National Rules for the Transportation of Goods; ICC	Containers without cargo fixation moving during transport
Manufacturing defects	Cargo defects that occurred before the insured event	Directive 85/374/EEC; ICC	Crack in glass products due to manufacturing defects
Discrepancies in quantity/weight accounting	Shortage or damage in the integrity of the package or discrepancies between documents and actual volume/weight	CMR Convention; ICC	Different weight of the cargo in transport documents and actual
Pest damage	Exposure to worms, rodents, insects, etc.	ICC;	Damage to grain by moths or insects during transportation
Unsuitability of the vehicle	Damage due to technical malfunction of the vehicle	Regulation (EC) No 392/2009; Directive 2009/103/EC	Truck breakdown resulting in damage to cargo while driving

Source: Regulation – 392/2009 – EN – EUR-Lex URL. https://eur-lex.europa.eu/eli/reg/2009/392/oj/eng; Convention on the contract for the international carriage of goods by road (CMR) URL. https://unece.org/DAM/trans/conventn/cmr_r.pdf; Directive – 2009/103 - EN - EUR-Lex - European Union URL https://eur-lex.europa.eu/eli/dir/2009/103/oj/eng, as well as the general principles of cargo insurance in the EU

It should be noted that despite all the shortcomings, insurance allows you to cancel the carrier's expenses that arose as a result of emergencies, which has a beneficial effect on the work of transport companies and allows you to maintain the quality of the carrier's services.

Despite the importance of the problem, research on effective strategies to reduce cargo losses in the field of risk management has not been carried out enough. Accordingly, the measures necessary to prevent the non-safety of the cargo remain unchanged:

– risk assessment;

– coordination of actions of all participants in the supply chain;

– improvement of regulatory documentation;

– training of personnel and providing them with clear instructions,

– analysis of accidents and incidents;

– strict reporting and auditing.

2.3 Conceptual approaches to risk management strategy

In general, the entity carries out risk management within the framework of a single strategy approved by its senior management and directs it to solve two main tasks.

The first of which is quite traditional for the practice of risk management and is aimed at preserving the basic capital of the enterprise or the existing share value of the company.

The second, less traditional, because it is primarily related to the creation of additional capital or a new share value of the enterprise. It is clear that a certain share of the total resources of the enterprise should be directed to solving these problems.

However, how to distribute these resources of the enterprise into parts between the tasks and within the tasks themselves is the content of the strategy and tactics of risk management of the enterprise.

Today, when new methods are needed to ensure and maintain high rates of economic growth, trends based on an alternative, dynamic concept of risk management are clearly progressing[81]. It is safe to say that recently life itself forces entrepreneurs to deliberately integrate the dynamic concept of risk management into the center of the existing risk management system.

At the same time, in risk management itself, two tendencies or two principles still prevail (Fig. 2.9).

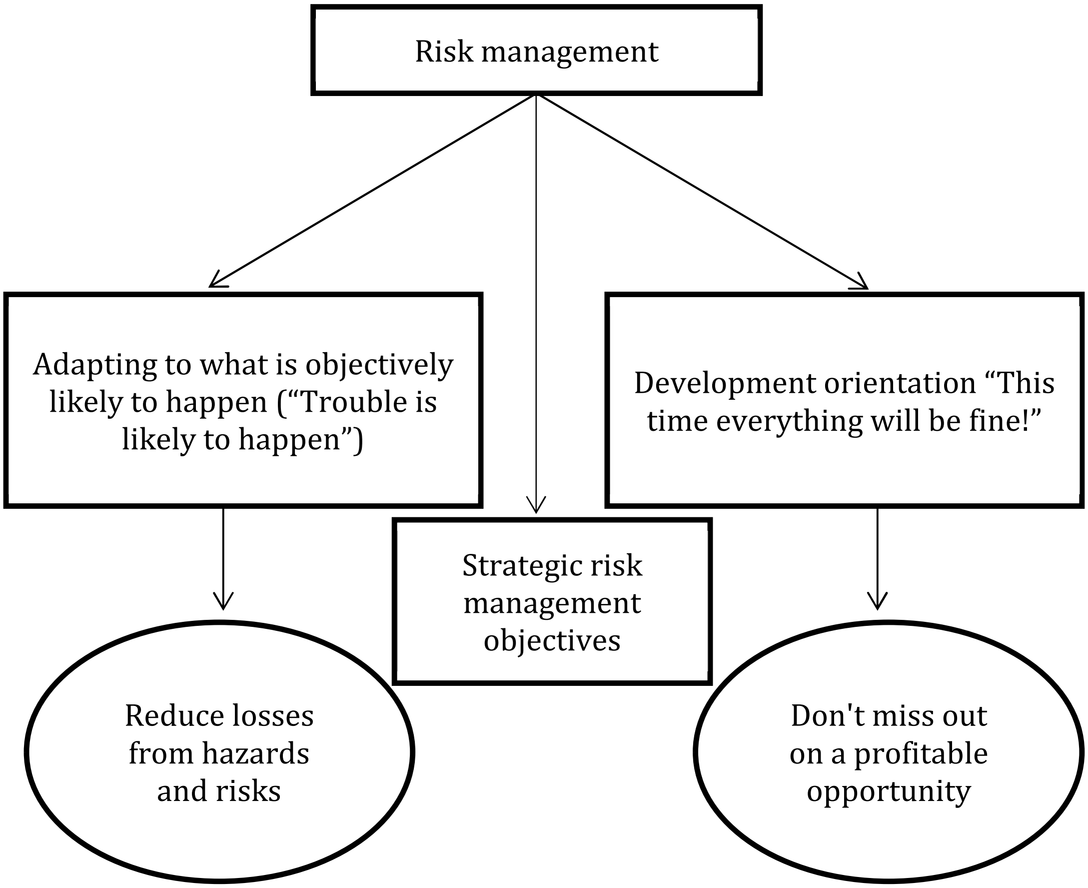

Fig. 2.9. Principles and strategic objectives of risk management
Source: compiled by the authors

[81] Cheimonidis P., Rantos K. A Dynamic Risk Assessment and Mitigation Model. Appl. Sci. 2025, 15, 2171. https://doi.org/10.3390/app15042171; Rampini A., Sufi A., Viswanathan, S. Dynamic risk management, Journal of Financial Economics, Volume 111, Issue 2, 2014, 271-296.; Fehle F., Tsyplakov S. Dynamic risk management: Theory and evidence. Journal of Financial Economics. 2005. 78. 3-47. 10.1016/j.jfineco.2004.06.013.

One of these tendencies can be considered conformist. It preaches the adaptation, or conformance, of current decisions and actions to the future, forecast situation. Another trend is the orientation of the enterprise to development, achievement (performance).

For the conformist principle of adaptation or compliance with what can objectively happen, the essence of the psychological mood for the possible development of events is encapsulated in a pessimistic phrase like: "If trouble can happen, then they are likely to happen." But for the alternative, performance principle, which orients the entrepreneur to the need for development, an optimistic view of the future, to which everything does not seem so bad, is more suitable. The psychological attitude that gives rise to creative preferences in an entrepreneur fits well into the following expression: "Yes, it happens that something does not turn out the way you want, but this time everything will be fine!"

"Technically" adaptation is manifested in the fact that managers, developing economic solutions, still begin by asking experts, specialists, managers and consultants the traditional question: "What threats will our enterprise be exposed to?" In its epistemological essence, the tactics of action, expressed by the desire to avoid any losses in every possible way, are due exclusively to pessimistic assessments, that is, it goes back to the ideas of risk as a danger.

Now, as we have already noted, another "technique" is often used, when managers of all levels ask an alternative question focused on the development of the enterprise. Its essence expresses doubt: "Are we risking enough not to fall into stagnation?" As a result, senior managers are gradually moving on to new initiatives to improve the risk management of their enterprises. Thus, the essence of such innovative initiatives is to manage not only the process of studying and analyzing possible risks of the enterprise, but also the risks themselves. And this, in turn, opens up the prospect of new opportunities and, ultimately, the prospect of increasing profits. So, this is another, namely optimistic, assessment, which is based on the idea of risk as an integral and useful part of the business. Adhering to this view of the nature of risk, it is believed that any risk can be positive[82] where and when the level of risk (loss) itself is commensurate with the level of benefit (income).

Today, senior executives of the most advanced firms and companies expect management to be able to take into account both risk assessments (both optimistic and pessimistic) and manage risks in order to increase the chances of success, reduce the degree of propensity to fail and stabilize the overall financial and economic performance of economic entrepreneurial activity.

That is why, in order to successfully exist in a market economy, an entrepreneur needs to correctly assess the degree of risk and be able to manage it in order to achieve more effective results in the market.

Risk management is a very broad concept that covers a variety of problems related to almost all areas and aspects of management, which are characterized by both negative and favorable consequences. The essence of risk management is to identify potential deviations from the planned results and manage these deviations to improve the outlook, reduce losses and improve the validity of the decisions made. Risk management means identifying prospects and opportunities for improvement, as well as preventing or reducing the likelihood of undesirable course of events.

Risk management requires a clear distribution of responsibilities and powers necessary for managerial decision-making. Decisions made in the process of risk management must be within the framework of legal requirements and comply with corporate goals. Thus, it is very respectful to determine the optimal balance between responsibility for risk and the ability to control that risk.

Risk management requires a balanced decision[83]. In the process of risk management, it is necessary to clearly define the economic feasibility of reducing the risk measure and achieving the planned results.

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[82] Fryt J., Duell N., Szczygieł M. Psychological profiles associated with positive and negative risk-taking in adults. Curr Psychol 43, 12744–12753 (2024). https://doi.org/10.1007/s12144-023-05349-8.

[83] Høj N.P., Kroon I.B., Nielsen J.S., Schubert M. System risk modelling and decision-making – Reflections and common pitfalls, Structural Safety, Volume 113, 2025, 102469.

The direction and content of the noted signs of entrepreneurship give rise to the following dilemma: on the one hand, the management of an organization that avoids risky decisions dooms the company to inevitable stagnation and loss of competitiveness, on the other hand, the unreasonableness of the decisions made by the management in risky situations can lead to the complete collapse of the organization. Approaches to solving management problems can be different, so risk management is multivariate, providing for a combination of standard and originality of financial combinations, flexibility and uniqueness of certain ways of acting in a particular situation. The main thing in risk management is the correct setting of a goal that meets the economic interests of the object of management.

Thus, the main goal of the risk manager is to ensure that even the worst scenario implies only a certain (permissible) decrease in the level of the planned result with a guaranteed preservation of the viability of the enterprise.

When choosing a risk management strategy and tactics, the manager must adhere to the following basic principles:

– it is inappropriate to risk more for less;

– it is inexpedient to risk more than one's own funds allow (capital, etc.);

– it is necessary to take care (make a forecast) in advance regarding the possible (probable) consequences of the risk.

The implementation of the first principle means that before making a decision under conditions of risk, an entrepreneur must:

determine the maximum possible amount of damage in the event of a risk event;

compare it with the amount of invested capital and own financial resources to determine whether these losses will lead to the bankruptcy of the enterprise.

The implementation of the second principle requires that the entrepreneur, knowing the maximum possible amount of damage, would determine what it can lead to, what is the probability of risk, in order to make a competent decision based on this information.

The implementation of the third principle assumes that it is necessary to compare the expected result with the possible losses that the entrepreneur will suffer in the event of a risk event.

Only with an acceptable ratio of return and possible losses for an entrepreneur, a decision should be made on the implementation of a risky project. It is necessary to know about the possible occurrence of risk, but not enough.

It is important to establish how a particular type of risk affects the results of activities and what are the consequences of risk, and first you need to assess the probability that a certain event will actually occur, and then how it will affect the economic situation of the firm.

Taking into account the fact that in economic relations the decision-making process at all levels of responsibility takes place in conditions of constantly present uncertainty of the state of the external and internal environment, which causes partial or complete uncertainty of the final results, there is an objective need to organize a strategic risk management system at each enterprise, as a result of the implementation of which the vulnerability of the enterprise to external and internal risk factors is significantly reduced.

At the same time, risk management must adequately respond to the relevant trends in the development of entrepreneurial activity and be able to adapt to the expected changes.

Leading scientists recommend risk management measures to be carried out in four stages[84]:

1. Identification (identify risks that may interfere with the goals of the project);

2. Analysis (to determine which of the identified risks are the most dangerous);

3. Planning (plan the most dangerous risks);

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[84] AL-Dosari K., Fetais N. Risk-Management Framework and Information-Security Systems for Small and Medium Enterprises (SMEs): A Meta-Analysis Approach. Electronics 2023, 12, 3629. https://doi.org/10.3390/electronics12173629.; Ansyari S. Implementation of Risk Management in Strategic Decision Making. Journal of Scientific Interdisciplinary. 2024. 1. 35-44. 10.62504/t7c2r379.; Glette-Iversen I., Flage R., Aven T. Extending and improving current frameworks for risk management and decision-making: A new approach for incorporating dynamic aspects of risk and uncertainty, Safety Science, Volume 168, 2023, 106317.

4. Monitoring and control (keeping the project plan and risk list up to date).

As for risk management in the transport sector, it also includes a number of key stages that are aimed at systematic and effective identification, assessment and management of risks in order to ensure the safety, reliability and efficiency of transport operations.

At the stage of identifying risk problems, an analysis of potential threats and problems that may arise during various transport operations is carried out. Once the risks have been identified, the risks are diagnosed and ranked, where they are evaluated and ranked according to their importance and possible impact on the performance of transport tasks.

The collection of information on sources and objects of risk is carried out through detailed analysis and collection of information on sources of risk that may be related to various aspects of transport activities.

Further, a comprehensive analysis of the factors that may affect the occurrence of risks in the transport sector, including technical, environmental, economic and social aspects, is assessed, the potential consequences of risk situations for transport systems, including financial, reputational, environmental and other aspects.

At the next stage, criteria are developed to evaluate the effectiveness of the proposed risk management strategies. Once decisions are made, they are handed over to responsible executors for implementation.

And at the final stage, constant monitoring and control over the implementation of decisions and taking the necessary measures in case of risky situations is carried out.

The process of risk management is summarized in the form of a flowchart in Fig. 2.10.

As a result of a thorough qualitative and quantitative analysis, the manager, based on the data obtained, chooses one of the means or superposition of risk management tools: avoidance, prevention, acceptance (preservation or even increase) or reduction of the degree of risk (optimization).

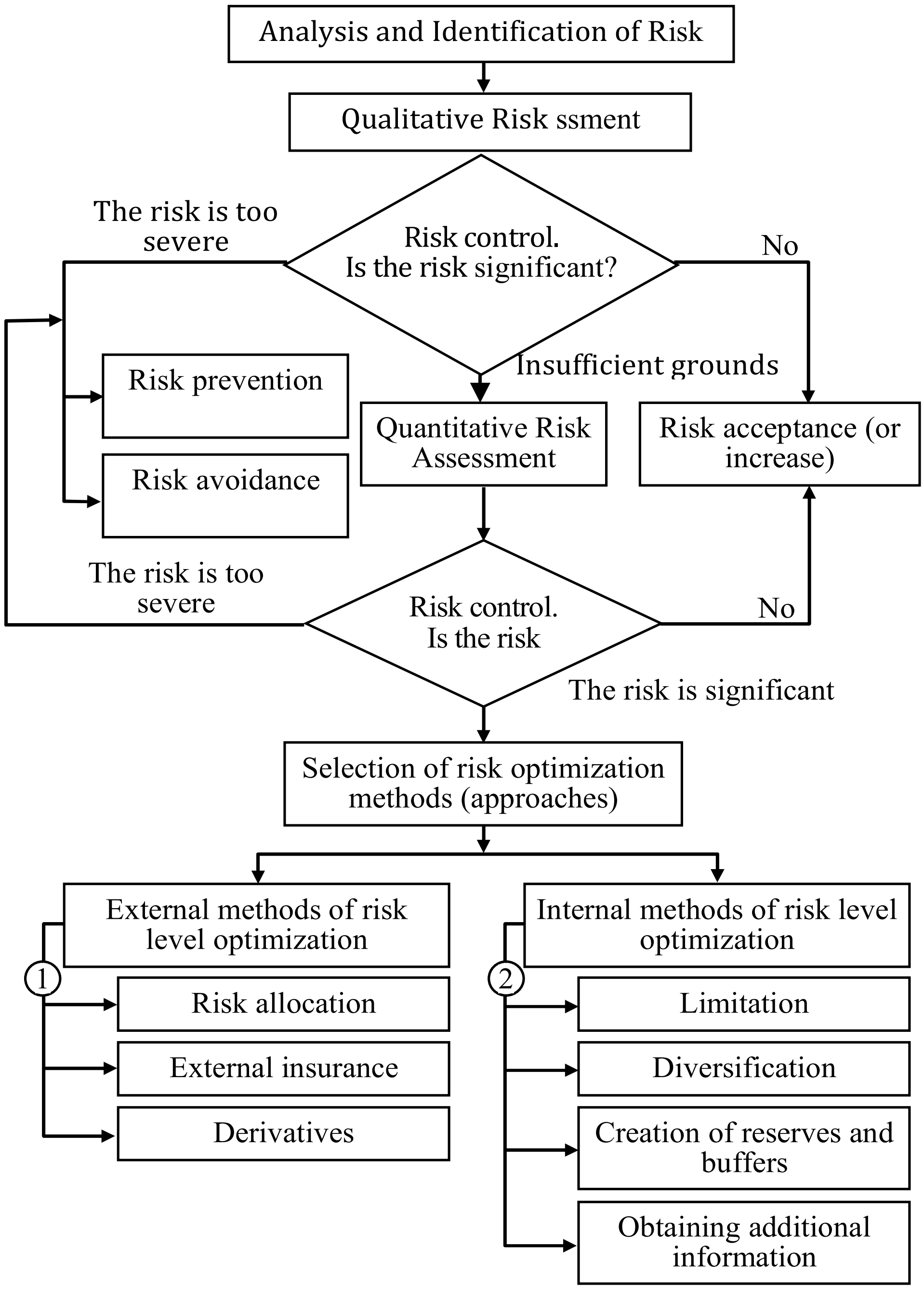

Fig. 2.10 Generalized flowchart of the risk management process
Source: compiled by the authors

Grouping of strategies for managing entrepreneurial risks and the corresponding tools for their implementation are given in Table. 2.9.

Table 2.9 Grouping of risk management strategies and relevant tools for their implementation

Risk Management Strategy	Tools for implementing a risk management strategy
Risk avoidance strategy	exclusion of entrepreneurial activity from business areas where there is a high level of risk; rejection of unreliable partners; rejection of risky projects; diversification of entrepreneurial activity.
Preventive risk management strategy	reducing the time spent by the organization in risk areas; reducing the likelihood of risk events; separation (disaggregation) of objects that are sources of increased risk; rational distribution of risky areas of the enterprise's activity in the time space; formation of targeted risk management programs; preventive influence on the source of risks; introduction of measures to ensure the security of enterprise assets; use of the risk dissipation mechanism.
Risk Compensation Strategy	formation of a reserve fund to cover possible losses.
Risk Acceptance Strategy	the practical absence of risk management and distribution measures; functioning of the enterprise in a mode that excludes the use of preventive actions regarding risk factors; actual compensation for losses as a result of adverse events, etc.
Risk Insurance Strategy	insurance of local risks; hedging; non-insurance transfer of risk; insurance of aggregate risks.

Source: compiled by the authors on the basis ofGlette-Iversen I., Flage R., Aven T. Extending and improving current frameworks for risk management and decision-making: A new approach for incorporating dynamic aspects of risk and uncertainty, Safety Science, Volume 168, 2023, 106317; Han N., Um J. Risk management strategy for supply chain sustainability and resilience capability. Risk Management. 2024. 26. 10.1057/s41283-023-00138-w.; Dhlamini J. Strategic risk management: A systematic review from 2001 to 2020. Journal of Contemporary Management. 2022. 19. 212-237. 10.35683/jcm22008.165.

It is customary to distinguish preventive instruments focused on risk[85] prevention and compensatory ones, which are used to eliminate or reduce negative consequences[86]. To reduce the risk of undesirable situations during road transportation, the internal action monitoring system turns out to be an effective tool. Risk assessment in practice requires the application of a methodology for managing the actions of participants, taking into account the prerequisites of the process, which allow you to prevent possible negative scenarios. This means that the monitoring system must take into account a variety of aspects, including technical parameters, safety requirements, regulatory requirements, and behavioral factors of the system participants. This approach allows you to prevent possible negative consequences and ensure the effective functioning of the transportation system. The procedure for choosing a risk management method is carried out according to the following algorithm:

the stage of setting risk management goals is characterized by the use of methods of analysis and forecasting of the economic situation, identification of opportunities and needs of the enterprise within the framework of the strategy and current plans of its development;

at the stage of risk analysis, methods of qualitative and quantitative analysis are used: methods of collecting existing and new information, modeling of enterprise activities, statistical and probabilistic methods, etc.;

3) at the third stage, a comparison of the effectiveness of different methods of influencing risk is carried out: risk prevention, risk reduction, risk assumption, transfer of part or all of the risk to third parties, which ends with the development of a decision on the choice of their optimal set;

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[85] Aven T. A risk and safety science perspective on the precautionary principle, Safety Science, Volume 165, 2023, 106211.

[86] Roberts A, Risk, Reward, and Resilience Framework: Integrative Policy Making in a Complex World, Journal of International Economic Law, Volume 26, Issue 2, June 2023, 233-265, https://doi.org/10.1093/jiel/jgad009

4) at the final stage of risk management, an analysis of the effectiveness of the selected methods of influencing the risk is carried out, as well as the formation of a decision on the components of the object of influence.

However, the field of transport and logistics is special, because it is present in any type of economic activity and connects all sectors of the economy. Therefore, risk management and it faces a number of significant and inherent obstacles:

– information barriers (difficulty in obtaining reliable data on risks, lack of uniform standards for their assessment);

– insufficient transparency of supply chains;

– financial constraints (high cost of introducing cargo transportation monitoring systems, significant insurance costs);

– organizational difficulties (lack of a clear distribution of responsibility, difficulties in coordinating actions between departments or companies that organize and implement the transportation process).

Based on the identified obstacles according to the classification defined by us in the previous sections, an integrated matrix for managing the risks of non-safety of goods has been developed (Table 2.10). The technological and technical advances reflected in it, combined with institutional changes, political and economic reforms, and global cooperation, will be crucial to creating sustainable and safe road transport systems that effectively eliminate risks and ensure the safety of goods in road transport.

However, it should also be noted that it is equally important for transport vehicles to develop an integrated risk management system[87], since they usually interact with other elements and mechanisms, which can create new risk scenarios. For example, in the case of interaction with other means of labor or transport systems, a situation

[87] Lahuta P., Kardoš P., Hudáková M. Integrated Risk Management System in Transport, Transportation Research Procedia, Volume 55, 2021, 1530-1537.; Labodová, A. Implementing integrated management systems using a risk analysis based approach. Journal of Cleaner Production. 2004. 12. 571-580. 10.1016/j.jclepro.2003.08.008. Thalmann S., Manhart M., Ceravolo P., Azzini A. An Integrated Risk Management Framework:. International Journal of Knowledge Management. 2014.10. 10.4018/ijkm.2014040103.

may arise when the properties of one means of transport affect the overall level of operational safety.

Table 2.10 Integrated Cargo Risk Management Matrix

Factor	Source of risk	Risk mitigation direction	Compliance with standards	KPI (Performance Indicator))
Man	Fatigue, inattention, driver mistakes	AI-Driver Condition Monitoring, ADAS, Personalized Training	ISO 9001 (7.2, 7.3); UNECE R130, R151	– Share of flights without incidents (%) – Quantity ККБ[88]/100 thousand km
Method	Incorrect fastening methods	AR learning, standardization, touch control	ISO 9001 (8.1); UNECE CTU Code	–percentage of correct fastening– number of violations
Car	Failure of fasteners, wear of vehicles	IoT fastening, predictive maintenance, automated fastening cargo	ISO 28000 (A.9); UNECE Code XL	– equipment failures – frequency of cargo displacements
Material	Low strength, moisture, vibration	Innovative packaging, vibration-damping packaging, CFD modeling	ISO 9001 (8.5); ISO 28000 (A.8)	– the level of damage to the cargo (%)– loss of weight/quality
External environment	Thefts, weather conditions, poor infrastructure	ECTS, 5G/GNSS, Secure parking lots	ISO 28000 (A.11); UNECE SAFE Parking	– the number of thefts – time of unplanned stops

Source: compiled by the authors

[88] KSC (Key Security Criteria) – a set of measurable criteria that characterize the level of security of cargo, vehicles, personnel and information in supply chains and are used for monitoring, auditing and continuous improvement of security management systems.

An integrated approach to risk management allows you to ensure not only the safety of individual elements of the transport system, but also the coordinated and safe operation of the entire system as a whole. In transport systems, it is important to take into account their ability to integrate and analyze the initial data generated by the participants in the movement of goods. This can include information about vehicle traffic, road conditions, environmental conditions, and other parameters[89]. The integration of this data in the risk assessment process allows you to qualitatively and quantitatively assess potential threats and turn them into useful information for decision-making.

2.4 Modern directions of reducing the risk of non-safety of goods during transportation by road

To reduce the risk of non-safety of goods, first of all, it is necessary to clearly understand the reasons for their loss, to know the design features of various rolling stock objects, the rules and technology of transportation, the procedure for processing transportation documents, as well as the sequence of receiving, sending and issuing goods. In addition, it is necessary to have information about the safety of products transported on the road, as well as to have information about the markets of security and insurance services. In other words, without understanding the whole essence of the transport process as a whole, it is hardly possible to provide effective protection of transported goods.

Therefore, unlike traditional business risks, the management of which we discussed above, risks in transport logistics have a cascading effect. A failure in one link usually triggers a reaction throughout the supply chain. This requires a different comprehensive approach to risk management, namely:

[89] Renzi E., Zampino S., Palermo G., Tamasi G., Di Nucci F., Porretto V., Germanese L. An Integrated Risk Management System for Road Infrastructures: Focus on Seismic Risk and Network Performance, Procedia Structural Integrity, Volume 44, 2023, 355-362.

– identification and assessment of risks;

– development of a strategy for their management;

– control and monitoring of risks throughout the entire transportation process.

In conditions of uncertainty, the sustainability and efficiency of transport logistics depends on properly selected risk management tools and a more accurate assessment of their level. Accordingly, both methods and strategies for managing the risks of non-preservation of goods in the process of road transportation are diverse. Thus, S. Hansson[90] identifies five methods of analysis that help to carry out risk management in various aspects of the enterprise:

1. The method of threat investigation and operational readiness allows you to identify potential threats and hazards in processes and systems, as well as consider possible scenarios of accidents and their consequences. It helps to develop risk prevention and management strategies.

2. The method of analysis of types, consequences and critical limits of acceptable risk allows you to determine potential defects (types), their possible consequences and critical limits that indicate when a defect becomes unacceptable for safe operation.

3. The method of decision tree analysis allows you to determine possible sequences of events that can lead to an undesirable outcome. It helps to identify key factors that can lead to the occurrence of undesirable events and develop risk management strategies.

4. The method of preliminary analysis of possible threats is used to assess the probability of occurrence of risky events and their consequences. It allows you to identify potential threats and develop risk management strategies.

5. The method of assessing the reliability of the human factor allows you to assess the impact of human actions on the occurrence of risks and undesirable events. It helps to identify what factors can lead to errors and deficiencies in risk management systems.

And since the problem of non-safety of goods during road transportation is very multifaceted, it is quite natural that there is no

[90] Hansson S.O. Decision Theory: A Brief Introduction. Royal Institute of Technology (KTH), Stockholm, 2005. 94.

universal means of preventing losses. However, something must be done, it is possible, and necessary. Below are the main ways to reduce the risks of not saving goods.

1) The use of means that complicate theft or prevent them[91]. These include:

– seals and locking and sealing devices;
– locks and locks, including non-standard ones;
– devices that block the doors of the vehicle;
– fencing;
– security lighting;
– Checkpoint.

2) Application of means of prevention and/or termination of theft of goods[92]. These include various burglar alarm systems that warn of vehicle break-ins and scare away thieves.

3) The use of means that accelerate the detection of embezzlement[93], namely:

– video surveillance of loading platforms and vehicles;
– trap marks marking the criminal;
– devices that record the fact of penetration into the cargo compartment.

4) The use of recorders that record non-standard effects on the cargo[94]. This refers to various sensors that mark certain parameters

[91] Daniel E. The use of violence in cargo theft – a supply chain disruption case. Journal of Transportation Security. 2018. 11. 10.1007/s12198-018-0186-0.; Liang X., Fan S., Lucy J., Yang Z. Risk analysis of cargo theft from freight supply chains using a data-driven Bayesian network, Reliability Engineering & System Safety, Volume 226, 2022, 108702.

[92] Klopott M., Urbanyi-Popiołek Cargo Theft as a Systemic Risk in Global Supply Chains: Data, Modus Operandi and Emerging Trends (2019-2025). European research studies journal. XXVIII. 2025. 1298-1313. 10.35808/ersj/4219.

[92] Karam, A., Jensen, A.J.K. & Hussein, M. Analysis of the barriers to multimodal freight transport and their mitigation strategies. Eur. Transp. Res. Rev. 15, 43 (2023). https://doi.org/10.1186/s12544-023-00614-0

[93] Karam, A., Jensen, A.J.K. & Hussein, M. Analysis of the barriers to multimodal freight transport and their mitigation strategies. Eur. Transp. Res. Rev. 15, 43 (2023). https://doi.org/10.1186/s12544-023-00614-0

[94] Adi K., Subagio A., Widyanto, S. A., Putranto, A. B. Motor vehicle condition monitoring and recording system using arduino mega. International Review of Electrical Engineering, 2021. 16(3), 286-294. https://doi.org/10.15866/iree.v16i3.18344; Matias J., Pinto F.C., Couto P. Computer Vision Methods for Vehicle Detection and Tracking: A Systematic Review and Meta-Analysis. Appl. Sci. 2025, 15, 12288. https://doi.org/10.3390/app152212288

(pressure, temperature, humidity, roll, shock, etc.) during the entire period of cargo on the road.

5) Application of indicators of careful handling of goods[95]. The idea of the method is that the container filled with goods is equipped with a special indicator, which is either attached outside or placed inside the cargo compartment (sometimes for reliability, the cargo compartment is equipped with two indicators at once). Such a simple device, depending on its purpose of installation, records cases of impacts, falls, temperature deviations, unacceptable tilts of the load or other abnormal influences on the road. At the same time, permissible shocks or other similar phenomena that occur during transportation do not lead to the operation of the indicator. The cost of such an indicator is much lower than that of a recorder, so it records only the fact of violation of the conditions of transportation, without tying it to time. Thus, the use of indicators of careful handling of cargo does not always allow you to establish a specific culprit of damage to the cargo, for example, in mixed transportation or its delivery by car with two drivers.

6) Application of sliding racks. A modern way to protect cargo from movement in the car body is to fix it with the help of inventory telescopic sliding racks[96]. It is typical for cases where the load does not occupy all the space inside the vehicle.

The installation of such racks prevents the horizontal displacement of the load or the fall of pallets from the second tier when the vehicle is not fully loaded.

7) Use of inflatable pillows[97]. These pillows (air pneumatic shells) in a swollen state are laid in the voids between the loading units, and then air or, better, pure nitrogen is injected into them from the compressor unit. Thus, the pillows prevent possible displacement

[95] Mustafa M., Navaranjan N., Demirovic A. Food cold chain logistics and management: A review of current development and emerging trends, Journal of Agriculture and Food Research, Volume 18, 2024, 101343

[96] Vlkovský M., Veselík P. Cargo securing - Comparison of the selected trucks. Transport Problems. 2020. 15. 265-274. 10.21307/tp-2020-065.

[97] Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https://doi.org/10.3390/safety11010020

of goods during transportation, and even exclude friction and impact of cargo pieces against each other.

This method is of particular importance in cases where cargo pieces are diverse in size, which is why it is quite difficult to place them on a vehicle without voids and, therefore, without possible movements on the road. The use of such means can significantly improve the quality of delivery and reduce cargo losses during transportation.

8) Use of reinforced and/or specialized containers and packaging[98]. Containers and packaging should protect the goods from shock loads and other influences or at least reduce the degree of their impact, but the higher the level of protection of containers and packaging, the more expensive it is. Moreover, no packaging saves the goods from the negligence of movers or the driver, as well as from thieves.

9) Replacement of the vehicle as unsuitable in commercial terms. The commercial suitability of the supplied rolling stock is determined by the consignor. If the consignor has loaded the provided vehicle, he thereby assumed all possible consequences in the sense of commercial non-conformity, including those related to the safety of the cargo.

10) Strengthening and arrangement of the vehicle. If the vehicle is suitable for transportation, then the consignor of the cargo must take measures to exclude (impede) the penetration of unauthorized persons into it on the way, as well as to ensure the safety of the cargo during transportation.

11) Tracking cargo in transit[99]. This measure increases the safety of cargo during transportation only indirectly, but allows you to quickly find out about some events that occurred on the way.

[98] Guzmán E., Andrés B., Poler R. Hybrid MILP-deep reinforcement learning approach for reusable container flows in the automotive industry, International Journal of Production Economics, 2026, 109927.; Mahmoudi M., Parviziomran I. Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management. International Journal of Production Economics. 2020. 228. 107730. 10.1016/j.ijpe.2020.107730.

[99] Donne D., Alfandari L., Archetti C, Ljubić I. Freight-on-Transit for urban last-mile deliveries: A strategic planning approach, Transportation Research Part B: Methodological, Volume 169, 2023, 53-81.

12) Route planning in such a way as to make it impossible for the vehicle to pass through the most dangerous areas[100]. You should not rely on a favorable coincidence, it is much wiser to simply avoid dangerous areas, even if the price for this will be an increase in mileage.

13) Parking of cars only in special protected areas[101]. If there are none on the way, then it is recommended to avoid parking alone and stopping in poor areas, since it is they who increase the likelihood of both theft and attacks.

14) Constant work with personnel to practice actions that allow you to avoid potentially dangerous situations, and in cases of their occurrence, to respond appropriately[102].

Practice shows that drivers and freight forwarders, in the event of some events on the road, often get lost and begin to either passively react to events (it happens that they panic altogether), or do not do at all what should be done in such a situation. To avoid this with them, it is necessary to regularly conduct appropriate trainings on behavior in a particular setting.

15) Transportation insurance[103]. It is believed that insurance is one of the main ways to manage risks. For relatively little money, the insurer accepts the agreed risks, thereby relieving cargo owners of them.

[100] Córdoba-Misas M., Calderón O., Brakewood C. Freight-on-transit: A systematic review centered on freight needs, methods, and real-world implementations, Transportation Research Part A: Policy and Practice, Volume 205, 2026, 104864.

[101] Fahim A, Hasan M, Chowdhury MA. Smart parking systems: comprehensive review based on various aspects. Heliyon. 2021 May 15;7(5):e07050. doi: 10.1016/j.heliyon.2021.e07050. PMID: 34041396; PMCID: PMC8141779.; Mahmud R., Saif S., Gomes D. A Comprehensive Study of Real-Time Vacant Parking Space Detection Towards the need of a Robust Model. AIUB Journal of Science and Engineering (AJSE). 2021. 19. 99-106. 10.53799/ajse.v19i3.80

[102] Kuipers J., Mulder M., Voskes M. Training for the Unexpected: Enhancing Driver Preparedness Through Hazard Awareness. 2025. 10.13140/RG.2.2.31873.57444.

[103] Kubáňová J., Kubasáková I., Poliak M. Risks of the insurance in road transport. IOP Conference Series: Materials Science and Engineering. 2022. 1247. 012002. 10.1088/1757-899X/1247/1/012002.; Owens E., Sheehan B., Mullins M., Cunneen M., Castignani G., Masello L.Towards Pay-As-You-Move (PAYM) insurance: The multimodal mobility risk transfer solution, Transportation Research Interdisciplinary Perspectives, Volume 28, 2024, 101283.

In addition, the scientific literature[104] provides a significant number of tools for managing the risks of non-safety of goods, each of which has its own modifications due to the specifics of the manifestation of certain economic risks.

When planning and organizing the process of cargo transportation, the logistics operator is obliged to ensure its safety.

Based on this provision, the organization of transportation should be based on ensuring the integrity of the cargo from the moment of its acceptance for transportation and on minimizing all identified and hidden risks.

The occurrence of cases of cargo non-safety, that is, the transition from risk to event, is most often observed directly during transportation.

It is possible to avoid such situations by reducing the risk potential at the stage of organizing transportation, using appropriate tools in the form of a set of preventive measures. This provision determines the choice of a preventive risk management strategy within the framework of this study and the need for a rational and objective assessment of the risk of cargo non-safety.

Considering comprehensive measures to prevent non-safety of goods, according to the risk classification proposed by P. Panjee, V. Kaewchueaknang, S. Amornsawadwatana[105], we note that further risk reduction in the field of road transportation should be focused on:

1. Improving driver behavior monitoring systems, introducing advanced digital technologies, and integrating real-time data into predictive safety models.

Artificial intelligence plays a key role here in driver monitoring systems to detect risky behaviors, including fatigue and distraction. (Table 2.11).

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[104] Bernardelli A.E., Giudici P.A. I Risk Management: A Bibliometric Analysis. Risks 2025, 13, 131. https://doi.org/10.3390/risks13070131; Damayanti E. Risk Management: In an Overview of Literature Review. Formosa Journal of Science and Technology. 2023. 2. 1115-1122. 10.55927/fjst.v2i4.3837.; Glette-Iversen I., Flage R., Aven T. Extending and improving current frameworks for risk management and decision-making: A new approach for incorporating dynamic aspects of risk and uncertainty, Safety Science, Volume 168, 2023, 106317

[105] Panjee P., Kaewchueaknang V., Amornsawadwatana S. A Systematic Literature Review of Cargo Loss Risks in Road Transportation: Impacts and Future Directions. Safety 2025, 11, 20. https://doi.org/10.3390/safety11010020

Such systems, based on machine learning algorithms, are able to analyze safety-critical events, predict the likelihood of accidents, and make recommendations for preventive measures.

A promising direction is the use of deep learning algorithms in order to improve the accuracy of assessing the driver's condition and personalize training programs taking into account individual shortcomings.

Taken together, these approaches form a comprehensive basis for improving the safety of road transportation and reducing cargo losses caused by the human factor.

Table 2.11 Directions for reducing the risks of cargo non-safety associated with the human factor

Direction	Technology	The essence of the measures	Expected effect
Intelligent driver monitoring	AI, Machine Learning, and Deep Learning	Real-time detection of driver fatigue, inattention and dangerous actions	Reducing accident rates, increasing driving discipline
Critical Event Analysis	Big Data, predictive models	Critical Event Handling to Predict Accidents	Preventive risk management
Personalized driver training	Adaptive learning platforms	Adjustment of training programs taking into account individual mistakes	Improving the professional reliability of drivers
ADAS integration	ADAS, CV, V2V, V2I	Combining warning systems and recommendations into a single environment	Comprehensive improvement of traffic safety
Improving human-system interaction	HMI, Ergonomic design	Increasing the convenience and accessibility of digital systems	Increasing technology adoption and reducing errors

Source: compiled by the authors

2. Harmonization of the rules for the organization of the transport process (Table 2.12) relating to the securing of goods, their strict observance and comprehensive training of drivers in the proper methods of securing goods in transport.

The use of autonomous fastening systems, especially those that integrate robotic technologies, ensure the accuracy of operations, reducing the need for manual labor.

Table 2.12 Directions for reducing the risks of cargo non-safety associated with the organization of the transport process

Direction	Tools	Main content	Expected effect
Augmented reality learning	AR platforms	Practicing the correct fastening methods	Reducing staff errors
Touch Control	Shock and vibration sensors	Monitoring during transportation	Prompt response to risks
Harmonization of standards	Uniform rules and instructions	Unification of fastening practices	Accident reduction

Source: compiled by the authors

Innovative augmented reality (AR) technologies, autonomous mounting systems and advanced sensor-based monitoring systems demonstrate great potential. AR-enabled training platforms can increase the competence of drivers and logistics service employees by offering interactive and immersive safety training tailored to real-world mounting scenarios.

Thus, according to the modeling of the correct methods of securing goods in dynamic conditions[106], it reduces the human factor and increases compliance with safety protocols.

3. Introduction of advanced technologies and innovations in mechanical engineering. Predictive vehicle maintenance.

[106] Gong P., Lu Y., Lovreglio R., Lv X., Chi Z. Applications and effectiveness of augmented reality in safety training: A systematic literature review and meta-analysis. Saf. Sci. 2024, 178, 106624

Development of intelligent mounting systems equipped with IoT-based sensors to monitor tension and integrity in real time.

Shock monitoring systems based on intelligent sensors, which can monitor vibration stress and tension of fasteners during transportation, instantly notifying about the need for corrective actions (Table 2.13), become a modern solution for managing the risks of cargo failure in real time.

Table 2.13 Directions for reducing the risks of cargo non-safety associated with vehicles and equipment

Direction	Key Technologies	Main content	Expected effect
Intelligent Mounting Systems	IoT Interference Sensors	Real-time monitoring of the status of fasteners	Preventing cargo displacement
Standalone mounting methods	Robotic systems	Fine adjustment of fasteners	Increased cargo stability
Predictive maintenance	Data analytics, AI	Early detection of equipment wear and tear	Reducing equipment failures
Standardization of equipment	Certification, testing	Use of proven tools	Increased overall safety

Source: compiled by the authors

These systems allow you to respond in advance to fastener malfunctions, ensuring the stability of the cargo throughout the entire transportation process.

And as Ž. Kavaliauskas and colleagues[107] point out, the integration of such technologies with centralized logistics management systems can further increase their efficiency by providing a holistic view of the transport status and allowing data-driven decision-making. Combining these technologies with renewable energy sources, such as solar-powered sensors, can

[107] Kavaliauskas Ž., Šajev, I., Blažiūnas G., Gecevičius G., Kazlauskas S. Development and investigation of a smart impact detector for monitoring the shipment transport process. Appl. Sci. 2024, 14, 7102

increase system efficiency and reduce operating costs at the same time.

4. Integration of advanced technologies to improve packaging designs and optimization of environmental conditions to reduce cargo losses (Table 2.14).

Table 2.14 Directions for reducing the risks of cargo non-safety associated with cargo materials and their packaging

Direction	Key Solutions	Main content	Expected effect
Innovative packaging materials	Moisture-resistant and durable composites	Protection against deformation and moisture	Reduction of cargo spoilage
Vibration damping packaging	Polypropylene, shock-absorbing inserts	Reducing the impact of dynamic loads	Reduction of mechanical damage
Optimization of container design	Physical and CFD modeling	Ventilation and cooling improvements	Improving product safety
Biological protection	Metabolic Engineering, Biocontrol	Increasing the natural sustainability of products	Reduction of post-harvest losses

Source: compiled by the authors

In particular, within this direction, in order to solve the problem of grain spoilage during transportation, it is proposed:

– widely use innovative materials with better strength and moisture resistance;

– integrate methods of biological control and metabolic engineering of plants to improve internal mechanisms for the protection of perishable goods;

– provide a systematic approach to assessing cooling efficiency and condensation risks, allowing for the optimization of tray designs that improve airflow and reduce the risks of food spoilage.

5. Implementation of the Electronic Cargo Tracking System (ECTS) to reduce fraud during transit and improve security in logistics networks.

Ensuring uninterrupted communication for continuous monitoring and reduction of risks associated with theft and environmental impact (Table 2.15).

Table 2.15 Directions for reducing the risks of cargo non-safety associated with the external environment

Direction	Technology	Main content	Expected effect
Electronic Tracking Systems	ECTS, GPS	Real-time transit control	Theft Reduction
Communication infrastructure	5G, satellite systems	Continuous monitoring of loads	Increasing transparency of transportation
IoT Environment Monitoring	Temperature sensors, vibrations	Early detection of threats	Prevention of damage to cargo
Secure parking lots	Video surveillance, lighting	Protection during stops	Reducing criminal risks

Source: compiled by the authors

The integration of IoT-enabled devices into logistics structures significantly improves environmental monitoring. IoT technologies can provide real-time data on weather conditions, road quality, and cargo conditions, allowing precautions to be taken to protect goods in transit. E. Connolly and P. Martin[108] believe that implementing machine learning algorithms to analyze historical and real-time data from tracking systems can further optimize route planning and risk management, reducing environmental concerns and vulnerability of cargo during transportation.

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108 Connolly E.L., Martin P.G. Current and prospective radiation detection systems, screening infrastructure and interpretive algorithms for the non-intrusive screening of shipping container cargo: A review. J. Nucl. Eng. 2021, 2, 246-280.

The considered promising measures to prevent cargo non-safety showed that investments in advanced technologies open up significant economic and operational opportunities for enterprises in the logistics and transport sector. Despite the high costs associated with their implementation, technologies such as predictive maintenance, IoT-based monitoring systems, and AI-powered analytics can transform risk management, enabling companies to achieve greater efficiency, cost savings, and reliability in transportation operations.

For example, predictive maintenance not only reduces maintenance costs by 25-30%, but also significantly reduces the number of unforeseen breakdowns by 70-75%, providing up to a 10-fold increase in return on investment[109]. These technologies minimize downtime, increase fleet reliability, and improve supply stability, which is critical to maintaining a competitive advantage in today's logistics industry.

However, it should be noted that high initial investment continues to be a significant barrier to the adoption of advanced technologies, especially for small and medium-sized enterprises (SMEs), which are often limited in financial resources. Overcoming this limitation also requires systemic strategic decisions. State subsidies and tax incentives can play an important role in this process, reducing the financial burden and increasing the availability of innovative solutions. Supporting investments in Internet of Things (IoT) and artificial intelligence (AI) technologies enables SMEs to integrate modern digital solutions into fleet management, increasing safety and operational efficiency.

An effective tool for reducing costs is cooperative procurement programs, within which SMEs combine demand to purchase technologies at reduced prices. This approach allows you to reduce specific costs and provides access even for small operators to real-time cargo monitoring systems and automated means of ensuring their safety. An additional advantage is the formation of a knowledge-sharing environment and the dissemination of best practices in logistics risk management.

[109] Franceschini L., Midali A. Industrial IoT: A Cost-Benefit Analysis of Predictive Maintenance Service. Masters's Thesis, Politecnico di Milano, Milano, Italy, 2019. 192.

A promising direction is also a public-private partnership focused on creating a common technological infrastructure, in particular secure IoT networks for cargo tracking and centralized risk management platforms. An important element of such initiatives are staff training programs, which increase the readiness of SMEs to effectively use digital solutions and reduce the risks of their implementation, in particular in the field of predictive vehicle maintenance. After all, the economic and social effects of the digital transformation of the logistics sector go far beyond individual enterprises.

Reducing operational risks, accidents and cargo damage increases the reliability of supply chains, customer satisfaction and contributes to the formation of a sustainable logistics ecosystem with reduced resource losses and negative environmental impact. In this context, support for the introduction of advanced technologies should be considered as a strategic priority of industry policy.

To avoid the risk of non-safety of goods during international transit transportation, the following factors should be taken into account:

– the situation in the country through which the supply route lies;

– absence or minimization of robberies and thefts of goods and vehicles on communication routes and parking lots;

– lack of special meticulous attitude of the state control bodies over the carrier's compliance with the provisions of international conventions and agreements in the field of road transportation;

– too many penalties.

In general, investments in modern technological solutions contribute to the growth of operational efficiency, security and financial stability of logistics enterprises. The combination of government incentives, cooperative procurement, and public-private partnership mechanisms makes it possible to overcome price barriers and realize the potential of IoT systems, predictive service, and analytics based on artificial intelligence, ensuring the long-term competitiveness of the logistics sector.

Part III

ASSESSMENT OF RISKS OF NON-SAFETY OF GOODS DURING ROAD TRANSPORTATION

3.1 Identification of risk factors for non-safety of goods

Effective management of the risks of cargo non-safety is impossible without quantitative models that can predict the probability of losses, taking into account the interaction of factors.

Identification (from the Latin identifico – to identify, recognize) is the process of establishing, recognizing and defining objects or phenomena by comparing and comparing their features. In the context of transport logistics, identification of risks of cargo non-safety means identifying and determining the dominant factors that affect the safety of cargo during transportation, depending on the parameters of organized transportation. This process is aimed at identifying the dominant factors that form potential threats to safety, taking into account the mode of transport, route conditions, transportation technology, type of packaging, type of cargo and other parameters of organized delivery.

The main purpose of identification is to create an information base for further quantitative analysis of risks and the development of measures to minimize them.

Identification tasks include:

– identification of all possible factors affecting the safety of cargo;

– identification of sources and types of risks (technical, organizational, human, natural and climatic, etc.);

– establishing relationships between individual risks;

– formation of a list of critical risks that need to be controlled;

– preparation of data for further quantitative assessment and ranking of risks.

Taking into account the fact that the transportation process is characterized by a high degree of variability and the influence of external factors (discussed in the previous sections), the identification of risks of cargo non-safety is a complex and special task. The main features of this process are as follows:

1. Multifactorial. The safety of cargo is simultaneously influenced by the technical condition of the vehicle, traffic conditions, personnel actions, meteorological factors, etc.

2. Stochastic character. Risks manifest themselves randomly, and the probability of their realization changes over time.

3. Interdependence of factors. One type of impact can cause another (for example, poor road conditions → vibration → damage to packaging → damage to goods).

4. The presence of qualitative factors. Some of the risks are intangible or difficult to measure (driver's experience, quality of organization of the transportation process, staff discipline, etc.).

Identification of risks of cargo non-safety requires an expert approach, since: different factors can create the same level of risk. For example, mechanical stress and non-compliance with the conditions of fastening can equally affect the damage to the cargo; complex interaction of factors leads to invariance and alternative development of events, i.e. different scenarios for the occurrence of non-conservation; the qualitative nature of individual factors (for example, the level of training of personnel, the discipline of the driver) makes it impossible to quantify the risk by mathematical methods.

The lack of reliable and homogeneous statistical samples complicates risk analysis based on real observational data. And as M. Yazdi, P. Hafezi and R. Abbassi[110] note, there are two most important problems in the application of expert systems in risk analysis – obtaining professional knowledge of experts in the subject area and justifying and presenting this knowledge.

The first problem, in their opinion, can be successfully solved using a heterogeneous group. Experts are involved in the process of acquiring expert knowledge. Members of the expert group tend to have different experiences and knowledge. Subsequently, this diversity gives rise to different types of information, which can be known or unknown, accurate or inaccurate, complete or incomplete depending on their interdisciplinary and interfunctional nature.

[110] Yazdi M., Hafezi P., Abbassi R. A methodology for enhancing the reliability of expert system applications in probabilistic risk assessment, Journal of Loss Prevention in the Process Industries, Volume 58, 2019, 51-59.

The second problem is more complex – while a promising tool for knowledge-based reasoning, expert systems still suffer from a lack of parameters such as weight and confidence factor, and are insufficient to accurately represent complex rule-based expert systems. The expert method is based on the generalized experience and intuition of specialists who have knowledge of the specifics of the transport process. To ensure the reliability of the results, the following requirements must be met (Table 3.1):

Table 3.1 Requirements for the reliability of the results of the expert method

Conditions of application	Contents
Optimal number of experts	Ensures representativeness of assessments and statistical reliability of results. Too little reduces reliability, excessive – makes it difficult to coordinate opinions.
Independence of expert opinions	Excludes the influence of one participant on the assessment of others. Each expert forms an assessment without the influence of other participants or management. This reduces the risk of group pressure and conformity.
Competence of experts	Guarantees the validity of conclusions. All participants must have professional knowledge, experience in the field of transportation and an understanding of the factors influencing the safety of goods.
Unambiguity of questions	Makes it impossible to double interpretation of tasks. The formulation of the questions should exclude different interpretations so that the evaluations are comparable.
Lack of influence of extraneous factors	Provides sincerity and impartiality of assessments. The examination process should not be influenced by administrative, economic or personal interests.

Continuation of Table.3.1

Unambiguity of answers and the possibility of their mathematical processing	The results of the peer review should be presented in a form suitable for generalization, ranking and statistical processing (for example, in points or ranks).

Source: compiled by the authors on the Dorussen H., Lenz H., Blavoukos S. Assessing the Reliability and Validity of Expert Interviews. European Union Politics. 2005. 6. 315-337. 10.1177/1465116505054835.; Yazdi M., Hafezi P., Abbassi R. A methodology for enhancing the reliability of expert system applications in probabilistic risk assessment, Journal of Loss Prevention in the Process Industries, Volume 58, 2019, 51-59.; Nance D. A. Reliability and the Admissibility of Experts. 2003. 191-249. http://dx.doi.org/10.2139/ssrn.463200

a. the identification process using an expert approach can be structured in several successive stages:
b. preparatory stage
c. determination of the purpose of identification;
d. formation of a group of experts;
e. development of questionnaires or questionnaires.
f. collection of expert assessments
g. individual or group survey;
h. formation of tables with the results of the assessment of risk factors.
i. processing the results
j. checking the consistency of experts' opinions;
k. determination of average estimates and weighting factors
l. risk analysis and classification
m. grouping factors by types (technical, organizational, natural, etc.);
n. identification of dominant (key) risks.
o. Formation of conclusions
p. building a risk map;
q. identification of priority areas for risk reduction;
r. preparation of a report for further quantitative analysis.

The results of risk identification directly depend on the level of qualification, experience and competence of the specialists involved.

Any expertise should be carried out by highly qualified and competent specialists who have practical experience in the field of road transportation, logistics, traffic safety or risk management.

Moreover, as noted by R. P. Thomas and A. Lawrence, "... When studying expert knowledge, it is important for researchers to take into account differences in the levels of professional competence in different fields.

A low level of professional competence may be due to the complexity of measuring criteria, the replacement of criteria with "gold standards", the limited amount of useful feedback or the lack of reliable and accurate means of supporting decision-making"[111].

To assess the level of training and professional reliability of experts, the reliability indicator (competence coefficient) is used. It is defined as the ratio of the number of cases when the expert's opinion coincided with the generalized results of the examination to the total number of examinations in which he participatedь:

$$К_n = \frac{N_{comparability}}{N_{\text{total}}} \tag{3.1}$$

where: $К_n$ – is the reliability coefficient of the expert;

$N_{comparability}$ – the number of cases of coincidence of the expert's assessments with the final decision of the commission;

N_{total} – is the total number of examinations in which the expert participated.

Reliability parameters are a measure of the random deviation of an expert from other experts encoding the same cases; Experts who code according to schemes similar to those of their colleagues obtain higher reliability scores and, therefore, contribute more to the evaluation of the latent concept.[112]

Moreover, when conducting an expert assessment of complex systems, it is advisable to quantify the competence of experts in two stages:

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[111] Thomas R.P., Lawrence A. Assessment of Expert Performance Compared Across Professional Domains, Journal of Applied Research in Memory and Cognition, Volume 7, Issue 2, 2018, 167-176.

[112] Marquardt K. L., Pemstein D., Seim B., Wang, Y. What makes experts reliable? Expert reliability and the estimation of latent traits. Research & Politics, 2019. 6(4). https://doi.org/10.1177/2053168019879561

– the first stage is a preliminary determination of the level of competence of experts in the formation of an expert group. In this case, the expert's competence coefficient is a quantitative assessment of the level of experience and professional knowledge of a potential member of the expert group about the object of expert assessment;

– the second stage is a refined assessment of the level of competence of experts immediately before calculating performance indicators using the results of expert assessments. In this case, the expert's competence coefficient will be a quantitative measure of the level of reliability of the results of the expert assessment of a particular expert.

An example of the formation of criteria for assessing the conformity of experts to identify the risks of non-safety of cargo is shown in Table. 3.2

Table 3.2 Criteria for assessing the competence of experts in identifying the risks of cargo non-safety

Evaluation criterion	Content of the criterion	Scoring range	Explanation and method of determination
Level of education	Compliance of education with the research profile (logistics, transport, transportation safety, risk management).	0–2	2 – full compliance; 1 – partial compliance; 0 – lack of specialized education.
Professional experience in the transportation industry	Duration of practical or scientific-practical activities in the field of road transport.	0–3	3 – more than 10 years; 2 – 5–10 years; 1 less than 5 years; 0 – no experience.
Experience in participating in examinations or scientific research	The number of previous participations in similar expert assessments or publications in the relevant topic.	0–2	2 – significant experience (5 or more cases or publications); 1 – minor experience 1-4 cases; 0 – lack of experience.

Continuation of Table.3.2

Knowledge of the regulatory framework and standards of transportation	Level of familiarity with current international and national standards (ADR, ADR, ISO 28000, DSTU, etc.).	0–2	2 – full and practical application; 1 – partial knowledge; 0 – does not own.
Practical skills in risk assessment	Ability to analyze risks, formulate influencing factors, work with analytical methods.	0–3	It is evaluated based on the results of test tasks or interviews.
Ability to reasoned judgment	Logic, reasonableness, clarity of presentation of opinions during discussions or questionnaires.	0–2	It is determined based on the results of a preliminary or trial examination.
Degree of reliability of judgments (competence coefficient)	Compliance of the expert's previous decisions with the results of the agreed examinations.	0–3	3 — $К_н$>0,9; 2 – $К_н$ =0,7–0,9; 1 – $К_н$ <0,7; 0 –missing data.
Motivation and interest	The degree of expert involvement, objectivity and impartiality of assessments.	0–1	1 – high interest, adherence to ethical principles; 0 – indifference or conflict

Source: compiled by the authors on the basis of Thomas R.P., Lawrence A. Assessment of Expert Performance Compared Across Professional Domains, Journal of Applied Research in Memory and Cognition, Volume 7, Issue 2, 2018, 167-176.;Velychko O., Gordiyenko T., Kolomiets V. Methodologies of expert's competence evaluation and group expert evaluation. Metallurgical and Mining Industry. 2015. 7. 262-271.

This approach makes it possible to assess the stability and reliability of expert judgments, as well as to use this data to gradually improve the quality of expert groups in future studies. To implement such a system, it is necessary to accumulate and analyze a large amount of information about the results of the work of experts in various commissions, which ensures a continuous process of professional selection.

A combined approach is used to determine the level of competence of experts[113], which includes:

– testing – experts are offered tasks similar to real ones, but with known (secret for them) correct answers. This allows you to assess their level of professional knowledge and practical skills.

– individual interview – is conducted in order to clarify the expert's level of understanding of the problem of cargo unsafety, knowledge of the technology of road transportation, factors influencing risks and experience in solving such problems.

– assessment of previous results of activity – if possible, the experience of participation in similar examinations, scientific or industrial achievements of the expert is taken into account.

The quantitative composition of the expert group also significantly affects the accuracy and stability of the results. With the increase in the number of experts, the accuracy of average assessments increases and the impact of subjective deviations decreases. According to the recommendations of methods[114] for applying expert methods, the minimum number of experts in the group should be at least 7 people.

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[113] Gärtner Q., Ronco E., Cagliano A.C., Reinhart G. Development of an Approach for the Holistic Assessment of Innovation Projects in Manufacturing Including Potential, Effort, and Risk Using a Systematic Literature Review and Expert Interviews. Appl. Sci. 2023, 13, 3221. https://doi.org/10.3390/app13053221.; Rousseau D., Stouten J. Experts and Expertise in Organizations: An Integrative Review on Individual Expertise. Annual Review of Organizational Psychology and Organizational Behavior. 024. 12. 10.1146/annurev-orgpsych-020323-012717.; Thomas R.P., Lawrence A. Assessment of Expert Performance Compared Across Professional Domains, Journal of Applied Research in Memory and Cognition, Volume 7, Issue 2, 2018, 167-176.

[114] Antoshchuk V., Filippov V., Kuvaieva V. Development of methodological support for improving the quality of expert assessment of business processes. Technology Audit and Production Reserves, 2021, 1(4(57), 22–27. https://doi.org/10.15587/2706-5448.2021.225336; Yazdi M., Hafezi P., Abbassi R. A methodology for enhancing the reliability of expert system applications in probabilistic risk assessment, Journal of Loss Prevention in the Process Industries, Volume 58, 2019, 51-59.; Velychko O., Gordiyenko T., Kolomiets V. Methodologies of expert's competence evaluation and group expert evaluation. Metallurgical and Mining Industry. 2015. 7. 262-271.

The optimal number, as a rule, is determined depending on the complexity of the object of study and the variety of risk factors. For complex transport and logistics systems, it is advisable to involve 9-15 experts, which will ensure a balance between the accuracy of assessments and the manageability of the examination process.

One of the most important requirements for the formation of an expert group is the consistency of opinions of its members, which characterizes the level of objectivity and stability of results.

During the preliminary formation of the group, control measurements (trial examinations) are carried out, followed by mathematical processing of the results.

To quantify the degree of agreement of experts' opinions, the concordance coefficient W is used, which is calculated by the formula:

$$W = \frac{12}{n^2(m^3 - m)} \quad (3.2)$$

where: S- is the sum of the squares of deviations of all assessments (ranks) of each object of examination from the mean value;

n -is the number of experts;

m -is the number of objects of examination.

The value of the concordance coefficient W varies from 0 to 1 W=0 means a complete disagreement of expert opinions, and W=1 means complete consistency of judgments. In the practice of expert assessments, it is considered that at W>0.7 the level of consistency is high, and the results of the examination are reliable.

The minimum value of the concordance coefficient is determined depending on the number of experts:

$$\left\{ \begin{array}{l} W_{min} = \frac{n-1}{n^2-1} \;\; if\ n\ is\ odd \\ W_{min} = \frac{n-2}{n^2-1} \;\; if\ n\ is\ even \end{array} \right. \quad (3.3)$$

The obtained value of the W indicator is compared with the tabular (critical) value according to the Pearson criterion (χ^2). If W is statistically significant, then the consensus of the experts' opinions is considered satisfactory.

In case of insufficient consistency of experts' opinions, when the obtained value of the concordance coefficient indicates a low degree of consistency, special corrective measures are taken, namely:

– additional discussions of the results of the examination are held in order to identify the reasons for the discrepancies;

– discussions are organized on real cases of non-preservation of goods;

– a second expert survey is carried out after clarifying the terminology, assessment criteria and conditions for the interpretation of risk factors.

Such actions make it possible to increase the objectivity of judgments, eliminate ambiguity of interpretations and achieve greater unanimity in determining priorities.

Depending on the form in which experts express their opinions, there are three main ways of conducting an examination:

1. Direct measurement. Experts determine the values of indicators in specific units of measurement – physical (SI), economic (hryvnia, standard hours) or relative (points, coefficients). This approach is applied when the evaluated characteristics can be quantified with sufficient precision.

2. Ranking. Objects (or factors) are ordered according to their degree of importance or preference. Each of them is assigned a rank - a serial number in a row. The higher the rank, the more significant the factor is considered. Ranking is effective in the presence of a relatively small number of factors between which hierarchical relationships can be easily established.

3. Comparison. It is used when it is difficult to directly assess or order factors by significance. There are two varieties of this method:

– sequential comparison, in which each object is compared with all those that have a lower rank;

– pairwise comparison, when each object is compared with each other.

Pairwise comparison allows you to obtain a quantitative matrix of mutual advantages, on the basis of which the weighting factors are calculated.

The results of pairwise comparisons are drawn up in the form of a matrix of pairwise comparison (Table 3.2), the elements of which reflect the superiority of one factor over another in relative units or points.

Table 3.2 Example of a pairwise matching matrix

	A	B	C	D
A	1	3	4	2
B	1/3	1	2	1/2
C	1/4	1/2	1	1/3
D	1/2	2	3	1

On the basis of this matrix, the weighting factors used in the complex model for assessing the risks of non-safety of goods are further calculated.

For example, we have m factorsV1,V2,…,Vm.

Each expert is invited to compare them in pairs and enter the results into the matrix of paired comparisons.

S=|s(k,p)|m×m1 where each element s(k,p) is defined by the rule:

$$\{s(k,p) = \begin{cases} 1, \mathit{if\ Vk\ is\ more\ significant\ than\ Vp}, \\ 0{,}5, \mathit{if\ Vk\ and\ Vp\ are\ equivalent} \\ 0, \text{if}\ \mathit{Vp\ is\ more\ significant\ thanVk} \end{cases}$$

Thus, each element of the matrix reflects the result of a comparison of two factors. Next, only the lower part of the matrix (below the main diagonal) is filled.

– V1 is first compared with V2,V3,...,Vm;

– then V2 with V3,...,Vm;

– and so on.

Elements above the main diagonal are determined automatically according to the rule: V(p,k)=1−V(k,p),
and the elements on the main diagonal take a value of 0.5, since the factor is equivalent to itself.

Table 3.3 Example of filling in the matrix for one expert

Factor	V_1	V_2	V_3	V_4
V_1	0,5	1,0	0,5	0,0
V_2	0,0	0,5	1,0	0,5
V_3	0,5	0,0	0,5	1,0
V_4	1,0	0,5	0,0	0,5

Thus, from table 3.3 it can be seen that V1 is more significant than V2, but less significant than V4.

After each expert has filled in their S matrix, for each factor Vk, the total value of the points is calculated according to the formula:

$$B(j,k) = \sum_{p=1}^{m} V(j,k,p) \quad (3.4)$$

where: j -is the number of the expert,

k -is the number of the evaluated factor,

V(j,k,p) -is the result of comparing the factor Vk with Vp by this expert.

The resulting sums of B(j,k) show the relative significance of the factors for each expert.

Based on these total points, each factor is assigned a rank R(j,k): the largest sum of points corresponds to rank 1, the next – rank 2, and so on.

If the examination is carried out by n experts, then a summary table is formed, which reflects:

– total points of each expert for each factor;

– appropriate ranks.

Next, for each factor, the average values of the sum of points and average ranks are calculated, which are used to analyze the consistency of experts' opinions, in particular when determining the concordance coefficient W.

The total value for all experts is determined by the formula:

$$B(k) = \sum_{j=1}^{n} B(j,k) \quad (3.5)$$

and the determination of the rank of the factor based on the results of the experts is as follows: R(k)=f(B(k))(in descending order of points).

Table 3.4 Example of filling in the matrix for n experts

№ expert	B_1	B_2	B_3	B_4	…	R_1	R_2	R_3	R_4	…
1	2,0	2,5	3,0	2,5	…	4	3	1	2	…
2	1,5	3,0	2,5	3,0	…	4	1	3	2	…
…	…	…	…	…	…	…	…	…	…	…

The ranked factors of non-preservation of cargo as a result of the conducted pairwise comparison will be a factor space for the development of a model for assessing the risk of non-preservation of cargo, provided that the consensus of experts' opinions is achieved.

In our study, the methodology of multi-criteria decision-making (MCDM)[115], in particular the analytical hierarchy (AHP)[116] method, will be used to systematically analyze and prioritize the risks of cargo non-conservation, which allows pairwise comparisons between many criteria to obtain relative weights that quantitatively reflect the collective assessments of experts. This is due to the following considerations:

– factors of non-safety of goods have different physical nature (mechanical, climatic, organizational, human, etc.), so it is difficult to compare them in common units of measurement;

– the point scale does not always adequately reflect the real degree of influence of factors on the result, since the score in points is conditional;

– the method of pairwise comparison makes it possible to obtain a structured matrix of decisions, in which the superiority of one factor over another is recorded;

– double pairwise comparisons (with a change in the order of objects) helps to reduce the influence of psychological biases associated with the sequence of presentation of factors.

In the method of analytical hierarchy (AHP), on the basis of pairwise comparisons of criteria and individual indicators, the choice of the best of the proposed alternatives, the characteristics of which are vectors with heterogeneous, including with vaguely defined, separate components is justified (Fig. 3.1). Therefore, when comparing values, it is possible to work not only with numbers (formalized indicators), but to draw logical conclusions in verbal form (non-formalized indicators).

[115] Ishizaka A., Mu E. What is so special about the analytic hierarchy and network process? Ann Oper Res 2023. 326, 625-634.; Zagurskiy O., Savchenko L, Ohiienko A., Zagurska S., Domin O. Methodology for the formation of the company's logistics service system. Proceedings of 23st International Scientific Conference Engineering for Rural Development 22-24.05.2024 Jelgava, LATVIA. 105-112.

[116] Madzı´k P, Fala´t L State-of-the-art on analytic hierarchy process in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modelling. PLoS ONE . 2022. 17(5): e0268777. https://doi.org/10.1371/journal. pone.0268777; Petrillo, A.; Salomon, V.A.P.; Tramarico, C.L. State-of-the-Art Review on the Analytic Hierarchy Process with Benefits, Opportunities, Costs, and Risks. *J.* Risk Financial Manag. 2023, 16, 372. https://doi.org/10.3390/jrfm16080372

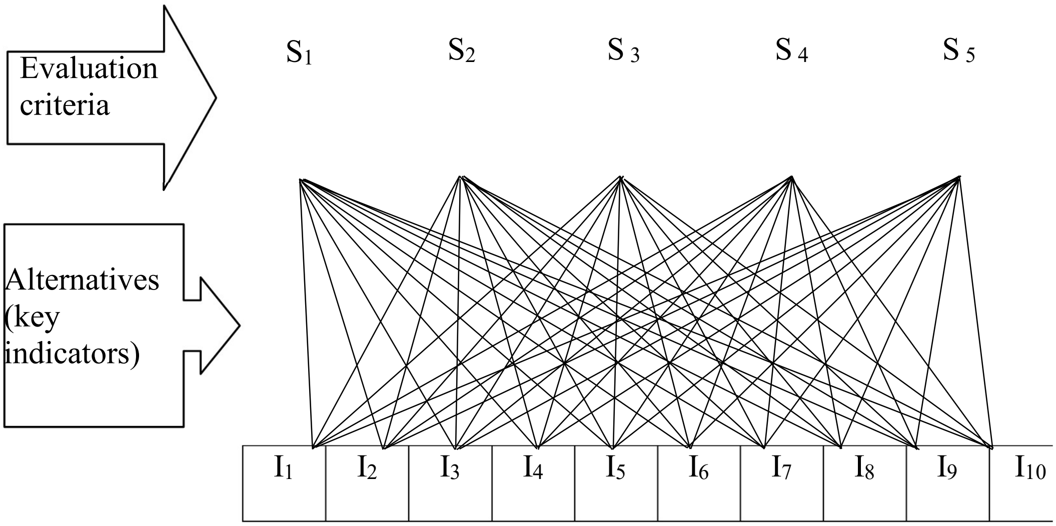

Fig. 3.1 Hierarchy of selection of a set of key factors when assessing the risks of non-safety of goods

Source: compiled by the authors

The algorithm for applying the analytical hierarchy method is as follows.

1. Before performing the procedure of pairwise comparisons of elements for each level of the hierarchy, the considered alternatives are evaluated for their Pareto optimality. Those alternatives that are known to be losing (not optimal according to Pareto) are excluded from the analysis.

2. The sum of the ranks of alternatives (key indicators) is determined, the lower the sum of ranks, the higher the priority of the factor

3. A matrix of paired comparisons is built according to the following rule:

$$a_{ij} = \frac{w_i}{w_j} \tag{3.6}$$

4. The weights of the alternatives are determined by the formula for normalizing the inverse ranks:

$$w_i = \frac{1/S_i}{\sum_{j=1}^{n} 1/S_j} \tag{3.7}$$

This allows you to obtain dimensionless coefficients, interpret wi as a fraction of the influence of the factor and provide the condition:

$$\sum_{i=1}^{n} w_i = 1 \quad (3.8)$$

Which, in turn, ensures a correct comparison of factors with each other.

5. The integrated risk index is defined as the weighted sum of normalized factor risks:

$$R_{int} = \sum_{i=1}^{n} w_i \times r_i \quad (3.9)$$

where: wi -is the weight of the factor and;

ri -is the risk level of factor i;

N- is the number of factors.

Thus, the pairwise comparison method in combination with the calculation of the concordance coefficient provides:

– objectivity and validity of the results of the expert assessment;

– the possibility of quantitative reflection of qualitative judgments of experts;

– checking the consistency of assessments at the statistical level;

– formation of reliable weight coefficients of risk factors for further mathematical modeling.

3.2 Formalization of risk factors for non-safety of goods

Taking into account the complexity and multifactoriality of the risks of non-safety of goods, it is not advisable to assess their admissibility on the basis of classical methods of risk management. First of all, this is due to the need to use both statistical (formalized) and expert (non-formalized) indicators that characterize the level of a particular risk. Moreover, the complexity of the object of study determines the need to allocate fuzzy evaluation intervals, and are also characterized by the level of confidence of the expert in the conclusions made. Therefore, one of the most suitable for building a model for assessing the level of admissibility of risks of cargo non-safety, in our opinion, will be a vague-multiple approach.

Building a model for assessing the risk of non-safety of goods using fuzzy logic[117] includes the following steps:

[117] e Ru W.G., Eloff J.H.P. Risk analysis modelling with the use of fuzzy logic, Computers & Security, Volume 15, Issue 3, 1996, 239-248.

1. Independent variables, consequential factors that affect the value of the dependent variable, are selected.

2. Fuzzy sets of values for independent and dependent variables are described. In this case, linguistic terms are used instead of numerical values.

3. The withdrawal rules are described. Each rule is written in the form "if" (the independent variable is equal to the value), "then" (the dependent variable is equal to the value). At the same time, the linguistic terms described in paragraph 2 are used as "meanings".

4. Based on independent variables and inference rules, fuzzy sets of the dependent variable are generated. Software tools are usually used to implement this step.

5. The result is then used for informed decision-making.

Formalization of cargo non-safety risks is the process of presenting the characteristics of individual risk factors in quantitative form within a single scale for assessing the risk of its non-safety. The formalization procedure is designed to form a factor space and further build a mathematical model. It is the next stage after the identification of factors and is based on the dominant factors determined during this procedure.

The need for formalization is due to the fact that some of the factors have only a qualitative (verbal) assessment, which needs to be translated into a quantitative form. To describe such parameters, it is advisable to use triangular or trapezoidal fuzzy numbers that allow you to take into account the uncertainty within the permissible values.

1. According to the theory of fuzzy sets[118], the concept of a unimodal fuzzy number of the LR-type is used to represent uncertain quantities, which is given by a trio of parameters:

$$A = (a, \alpha, \beta), \tag{3.10}$$

where a- is the mean value (mode) of the fuzzy number;

α and β -are the left and right boundaries of possible variations of a fuzzy number, respectively.

[118] Fuzzy Sets and Fuzzy Logic: Theory and Applications. By George J. Klir and Bo Yuan. Prentice Hall: Upper Saddle River, NJ, 1995. 574.; Gupta M.M. Ragade R.K. Fuzzy set theory and its applications: A survey, IFAC Proceedings Volumes, Volume 10, Issue 6, 1977, 247-259.

For such a fuzzy number, the function of belonging to the variable x of the universe X is of the form:

$$\mu_A(X)\begin{cases}\{L(\frac{a-x}{\alpha}), \text{if x} \leq \text{a} \\ \{R(\frac{x-a}{\beta}), \text{if x} > \text{a} \\ 0, \ in\ other\ cases\end{cases} \tag{3.11}$$

where L and R- are respectively the left (ascending) and right (descending) parts of the fuzzy number belonging function (Fig. 3.2).

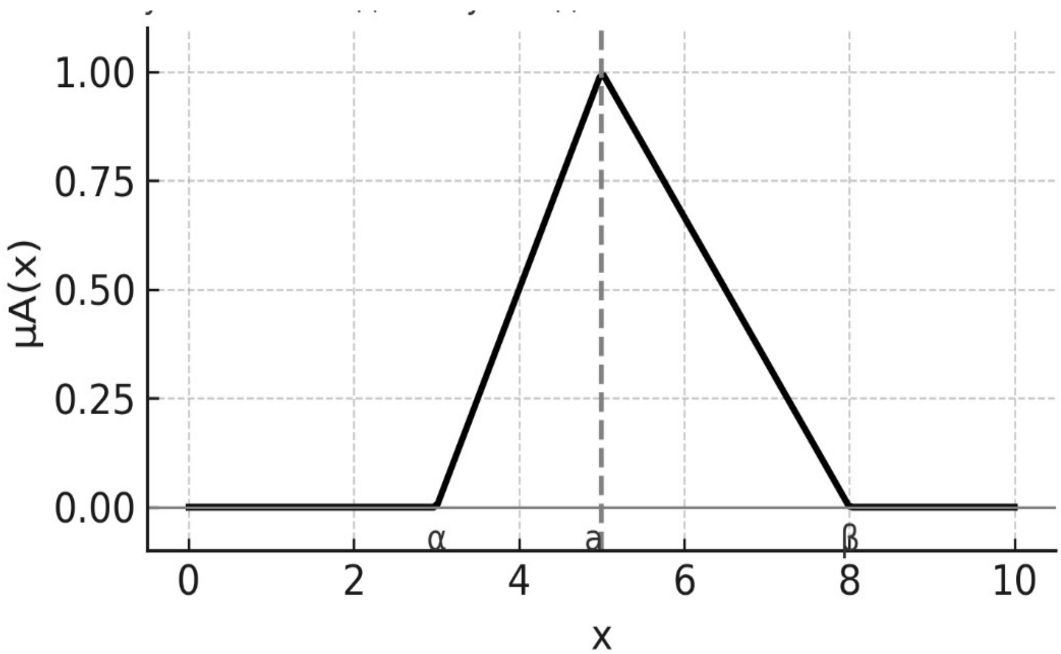

Fig. 3.2 Representation of a Unimodal Fuzzy LR-Type Number
Source:González Campos, J.A., Manríquez Peñafiel R.A. A Method for Ordering of LR-Type Fuzzy Numbers: An Important Decision Criteria. *Axioms* 2016, 5 22. https://doi.org/10.3390/axioms5030022

Fuzzy set theory and fuzzy logic form the basis of the linguistic approach, within which the variables involved in the analytical description of the model can take on linguistic values (for example: low, medium, high risk, etc.).

For further processing, the values of the variables are normalized by the formula:

$$X_j^c = \frac{X_j - X_j^{average}}{\Delta X_j} \tag{3.12}$$

where X_j^c – normalized (standardized) value of the variable;

X_j – the actual value of the variable based on the results of observations;

$X_j^{average}$ – the average value of the variable;

ΔX_j – the interval of change of the variable between terms (gradations of the linguistic scale).

According to R. Barker and R. Imhoff[119] human perception of the world is based on an oppositional scale, in which only extreme values are indicated, and the middle corresponds to a neutral level between them. The intermediate values of the scale are formed by further dividing the scale, so that experts can rank their conceptual assessments.

Oppositional scales and terms of quality are developed in accordance with the chosen methodology for each individual factor. Quantitative and qualitative information is described in the form of tables, graphs, nomograms, formulas, procedures, ranges of change, fuzzy values, behavior patterns, and comparison relations.

However, in many cases, there is a need to obtain additional conclusions about these quantities based on a minimum amount of data, which were not previously explicitly defined. However, such assessments, as a rule, are conditional and subjectively true only under certain circumstances and within established limits. Therefore, in complex decision-making problems, it is quite difficult to rely on discrete algorithms that could provide the only correct and unambiguous solution[120].

However, in modern decision-making theory, there are a number of methods that make it possible to formalize the decision-making process, including in the context of multiple criteria that

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[119] Barker P., Imhoff R. The dynamic interactive pattern of assimilation and contrast: Accounting for standard extremity in comparative evaluations, Journal of Experimental Social Psychology, Volume 97, 2021, 104190

[120] Boche H., Fono A., Kutyniok G. Mathematical algorithm design for deep learning under societal and judicial constraints: The algorithmic transparency requirement, Applied and Computational Harmonic Analysis, Volume 77, 2025, 101763.

interact in a fuzzy environment. Therefore, before carrying out the transformation, it is necessary to formalize the information embedded in the input data.

The theory of fuzzy sets operates in a language close to natural human concepts and ideas. The use of linguistic variables makes it possible to translate such concepts as "high", "medium", "low" degree of parameter manifestation, etc., to a clearly mathematical level, as well as to conduct surveys of experts using professional terminology of a specific subject area.

A fuzzy variable is characterized by a set of components:

$$<x,T,D>, \qquad (3.13)$$

where x – name of the linguistic variable;

T – a term set or a set of its possible values;

D – the area of definition of these values.

The values of linguistic variables are words, not numbers. It is defined as a tuple

$$(a, T, X, G, M), \qquad (3.14)$$

where a – name of the linguistic variable;

T – the basic term set of a linguistic variable, or a set of its values (terms), each of which is the name of a separate fuzzy variable;

X – the domain of definition (universe) of fuzzy variables included in the term set;

G – a syntactic rule that generates from the basic term set T many new values of the linguistic variable that make sense for a particular situation;

M – a semantic rule that matches each value of a linguistic variable obtained by rule G with some fuzzy set of values.

In this case, a comprehensive assessment of the risk of non-preservation of cargo can be expressed through a linguistic variable, and its values will be linguistic terms (for example: low, medium, high risk level).

An oppositional scale containing k values of a linguistic variable is a scale with k−1 equally perceived intervals.

Its divisions are located on the psychological continuum at equal distances, so errors in the classification of the values of linguistic terms are equally probable (Table 3.5).

Table 3.5 Oppositional scale of the linguistic variable "Risk level"

Linguistic term	Designation	Numerical interval (normalized)	Characteristics (qualitative description)
Very low	VL	0,0 – 0,1	There is practically no risk, conditions are stable
Low	L	0,1 – 0,3	The risk is negligible, the influence of factors is minimal
Medium	M	0,3 – 0,5	There is a moderate probability of manifestation of risk
High	H	0,5 – 0,7	The probability of risk realization is significant
Very high	VH	0,7 – 1,0	The risk is critical, with a high probability of causing losses

Source: compiled by the authors

A graphical representation of such a scale is shown in Fig. 3.3

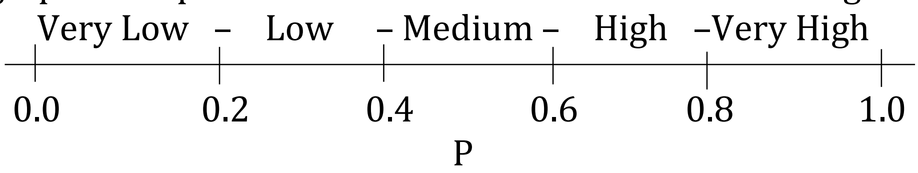

Fig. 3.3 Graphical representation of the oppositional scale of the linguistic variable "Risk level"

Such a scale is oppositional, since its extreme terms ("very low", ↔ "very high") are opposed to each other, and the middle ("medium") has a neutral value. The marking of intermediate values is achieved by further distributing the scale, and thus the experts rank their conceptual evaluations.

The main purpose of the risk matrix is to analyze the risks that exist in various factors, as well as to analyze the risks inherent in the implementation of one of the factors.

3.3 Mechanism for the formation of a comprehensive assessment of the risk of non-safety of goods

The assessment of the risks of non-safety of goods during road transportation assesses the threats faced by logistics companies in the process of transportation, shows their existing weaknesses, consequences and risks caused by the combined impact of all factors. The main elements of the cargo non-safety risk assessment process are general (identification of events that may occur, identification of potential outcomes (consequences) and description of related uncertainties) and include a set of basic steps:

1. Defining the context: identifying and defining the scope and objectives of the process.

2. Risk assessment: identification of key events/hazards, their potential consequences and uncertainties associated with these events and consequences.

3. Assessment: Analysis of the results of risk assessment and identification of priority options.

4. Solution: Selection and start of implementation of options[121].

However, the complexity of obtaining reliable samples of large volume implies the choice of such a method of convolution of heterogeneous information, which does not depend on the size of the sample and allows you to study the phenomenon of the formation of the risk of non-preservation of cargo during road transportation. It can be based on stratification methods (division into homogeneous groups) or probable methods that will reduce the impact of sample size on accuracy and investigate risks through expert assessments or analogy methods.

[121] Glette-Iversen I., Flage R., Aven T. Extending and improving current frameworks for risk management and decision-making: A new approach for incorporating dynamic aspects of risk and uncertainty, Safety Science, Volume 168, 2023, 106317.

Moreover, such a convolution technique should simultaneously take into account both the influence of a single factor on the integrated fitness indicator and their interaction. However, generally accepted methods of expert assessment[122], based on point assessment, have a significant drawback, which limits the possibility of using statistical methods in full. In particular, the construction of regression equations on their basis is fundamentally impossible[123]. As for multiple regressions on "passive experiment"[124] data, they are also not entirely suitable for modeling due to the presence of multicollinearity between variables.

In view of this, for further processing of expert data and building a model for assessing the risk of cargo non-safety during road transportation, it is proposed to apply a complex method of logical-linguistic modeling[125], which is a synthesis of the theory of experimental planning (in particular, the algorithm of the analytical hierarchy method (MAI)) and elements of linguistic variables of the theory of fuzzy sets. It provides the formalization of experts' knowledge in the form of an analytical expression of the polynomial type:

$$Y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} \sum_{j \neq 1}^{n} b_{ij} x_i x_j + \ldots \qquad (3.15)$$

[122] Karoulis A., Demetriadis S., Pombortsis A. Comparison of expert-based and empirical evaluation methodologies in the case of a CBL environment: the “Orestis” experience, Computers & Education, Volume 47, Issue 2, 2006, 172-185.; Reed M.S., Ferré M., Martin-Ortega J., Blanche R., Lawford-Rolfe R., Dallimer M., Holden J. Evaluating impact from research: A methodological framework, Research Policy, Volume 50, Issue 4, 2021, 104147.

[123] Sluijterman L., Cator E., Heskes T. How to evaluate uncertainty estimates in machine learning for regression?, Neural Networks, Volume 173, 2024, 106203.; Tedoldi D., Kim B., Sandoval S., Forquet N., Tassin B., Position paper: Common mistakes and solutions for a better use of correlation- and regression-based approaches in environmental sciences, Environmental Modelling & Software, Volume 192, 2025, 106526.

[124] Marwan N., Kraemer K.H. Trends in recurrence analysis of dynamical systems. Eur. Phys. J. Spec. Top. 232, 2023, 5-27. https://doi.org/10.1140/epjs/s11734-022-00739-8

[125] Dignum F., vab de Riet R.P. Knowledge base modelling based on linguistics and founded in logic, Data & Knowledge Engineering, Volume 7, Issue 1, 1991, 1-34.; Chen S., Liu J., Wang H., Xu Y., Augusto J., A linguistic multi-criteria decision making approach based on logical reasoning, Information Sciences, Volume 258, 2014, 266-276.; Zagurskiy O., Yukhymenko P., Sokolska T., Paska I, Lobunets V., Zhytnyk T., Zharikova O. «Management Models and Evaluation of Reputation Risks» International Journal of Recent Technology and Engineering, 2019. Volume 8 Issue-3S3. 136-141.

In which the coefficients bj are determined by the formula:

$$b_j = \frac{1}{N}\sum_{i=1}^{n} x_{ij}Y_i \qquad (3.16)$$

where: x_{ij}, Y_i – respectively, the values of the independent and dependent variables for the i-th row and the j-th column of the computational matrix;

N – the number of lines of the survey matrix (production rules);

j – indices of all coefficients of equation (3.15) in the range from j=1 до j=Q−k_j:

Q = 1 + $C_1^n + C_2^n + C_3^n$ – the total number of coefficients of a polynomial of the third degree as the sum of combinations of variables;

k – the number of rejected (insignificant) coefficients.

The use of the method of analytical hierarchy (MAI) allows, along with mathematical procedures, to take into account psychological aspects, namely the subjective assessment of experts' judgments.

In particular, it allows:

– to structure a complex problem of decision-making in the form of a hierarchy in an accessible and rational way;

– compare and quantify alternative solutions in order to choose the best one, taking into account the benefits of ODA.

The use of the mathematical apparatus of fuzzy sets is due to the following reasons:

– insufficient statistical data on cases of non-preservation of cargo in road transport, taking into account the influence of external and internal factors:

– the presence of qualitative factors that do not have a quantitative expression and can only be evaluated verbally, which complicates the determination of the limits of their variation;

– non-linear and implicit nature of the impact of non-safety factors on the risk of damage, loss or damage to the cargo during transportation:

– the practical impossibility of conducting full-scale experiments in the required volume.

Also, the use of an integrated approach allows:

– summarize (collapse) expert judgments, taking into account both the individual influence of individual factors and their combined effect on the comprehensive risk assessment;

– change the parameters in accordance with the specifics of the characteristics under study.

– to ensure the transition to a formalized mathematical description of such qualitative concepts as "high", "low" level of manifestation of factors. Thanks to this, an integral assessment of the risk of non-safety of cargo can also be presented in the form of a linguistic variable, which simplifies the use of expert knowledge during the survey.

According to the method of logical-linguistic modeling, the expert survey matrix is a set of production rules of the implicative form of the form "IF ..., THEN ...". The part of the rule that is located after the word "if" is called a premise, condition or product, and the part after "that" is called a conclusion or transaction.

In the matrix, the values of the variables are labeled at the boundaries of the intervals of variation with the values "–1" and "1", which corresponds to the lower and upper limits, respectively. The number of rows of the matrix is determined by the number of requests to the expert and is clearly determined and, given the smallness of the full factor experiment, is given by the expression:

$$N=2^n, \tag{3.17}$$

where: n – number of factors.

Accordingly, the survey matrix takes the form of:

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{p1} & a_{p2} & \dots & a_{pn} \end{pmatrix} \tag{3.18}$$

The two key properties of the matrix are orthogonality and rotaability. Orthogonality ensures the independence of variables, which corresponds to the logic of human thinking from a psychological point of view, because the expert only assumes the presence of relationships between the variables, but does not have accurate information about them. Rotability, in turn, means that the information contained in the regression equation is evenly distributed within the sphere of the factor space, i.e. the errors are "the same" in all directions, which also corresponds to the essence of expert assessment, since the expert does not know in advance in which region of the response surface the studied area is located.

Both properties are of particular importance in cases where input variables form a factor space for extracting implicit expert knowledge.

After filling in the survey matrix, the experts calculate the coefficients of the regression equations. Further, statistically insignificant coefficients are discarded, the numerical values of which are less than the threshold error.

The error of a numerical experiment is determined by the formula:

$$S_{b_j} = t\frac{S_{error}}{\sqrt{N}} \quad (3.19)$$

where: t – critical importance of the Student's criterion;

N – the number of degrees of freedom;

S_{error}– error threshold of expert assessment.

The adequacy of the obtained polynomial to the phenomenon under study is checked by standard statistical methods by the formula:

$$F = \frac{S^2_{\text{final}}}{S^2_{\text{errors}}} \quad (3.20)$$

where: S_{final} – residual dispersion,

S_{errors}– threshold error of expert assessment.

$$S^2_{\text{final}} = \frac{\sum_{i=1}^{N}(Y_{\text{exp}}-\hat{Y})^2}{k} \quad (3.21)$$

where: Y_{exp} – numerical assessment of the expert;

$\hat{Y}$ – pthe calculated value according to the regression equation;

k – the number of rejected polynomial coefficients;

On the basis of the selected mathematical apparatus for folding heterogeneous information, as well as the procedures of identification and formalization, we have developed an algorithm for forming a comprehensive assessment of the risk of non-safety of cargo during road transportation (Fig. 3.4).

The proposed algorithm is a sequence of processes of qualitative and quantitative analysis of the risk of non-safety of cargo, which provide a systematic quantitative assessment of the risk for a specific type of transportation.

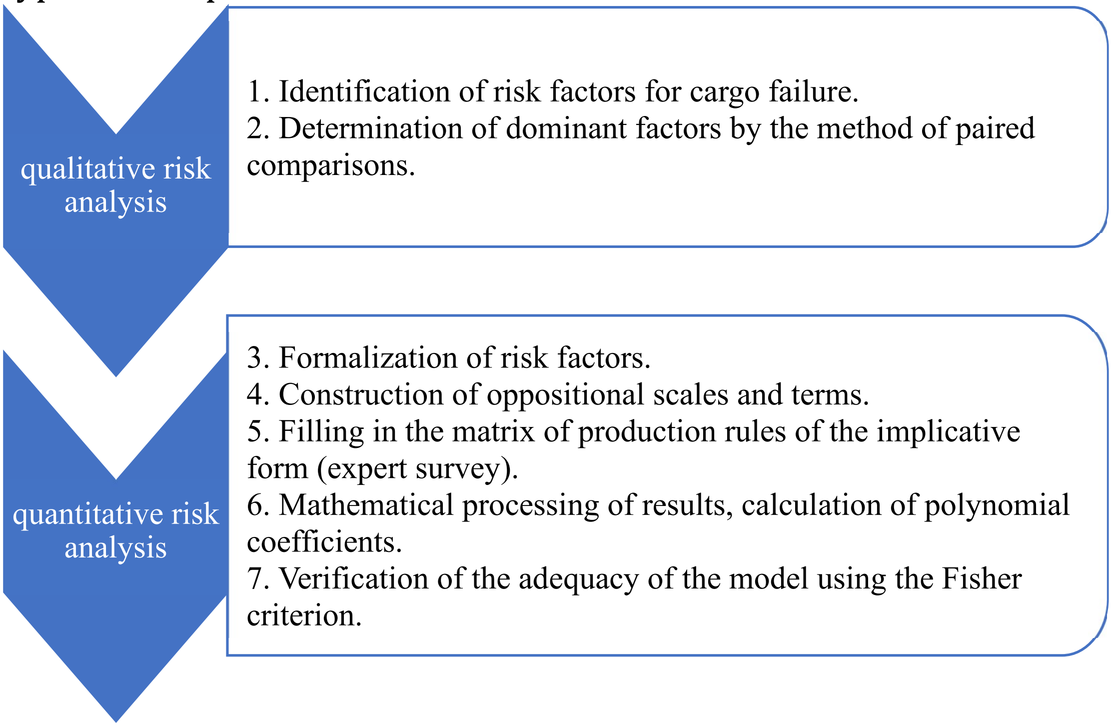

Fig. 3.4 Algorithm for the formation of a comprehensive assessment of the risk of non-safety of goods during road transportation

Source: compiled by the authors

The first stage is to identify the risks of non-safety of cargo by forming a factor space. At this stage, a nomenclature of factors of non-safety of cargo, including factors of environmental influence, is formed, taking into account the specifics of a particular type of transportation.

At the second stage, in order to reduce the dimensionality of the task and focus on the most significant factors, the method of paired comparisons of expert assessments is used (in particular, the hierarchy analysis approach).

Experts compare the factors with each other according to the degree of influence on the risk of cargo non-safety, as a result of which their relative weight coefficients are determined. Dominant factors are considered to have the highest values of weights and have a decisive influence on the formation of integral risk. The use of the method of paired comparisons is advisable due to the complexity of the object under study and the possible difficulties that experts have during the direct ranking or scoring of each factor of cargo unsafety.

At the third stage, the formalization of risks is carried out, which involves the choice of methods for quantifying the dominant factors of cargo non-safety and environmental factors. The selected dominant factors are translated from a qualitative description into a formalized form suitable for further mathematical analysis.

Each factor is corresponded to by a variable that characterizes the level of its manifestation. Formalization allows you to establish clear boundaries of factor values and prepare them for use in the model of fuzzy logical inference or regression analysis.

At the fourth stage, opposition scales and terms for each factor are developed, values are encoded according to a single system.

Each term is described by membership functions reflecting the degree of manifestation of risk factors. This approach allows you to combine the quantitative and qualitative characteristics of the transport process in a single model.

The construction of scales and terms takes into account industry terminology, each qualitative characteristic is set by the selected technique with the appropriate scale. The transition of all initial values for each factor to a single standardized scale makes it possible to compare them with each other and identify statistically insignificant coefficients of the equation against the background of the error.

At the fifth stage, an expert survey is carried out, during which experts fill in the lines of the matrix that look like production rules of implicative form ("If ..., then ..."). The number of rows of the matrix N corresponds to the number of requests to the expert. To reduce the burden on experts and avoid the need to process large amounts of data, a half-replica of the full factor experiment N=2n is used, where n is the number of factors.

At the sixth stage, mathematical processing of the survey results is carried out, in particular: calculation of the coefficients of the regression polynomial; discarding statistically insignificant coefficients, the values of which do not exceed the error threshold.

An analytical model is formed in the form of a polynomial, the coefficients of which determine the contribution of each factor to the overall level of risk.

The obtained polynomial allows you to calculate the integral indicator of the risk of cargo non-safety for specific conditions of transportation.

The last, fifth stage, involves checking the adequacy of the obtained model to the phenomenon under study using standard statistical methods. The application of the Fisher criterion makes it possible to check the statistical significance of the model and confirm the feasibility of its use to predict the level of risk of non-safety of goods in real conditions of road transportation.

This allows you to assess the compliance of the mathematical model with real data and confirm its suitability for practical use.

The proposed algorithm provides an integrated approach to assessing the risks of non-safety of goods, combining expert knowledge with formal methods of mathematical analysis. Its use allows you to contribute to the reduction of cargo losses in supply chains.

3.4 Application of the methodology for assessing the risks of non-safety of goods

Cargo transportation covers the processes of organization and transportation. Accordingly, the risks of non-safety of the cargo arise from the moment of acceptance of the cargo to transportation and may manifest themselves in cases of its partial or complete loss, damage or spoilage.

Based on the analysis of the results of previous studies on the problem of non-preservation of goods and the application of a systematic approach, we have formed a nomenclature of the main factors of non-preservation of cargo during road transportation: internal (Table 3.6) and external (Table 3.7).

Table 3.6 Nomenclature of factors of the internal environment of cargo non-safety during road transportation

Cargo non-safety factor	Design ation Factopy	Structure of the factor	Properties of the factor	The reason for the need to take into account
Cargo packing	F1	- packaging condition; -compliance with the type of cargo packaging	Packaging is the outer "shell" of the cargo, which provides its protection from external influences and mutual friction of elements	Performs a protective function during transportation
Cargo marking	F2	- labeling compliance	Provides information determination of possible cargo operations	Cargo manipulations are carried out in accordance with the marking
Loading of cargo	F3	- loading method; - means of loading; - caution during loading	The loading procedure directly affects the condition of the cargo when it is moved into the body of the vehicle	Determines the degree of mechanical impact on the load
Placement of cargo in the body of the vehicle	F4	-distribution of cargo; - cargo separation	Uniform distribution of the load reduces the effect of inertial forces and prevents mutual damage to its components	Ensures stability and safety of transportation

Continuation of Table. 3.6

Securing the cargo	F5	- condition of fastening; - method and means of fixation	Provides suppression of inertial forces acting on the load and vehicle	Improper fastening is the cause of damage to the cargo
Unloading cargo	F6	- unloading method; - means of unloading; - caution during unloading	Direct impact on the load during unloading from the body	Risk of damage during movement
Driver qualification	F7	-psychophysiological state; - personal qualities; - Driving experience	The movement of the load occurs as a result of the driver's actions (acceleration, braking, maneuvers)	Control affects the occurrence of inertial forces acting on the load

Source: compiled by the authors based on expert opinions

Table 3.7 Nomenclature of factors of the external environment of cargo non-safety during road transportation

Factor	Designation	Structure of the factor	Properties of the factor	The reason for the need to take into account
Natural and climatic impact	Z1	- weather conditions; - natural factors	Determine the traffic situation	Form a risky transportation environment
Political influence	Z2	- hostilities; - socio-economic conditions; - administrative restrictions	Reflects a complex of external and internal economic factors	Socio-political instability

Continuation of Table. 3.7

Accident rate	Z3	- traffic accidents	Accidents create a direct mechanical effect on the cargo	Probability of damage or loss of cargo
Criminal actions	Z4	- illegal actions in relation to cargo or vehicle	Criminal actions aimed at the transportation process	Risk of theft or damage
Technical condition of the vehicle	Z5	- the state of the main vehicle systems; - condition of the body and equipment	The vehicle is the carrier of the cargo	A technical malfunction can lead to loss of cargo
Cargo condition	Z6	- production status; -transportability	The characteristics of the cargo determine its resistance to influences	The cargo itself can be a source of risk
Supporting documents	Z7	- cargo information; -transportation instructions	Determine transportation parameters and requirements for transportation conditions	Non-compliance of documents can lead to violations of transportation regimes
Road impact	Z8	- condition of the coating; - curvature of the road; - information support (signs)	Forms vibration and mechanical effects on vehicles and cargo	Inertial forces directly affect the condition of the load

Source: compiled by the authors based on expert opinions

During the development of the nomenclature of the main factors of non-safety of cargo during road transportation, the opinion of the experts involved was taken into account, which ensured the representativeness and complexity of the selection of factors.

Further, a questionnaire of experts was conducted to determine the level of influence of internal and external environmental factors on the non-safety of goods during road transportation and the ranks of influence of each of the factors were determined.

The examination was attended by 10 experts who are specialists in the transport sector, have relevant knowledge about the specifics of the risks of non-safety of goods and meet the requirements of competence, objectivity and other criteria specified in section 3.1. Summary tables of processing expert questionnaires are presented in Tables 3.8, 3.9.

Table 3.8 Summary table of processing questionnaires of factors of the internal environment of non-preservation of cargo during road transportation

Internal environmental factors	Packaging cargo	Cargo marking	Loading of cargo	Placement of cargo in the	Fasteners cargo	Unloading cargo	Qualifications driver
Expert 1	5	6	1	3	1	2	5
Expert 2	2	7	4	4	6	3	1
Expert 3	6	6	3	2	2	4	3
Expert 4	4	6	5	2	1	6	5
Expert 5	2	5	6	5	2	7	1
Expert 6	5	5	4	6	1	6	2
Expert 7	5	5	4	1	2	5	4
Expert 8	5	6	4	2	1	7	3
Expert 9	4	3	5	4	2	5	6
Expert 10	4	5	5	3	2	7	2
Sum of ranks	42	54	41	32	20	52	32

Source: compiled by the authors based on the results of processing expert questionnaires

Table 3.9 Summary table of processing questionnaires on the impact of environmental factors of non-preservation of cargo during road transportation

Environmental factors	Natural and climatic impact	Political influence	Accident rate	Criminal actions	Technical condition of the vehicle	Cargo condition	Supporting documents	Road impact
Expert 1	6	7	2	1	4	8	5	4
Expert 2	7	8	6	5	1	7	4	2
Expert 3	5	6	2	5	4	8	5	3
Expert 4	1	7	6	4	5	7	3	1
Expert 5	3	6	3	6	5	6	7	2
Expert 6	2	8	5	5	6	7	5	1
Expert 7	1	6	7	3	6	8	6	2
Expert 8	2	4	5	6	3	7	6	2
Expert 9	3	6	7	2	3	8	6	2
Expert 10	3	8	4	1	6	7	5	3
Sum of ranks	33	66	47	38	43	73	53	22

Source: compiled by the authors based on the results of processing expert questionnaires

To carry out the risk identification procedure, i.e. to determine the dominant risk factors of cargo non-safety during road transportation, in accordance with the method of analytical hierarchy (AHP), matrices of paired comparisons for internal and external environmental factors were compiled (Tables 3.10, 3.11).

Table 3.10 Matrix of paired comparisons for environmental factors of non-safety of cargo during road transportation

	F1	F2	F3	F4	F5	F6	F7
F1	1	2	1	1/2	1/3	2	1/2
F2	1/2	1	1/2	1/3	1/4	1	1/3
F3	1	2	1	1/2	1/3	2	1/2
F4	2	3	2	1	1/2	3	1
F5	3	4	3	2	1	4	2
F6	1/2	1	1/2	1/3	1/4	1	1/3
F7	2	3	2	1	1/2	3	1

Source: compiled by the authors

Table 3.11 Matrix of paired comparisons for environmental factors of non-preservation of cargo during road transportation

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
Z1	1	3	2	2	2	3	2	1/2
Z2	1/3	1	1/2	1/2	1/2	2	1/2	1/5
Z3	1/2	2	1	1	1	2	1	1/3
Z4	1/2	2	1	1	1	2	1	1/3
Z5	1/2	2	1	1	1	2	1	1/3
Z6	1/3	1/2	1/2	1/2	1/2	1	1/2	1/6
Z7	1/2	2	1	1	1	2	1	1/3
Z8	2	5	3	3	3	6	3	1

Source: compiled by the authors

Since the initial expert assessments are presented in the form of sums of ranks, in order to ensure the correct interpretation of the significance of the factors (a higher numerical value should correspond to a higher significance of the factor), the inverse values of the indicators were calculated.

Further normalization of the inverse values made it possible to move to dimensionless weight coefficients reflecting the relative contribution of each factor to the formation of the risk of non-safety of cargo during road transportation and to satisfy the requirements of the analytical hierarchy method. (Tables 3.12, 3.13)

Table 3.12 Inverse values of indicators and their normalization for factors of the internal environment of non-preservation of cargo

Factor	Designation	Sum of ranks	1 / S	Weight w_i
Cargo packing	F1	42	0,0238	0,107
Cargo marking	F2	54	0,0185	0,083
Loading of cargo	F3	41	0,0244	0,109
Placement in the body	F4	32	0,0313	0,140
Securing the cargo	**F5**	**20**	**0,0500**	**0,224**
Unloading	F6	52	0,0192	0,086
Driver qualification	F7	32	0,0313	0,140
Σ				1.00

Source: compiled by the authors

Table 3.13 Inverse values of indicators and their normalization for factors of the internal environment of non-preservation of cargoy

Factor	Designation	Sum of ranks	1 / S	Weight wi
Natural and climatic	Z1	33	0,03	0,143
Political	Z2	66	0,015	0,071
Accident rate	Z3	47	0,021	0,100
Criminal actions	Z4	38	0,026	0,124
Technical condition of the vehicle	Z5	43	0,023	0,110
Cargo condition	Z6	73	0,013	0,065
Supporting documents	Z7	53	0,018	0,090
Road impact	**Z8**	**22**	**0,045**	**0,214**
Σ				1.00

Source: Road impact

According to the calculations, the dominant factors of influence were: cargo securing (w=0.224) for the factors of the internal environment of cargo non-safety, which confirms the critical role of the technological discipline of cargo operations and road impact (w=0.214) for the internal environment of cargo non-safety, which in turn necessitates the need to take into account the state of the infrastructure when planning transportation.

Given that the matrix is formed on the basis of an agreed vector of weights, the consistency indicators are within acceptable limits:

– maximum eigenvalue: λmax≈8.17

– consistency index: CI=(λmax−n)/(n−1)≈0.024

– consistency ratio: CR=CI/RI8≈0.017<0

The matrix is consistent, meeting the requirements of the Saati method.

Therefore, the application of the analytical hierarchy method made it possible to identify the key dominant risk factors for cargo non-safety during road transportation.

Further, to understand the nature of risks and determine their level, we will determine the integrated risk index of cargo non-safety during road transportation.

To calculate it according to formula 3.9, in addition to the weight of the factor, we need the factor risk level coefficient (ri), which will be determined by the scale (S1–S5), which is formed by us according to a vaguely multiple approach (Table 3.14).

Table 3.14 Normalization of risk degrees

Degree	Designation	Normalized value r_i
-	Absent	0
S1	Very low	0,2
S2	Low	0,4
S3	Medium	0,6
S4	High	0,8
S5	critical	1,0

Source: compiled by the authors

and the matrix of identified risk events (manifestations of factors), which was formed on the basis of an expert survey (Table 3.15).

Table 3.15 Matrix of identified risk events

Degree	S1	S2	S3	S4	S5
F1		N1	N2		
F2	N3	N4			
F3			N5		
F4			N6	N7	
F5				N8	N13
F6					
F7				N9	
Z1	N18		N19		
Z2					
Z3		N10		N11	
Z4				N14	
Z5			N12		
Z6					
Z7					
Z8				N15	

Ni – identified risk events (or manifestations of factors) formed on the basis of an expert survey; S -is the degree of risk manifestation; F; Z – factors.
Source: compiled by the authors based on the results of processing expert questionnaires

The constructed matrix allows you to systematize the risks of cargo non-preservation by the degree of manifestation and groups of factors of the internal and external environment. The resulting distribution is used as an input base for further application of the analytical hierarchy method (MAI) in order to determine weighting coefficients and dominant risk factors (Table 3.16).

Table 3.16 Assignment of risk levels

	F1	F2	F3	F4	F5	F6	F7	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
Degree	2	1	3	4	5	5	4	3	2	4	4	3	5	5	4
Weight	0.6	0.4	0.6	0.8	1.0	-	0.8	0.6	-	0.8	0.8	0.6	-	-	0.8

Source: compiled by the authors

Generalization of the calculation results in the form of Table 3.17 made it possible to quantify the contribution of each individual factor to the formation of an integrated risk index of cargo non-safety during road transportation.

Table 3.17 Calculation of the integrated risk index of cargo non-safety

Factor	S	r	w	w·r
F1 – Cargo packing	S3	0,6	0,107	0,064
F2 – Cargo Marking	S2	0,4	0,083	0,033
F3 – Load	S3	0,6	0,109	0,065
F4 – Body Placement	**S4**	**0,8**	**0,140**	**0,112**
F5 – Securing the load	**S5**	**1,0**	**0,224**	**0,224**
F6 – Unloading cargo	–	0,0	0,086	0,000
F7 – Driver Qualification	**S4**	**0,8**	**0,140**	**0,112**
Z1 – Natural and climatic impact	S3	0,6	0,143	0,086
Z2 – Political influence	–	0,0	0,071	0,000
Z3 – Accident rate	S4	0,8	0,100	0,080
Z4 – Criminal actions	**S4**	**0,8**	**0,124**	**0,099**
Z5 – Technical condition of the vehicle	S3	0,6	0,110	0,066
Z6 – Cargo condition	–	0,0	0,065	0,000
Z7 – Supporting documents	–	0,0	0,090	0,000
Z8 –Road impact	**S4**	**0,8**	**0,214**	**0,171**
Σ			1,000	1,114

Source: compiled by the authors

The greatest influence on the value of the integrated risk index of cargo non-safety has internal factors of 56%, among which the lion's share has: cargo securing (0.224), cargo placement (0.112) and driver qualification (0.112).

Among external factors, we note high values of factors of road impact (0.171), criminal actions (0.099) and natural and climatic conditions.

The normalized integrated risk index is equal to:

$$R_{int} = \sum_{i=1}^{n} w_i \times r_i = 0{,}56$$

The obtained value of the integral risk index Rint=0.56 corresponds to a medium-high level of risk of cargo non-safety, which requires the introduction of systemic organizational, technical and managerial measures focused primarily on the dominant internal and external factors, primarily cargo fastening, as well as factors related to road impact and accident.

CONCLUSIONS

The growth in the share of road freight transportation has revealed serious problems in ensuring the safety and efficiency of road freight transportation. Road transport faces numerous risks that can lead to cargo loss, including accidents, theft, improper packaging, vibrations, and environmental impacts. These risks not only compromise the quality and integrity of goods, but also lead to economic losses and reduced efficiency of supply chains. Accordingly, guaranteeing safety during transportation is the key task of transport and logistics companies.

The presence and variety of characteristics, terms and concepts regarding the safety of cargo and the safety of its transportation indicate that the problem of non-safety of goods remains one of the priorities for both logistics operators and their customers.

2. Non-preservation of cargo is a condition or phenomenon in which the cargo loses its original properties, quantitative or qualitative characteristics, or integrity in the process of transportation from the sender to the recipient. It includes all cases when the cargo has not been preserved in the condition in which it was transferred for transportation and can manifest itself in the following forms: loss of cargo, shortage of cargo, damage to cargo, including (decrease in chemical, physical or biological properties; deterioration of appearance; mechanical damage), damage to cargo. The main sign of non-preservation is a quantitative shortage relative to the data specified in the waybill, or damage and other signs of a decrease in the quality of the cargo or its complete unsuitability for its intended use.

In modern supply chains, the non-safety of goods is a systemic consequence of an insufficient level of management, fragmented and outdated legal regulation, a low level of technical and organizational culture of transportation, high accident rates and weak state control and force majeure.

For road transportation, cargo non-safety is a complex phenomenon characterized by partial or complete loss by cargo of its quantitative and/or qualitative characteristics, physical integrity or commercial value during transportation. It is directly identified with a violation of the safety of transportation and is interpreted as a result of certain special effects on the cargo. There are three groups of influences on the cargo: mechanical, climatic and biological.

3. The efficiency of the transportation process depends on the coordination of actions of all its participants, which should ensure the rational organization of transportation, taking into account external factors that cannot be eliminated, but can be partially neutralized due to the right management and technical decisions. Accordingly, the safety of the cargo at the stage of transportation is derived from the organizational measures carried out at the previous stages.

Factors affecting the safety of cargo, in most cases, are also risk factors for non-safety of cargo. They can be both internal (packing, labeling, loading, placement in the body of the vehicle, fastening, unloading, driver qualification, attitude to the technical condition of the vehicle, communication between participants in the transport process), depending on the economic entity, and external on which they do not depend on it (road-climatic and socio-political conditions, route risks and the state of transport infrastructure) and on which it has an indirect influence.

4. World practice demonstrates different approaches to the organization of control in the field of cargo transportation and reflects contrasting models of institutional provision of cargo safety. On the one hand, the developed countries of the world – as an example of a mature risk-based system: the EU – focuses on the unification of rules and environmental friendliness; The USA/Canada/Australia – on risk management and transport security, Asian countries – on innovative digital technologies and "smart logistics", on the other hand – African countries – as a system in the phase of institutional and regulatory development dominated by environmental factors, or the countries of South and Central Asia, representing a transit-oriented model of cargo security, in which the key are the control of infrastructure nodes (ports, corridors) and minimizing the risks of non-safety at the junctions of logistics systems.

Ukraine combines the European course of harmonization of the institutional environment with its own initiatives of digitalization and increased control over the safety of goods.

Despite the differences, a common feature is the growing attention to the issues of cargo safety, compliance with international standards and increasing the transparency of logistics processes.

5. The risk of non-safety of goods during road transportation is defined as the probability of partial or complete loss of commodity, physical or economic properties of the cargo as a result of managerial, technical, personnel, legal and external factors in the process of transportation. Its key sources are: imperfect legal field, low risk management culture, safety savings, weak control and supervision and a high accident rate.

The analysis of the risks of non-safety of goods in different phases of the road transportation process shows that uncertainty manifests itself in the form of incompleteness or inaccuracy of the implementation of the transportation process, provided that it is invariant. The existence of risk is directly related to the presence of uncertainty, since the spontaneity of the manifestation of risk factors for non-safety of cargo and the randomness of the occurrence of events caused by this risk determine different results of the transport process even with identical parameters of transportation organization.

6. At the legislative level of all countries, requirements are put forward for transport security as a system for preventing, counteracting and stopping crimes, including piracy and terrorism, prevention of natural and man-made emergencies in the transport sector in order to minimize material and moral damage. Various methods are used to ensure the safety of goods. Depending on the scope of application, they are divided into: universal, with the help of which, along with the reduction of losses, other tasks related to the improvement of transportation technology or improvement of vehicles are solved, and specific - narrow-purpose measures used only to ensure the safety of transported goods and settle cases of their damage or loss (technical, technological, legal, organizational and economic).

As for the measures necessary to prevent the non-safety of the cargo, they remain unchanged:

– risk assessment;

– coordination of actions of all participants in the supply chain;

– improvement of regulatory documentation;

– training of personnel and providing them with clear instructions,

– analysis of accidents and incidents;

– strict reporting and auditing.

7. Risk management requires a clear distribution of responsibilities and powers necessary for managerial decision-making. Decisions made in the process of risk management must be within the framework of legal requirements and comply with corporate goals. Thus, it is very respectful to determine the optimal balance between responsibility for risk and the ability to control that risk.

When choosing a risk management strategy and tactics, the manager must adhere to the following basic principles: it is inexpedient to risk more for less; it is inappropriate to risk more than one's own funds allow (capital, etc.); It is necessary to take care (make a forecast) in advance regarding the possible (probable) consequences of the risk.

The developed integrated cargo risk management matrix reflects technological and technical advances combined with institutional changes, political and economic reforms and global cooperation, which will be crucial for creating sustainable and safe road transport systems that effectively eliminate risks and ensure the safety of goods in road transport.

8. Unlike traditional business risks, risks in transport logistics have a cascading effect. A failure in one link usually triggers a reaction throughout the supply chain. This requires a different integrated approach to risk management, namely: identifying and assessing risks; development of a strategy for their management; control and monitoring of risks throughout the entire transportation process.

The considered promising measures to prevent cargo non-safety showed that investments in advanced technologies open up significant economic and operational opportunities for enterprises in the logistics and transport sector. Despite the high costs associated with their implementation, technologies such as predictive maintenance, IoT-based monitoring systems, and AI-powered analytics can transform risk management, enabling companies to achieve greater efficiency, cost savings, and reliability in transportation operations.

9. Identification of risks of cargo non-safety requires the use of an expert approach, since: different factors can create the same level of risk. The results of risk identification directly depend on the level of qualification, experience and competence of the specialists involved. Any expertise should be carried out by highly qualified and competent specialists who have practical experience in the field of road transportation, logistics, traffic safety or risk management.

In the study, the methodology of multi-criteria decision-making (MCDM), in particular the method of analytical hierarchy (AHP), which allows for pairwise comparisons between many criteria for obtaining relative weights, which quantitatively reflect the collective assessments of experts, was used to systematically analyze and prioritize the risks of cargo non-conservation. This is due to the following considerations:

– factors of non-safety of goods have different physical nature (mechanical, climatic, organizational, human, etc.), so it is difficult to compare them in common units of measurement;

– the point scale does not always adequately reflect the real degree of influence of factors on the result, since the score in points is conditional;

– the method of pairwise comparison makes it possible to obtain a structured matrix of decisions, in which the superiority of one factor over another is recorded;

– double pairwise comparisons (with a change in the order of objects) helps to reduce the influence of psychological biases associated with the sequence of presentation of factors.

10. Formalization of risks of non-preservation of cargo is the process of presenting the characteristics of individual risk factors in quantitative form within a single scale for assessing the risk of its non-

preservation. The formalization procedure is designed to form a factor space and further build a mathematical model.

In the study, a vague-multiple approach was used to build a model for assessing the level of admissibility of risks of cargo non-safety. The choice of such an approach is due to the need to use both statistical (formalized) and expert (non-formalized) indicators that characterize the level of a particular risk, and the complexity of the object of study determines the need to allocate fuzzy intervals for their assessment.

11. For the processing of expert data and the construction of a model for assessing the risk of cargo non-safety during road transportation, a complex method of logical-linguistic modeling was used, which is a synthesis of the theory of experimental planning (in particular, the algorithm of the analytical hierarchy method (MAI)) and elements of linguistic variables of the theory of fuzzy sets. The proposed approach to assessing the risks of cargo non-safety made it possible to carry out a quantitative hierarchization of both internal and external risk factors and move from qualitative judgments to formalized numerical estimates.

On the basis of the chosen mathematical apparatus for folding heterogeneous information, as well as identification and formalization procedures, an algorithm for forming a comprehensive assessment of the risk of non-safety of cargo during road transportation has been developed. Which is a sequence of processes of qualitative and quantitative analysis of the risk of non-safety of cargo, which provide a systematic quantitative assessment of risk for a specific type of transportation.

12. In the practical part of the study, a questionnaire of experts was conducted to determine the level of influence of internal and external environmental factors on the non-safety of goods during road transportation and the ranks of influence of each of the factors were determined.

The examination was attended by 10 experts who are specialists in the transport sector and meet the requirements of competence and objectivity.

13. According to the results of the construction of matrices of pairwise comparisons and the determination of weight coefficients, it was found that among the internal factors, the cargo fastening has a dominant influence on the risk of non-safety of cargo. This indicates the critical role of compliance with technological regulations for cargo operations and confirms the need to strengthen control over technical means of fixation and the qualification of personnel responsible for their use.

The analysis of the external environment showed that the most significant external factor is the road impact, which reflects the dependence of the safety of goods on the state of the transport infrastructure, the quality of the road surface and traffic conditions. The results obtained substantiate the expediency of taking into account infrastructure parameters when planning transportation routes and choosing traffic modes.

14. The calculation of the integral risk index of non-preservation of cargo gave the value of Rint=0.56, which corresponds to the medium-high level of risk of non-preservation of cargo. This level indicates the systemic nature of the impact of risk factors and the impossibility of reducing it only through local or one-time management decisions.

The obtained value of the integral index confirms that the risk of cargo non-safety is formed as a result of the cumulative action of internal and external factors, and the dominant factors belong to different levels of the hierarchy. This justifies the need to apply an integrated approach to risk management, which combines technical, organizational and infrastructural measures.

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ISBN 978-83-66567-97-9

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