DOI: 10.36163/aon-2024-0008

RISK ASSESSMENT IN THE TRANSPORTATION OF DANGEROUS GOODS ON INLAND WATERWAYS

1st Dorota Łozowicka
Maritime University of Szczecin
Szczecin, Poland
d.lozowicka@pm.szczecin.pl

2nd Magdalena Kaup
Maritime University of Szczecin
Szczecin, Poland
m.kaup@pm.szczecin.pl

3rd Eryk Łukjan
Maritime University of Szczecin
Szczecin, Poland
27763@s.pm.szczecin.pl

ABSTRACT

One of the basic problems of risk assessment of dangerous goods transportation on inland waterways is the correct identification of all potential threats. The article proposes the use of an Ishikava diagram to identify threats associated with the transportation of dangerous goods. Six categories of causes were distinguished, among which general risks associated with the transportation of dangerous goods by inland waterways were identified. Then the formal safety assessment methodology was used to analyze the identified risks. The article assesses the risks and gives examples of accidents on inland waterways. The result of the analysis is to indicate in which categories of causes potential opportunities for improving safety should be identified.

Keywords: inland waterways, dangerous goods, transport, risk assessment

1. INDRUCTION

Inland water transport, despite its benefits, is an underestimated branch of transportation today. It is primarily a safe transport in which, according to all statistics, accidents rarely occur, and even despite the fact that it is very often used to transport dangerous cargo. Nevertheless, it should be noted that the transportation of dangerous cargo always carries certain risks. Identifying these risks is important, as it allows you to protect yourself against them early, and thus avoid or reduce the consequences of an accident for people and the environment.

Dangerous goods are, according to the regulations set forth in the Law of August 19, 2011 on the Transportation of Dangerous Goods, "a material or object which, in accordance with ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route), RID (Règlement concernant le transport International ferroviaire des marchandises Dangereuse) or ADN (European agreement concerning the international carriage of dangerous goods by inland waterways), is not authorized, respectively, for carriage by road, carriage by rail or carriage by inland waterway, or is authorized for such carriage under the conditions specified in these regulations (Law of August 19, 2011 on the Transportation of Dangerous Goods, i.e. Dz. U. of 2022, item 2147, of 2023, item 1123.). By carriage of dangerous goods by inland waterways is meant any movement of dangerous goods by ship on inland waters, including stops required during this carriage and activities related to this carriage.

The characteristics of all vessels used for the transportation of dangerous cargoes must be in accordance with the guidelines of the ADN Agreement. The hulls of such vessels should be constructed of marine steel or

other metal whose properties are at least equivalent in terms of mechanical properties and resistance to temperature and fire (Dz. U. z 2021, item 1165). When analyzing the risks associated with the transportation of dangerous cargoes by inland waterway, it is important to remember that the basic problem is the proper identification of all potential risks. For this purpose, it is best to use a cause-and-effect method to identify potential sources of risks - in this article, an Ishikawa Diagram is proposed as a method for identifying risks associated with the transportation of dangerous cargo by inland waterway. The article will distinguish categories of causes and identify general risks associated with the transportation of dangerous goods by inland waterways. In the next part of the article, the method of risk analysis in the form of a formal safety assessment (FSA) will be discussed, and then it is used to verify the significance of the previously identified risks.

2. IDENTIFICATION OF THREATS

An Ishikawa diagram is a good tool when a given effect (e.g., an accident) can be obtained in many ways (Stefanova, 2021). This diagram, also known as a fishbone diagram, does not in itself indicate the actual causes (it does not indicate a single possible cause of the problem), but instead gives a picture of which aspects to keep an eye on and check (Wróblewski, 2018), (Luca, 2016), (Thunyaphun at al., 2023).

It is a tool often used in manufacturing industries, but this publication demonstrates that it can also be used effectively in transportation.

The Ishikawa diagram uses a range of cause categories known as 5M+E:

- Manpower;
- Machine;
- Material;
- Method;
- Management;
- Environment.

In each of these categories, the causes that may have caused the effect are determined, which is investigated by asking the question “why?” repeatedly. Using the Ishikawa Diagram in the following subsections of this subsection, possible threats during the transportation of dangerous goods by inland waterways are identified as an effect by taking an accident involving dangerous goods. It should be noted that the effect does not always have to have a single cause, and what is more, it can consist of various causes from different categories (Pacana & Siwiec, 2020), (Ciecińska, 2023).

2.1. MANPOWER

Studies in the area of transportation accidents show that human error is the main cause of accidents - for example, it is estimated that as many as 80% of shipping accidents were due to human error (Berg, 2013), (Oluseye & Ogunseye, 2016), (Galieriková 2019), (Bačkalov, 2021).

The cause of the accident (threats) on inland waterways involving dangerous goods in the human category can include:

- insufficient qualifications and skills to perform work in inland shipping in the transportation of dangerous goods;
- lack of work experience in the transportation of dangerous goods in inland shipping;

- negligence or breach of duty by the employee (this includes failure to follow procedures, as well as inappropriate behavior in the workplace - such as drinking at work);
- employee's poor mental state affecting the quality of work performance (fatigue, personal problems and lack of motivation);
- lack of awareness of the danger (this is at least the daily routine causing downplaying of potential danger - for example, something is not working as it should, but many times it has also not worked and nothing happened, so there is no point in worrying about it).

2.2. **MACHINE**

Another category to review is the condition of the ship and its equipment. This refers to the conditions of operation, their modernity, efficiency, safety, as well as verifying them through appropriate certificates and certifications. The basis for assessment in this case is the guidelines of the ADN agreement, The causes of accidents (threats) on inland waterways involving dangerous goods in the category of machinery can include:

- the technical condition of the vessel not in compliance with ADN requirements;
- condition of the vessel's equipment and facilities not in compliance with ADN requirements;
- lack of regular inspections;
- lack of or failed safety systems.

2.3. **MATERIAL**

In the material category, the focus should be on the properties of the dangerous goods in question and the appropriate packaging intended for these cargoes. Causes of accidents (threats) on inland waterways involving dangerous goods in the material category can include:

- release of dangerous goods in transport due to improper storage or production process (e.g., material pollution);
- improper or in poor condition packaging of dangerous goods.

2.4. **METHOD**

This is considered the most fluent and difficult to grasp category, as it includes all procedures and instructions with the help of which a task is carried out. It should be noted here that all regulations, procedures and instructions should be constantly updated (e.g., ADN is updated every 2 years) so that they take into account new situations and circumstances, as well as developments in technology. In the case of transportation of dangerous goods by inland waterway, this mainly concerns methods of loading and unloading dangerous goods. The causes of accidents (threats) on inland waterways involving dangerous cargoes in the category of method can include:

- lack of or outdated instructions, procedures, or laws (refers to the ownership of these documents by those organizing the transport);
- circumstances and situations not provided for in the instructions, procedures, or laws (applies to those involved in the development of instructions, procedures, or laws);
- non-compliance with, or misinterpretation of, instructions, procedures, or laws.

2.5. **MANAGEMENT**

This category is actually responsible for proper functioning in the other categories (except the environment). It is the management (management) that is responsible for the workforce, the ship and its equipment, as well as the cargo being transported by organizing the work according to proper methods (Jerzyło at al, 2018). The causes of accidents (threats) on inland waterways involving dangerous cargoes in the management category can include:

- improper work organization;

- lack of proper communication;
- lack of supervision.

2.6. **ENVIRONMENT**

This category is in addition to the others, but can have a significant impact on them. This category includes the characteristics of the inland waterway in question, local weather conditions, infrastructure and other objects occurring or operating on the waterway in question, as well as intentional actions of third parties (sabotage, terrorist attacks) (Bačkalov at al., 2023), (Mia, 2021), (Cheng, 2020). The conditions of the ship's environment affect the number of potential threats that additionally need to be considered. The cause of accident (threats) on inland waterways involving dangerous cargoes in the ambient category can therefore include:

- bad weather conditions (storms, fog);
- collision with other objects on the waterway (ground obstacles or other objects navigating on the river);
- sabotage or terrorist attack (ships with dangerous goods can be used as a target in case of acts of war);
- an increase or decrease in water levels on inland waterway.

2.7. SUMMARIZE THE THREATS USING AN ISHIKAWA DIAGRAM

The identified threats, which could result in an accident on inland waterways involving dangerous goods, were gathered together and shown in the Ishikawa Diagram (fig. 1).

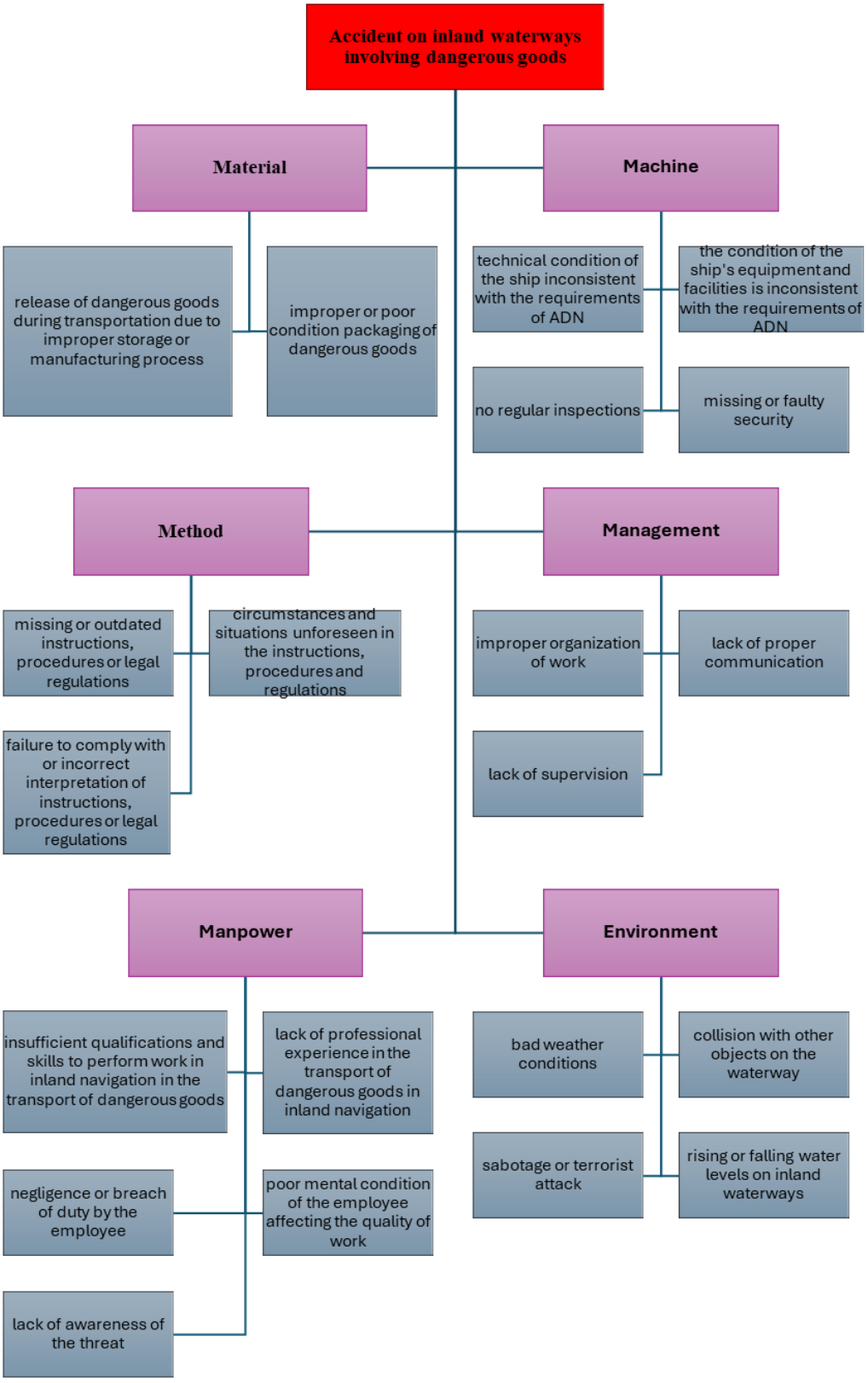

Fig. 1. Threats on inland waterways for transport of dangerous cargoes presented in the form of Ishikawa Diagram (source: own)

3. RISK ASSESSMENT

After identifying threats, it is possible to start risk assessment. As with identification, there are many methods and tools for risk assessment and analysis. However, most of these methods can be simplified to a comparison of two indicators. The first is the result of the multiple of the probability of an incident and its potential consequences, also called the risk index. The second indicator is the acceptable level of risk. Ultimately, the risk index should not be greater than the acceptable risk. The basic goal of the analysis is to identify the exposure of a specific project to a specific risk and thus try to reduce it to an acceptable level (Huang at al., 2021), (Molero et al., 2019) (Baryshnikova at al., 2021), (Galieriková & Sosedová 2018).

The formal safety assessment methodology (PRS, 2002) was used to conduct the risk analysis. The identified threats were analyzed and are shown in Tables 1 and 2.

Table 1. Risk assessment of dangerous goods transportation by inland waterways (source:own)

	Consequences	Probability	Comment	Risk Index
Material				
Release of dangerous goods in transport due to improper storage or manufacturing process	Catastrophic	Low	This should be detected even before the load is taken	U
Improper or in poor condition packaging of dangerous goods	Catastrophic	Low		U
Machine		Low		U
Technical condition of the vessel not in compliance with ADN requirements	Catastrophic	Low	Regular audits can identify some failures in this area, but they are usually not great failings	U
Condition of the ship's equipment and facilities not in compliance with ADN requirements	Catastrophic	Low		U
Lack of regular inspections	Catastrophic	Low		U
Lack of or inoperative safety features	Catastrophic	Low		U
Method				
Lack of or outdated instructions, procedures, or regulations	Catastrophic	Very low	Such situations should not cause much threat if there is a qualified and experienced crew	M
Unforeseen circumstances and situations in the	Catastrophic	Very low		M

instructions, procedures and regulations				
Failure to follow or improperly interpret instructions, procedures, or regulations	Catastrophic	Low	A staff member may not apply or misunderstand instructions and procedures. This threat is also linked to the category of manpower	U

Table 2. Risk assessment of dangerous goods transportation by inland waterways - continuation (source:own)

	Consequences	Probability	Comment	Risk Index
Management				
Improper organization of work	Catastrophic	Very low	If instructions, procedures and regulations are followed in this aspect, the likelihood of an accident due to these reasons is very low	M
Lack of proper communication	Catastrophic	Very low		M
Lack of supervision	Catastrophic	Very low		M
Manpower				
Insufficient qualifications and skills to perform the job	Catastrophic	Very low	Those who work with dangerous goods must undergo appropriate training and pass examinations. These trainings are repeated regularly every few years	M
Lack of work experience in transporting dangerous goods in inland navigation	Catastrophic	Very low	Lack of experience can happen with new employees, nevertheless, they undergo appropriate training and exams beforehand, and on top of that, in the first months of work they should work together with an experienced employee	M
Employee's negligence or failing duties	Catastrophic	Low	Such situations can happen, as shown by the statistics of transport accidents and, for example, the case of 12.06.2023 from Russia on the Lena River, where there was a collision of tankers and a spill of 90 tons of petrol - the captain of one of the ships was under the influence of alcohol	U
Poor mental condition of the employee	Catastrophic	Low		U
Lack of awareness of the threat	Catastrophic	Low		U
Environment				
Bad weather conditions	Catastrophic	Significant	No impact on weather conditions, which can often be unstable	U
Collision with other objects on the waterway	Catastrophic	Significant	Collisions with stationary objects can be avoided by navigating properly. However, there is no significant impact on the behavior of other users of the inland waterway	U
Sabotage or terrorist attack	Catastrophic	Very low	No such examples of deliberate action have been reported in	M

			Poland	
Increase or decrease of water levels on inland waterways	Catastrophic	Significant	In the event of flooding, there may be objects in the waterway that can damage the ship. During the lower level, the possibility of grounding the ship	U

The risk matrix selects in the column the type of consequences that may occur in an accident and in the row the probability of occurrence - the box crossing the row and column is marked with a letter indicating the level of risk. The letter **A** means acceptable risk (requiring no additional action). The letter **M** indicates moderate risk (preventive action is required). The letter **U**, on the other hand, indicates an unacceptable level of risk (sailing in such cases is unacceptable until the level of risk is reduced - corrective and remedial actions are required).

Due to the very serious consequences of accidents in inland waterway transportation of dangerous goods, it appears that most of the threats should be treated as unacceptable. The risk assessment has identified as many as four of the six categories in which risks are unacceptable if additional measures are not taken to reduce the risk. These categories are material, machine (ship and its equipment), manpower and environment..

The material is of key importance, as there are potential consequences of an accident depending on the properties of the dangerous goods. It should be emphasized here that its proper packaging is important, as well as its labeling, so that the ship's crew is aware of the potential threats associated with it. As for the ship and its equipment, it should be adequate for the dangerous goods being carried. Sticking to the ADN guidelines in this area should be a sufficient safeguard.

While safety in the category of material and machine can be directly influenced, there is very limited influence in the category of manpower and environment. The main threat in the case of manpower is his individual approach to work. If he follows procedures, instructions and regulations, the risk of an accident is very small. If, on the other hand, he intentionally or unintentionally ignores them for various reasons, tragedy can occur. A good example is the case of 12.06.2023 from Russia on the Lena River, where two oil tankers collided and spilled 90 tons of petrol - the captain of one of the ships was under the influence of alcohol.

In the case of the environment, one must be careful, first of all, about changing conditions, which do not always go early enough to predict.

SUMMARY

When assessing the risks in the transportation of dangerous goods, it should be emphasized that, despite everything, accidents in inland waterway transportation are extremely rare (in Poland this has not happened for at least 14 years, as indicated by data from the Central Statistical Office), and even if they do occur, they are unlikely to result in damage or leakage of cargo. This is if only because the regulations specify a mass of preventive measures. As a result, even if one of the safety features fails there is no automatic disaster. Accidents involving dangerous goods transported by inland waterway are marginal, which is why they are often overlooked in all kinds of statistics and studies on accidents in dangerous goods transportation. Nevertheless, it should be borne in mind that any accident involving dangerous goods on an inland waterway is much more dangerous to the environment than, for example, road transport, as it can potentially pollute, or contaminate, a much larger area. It should also be emphasized that the risk assessment presented here is for a general case - in each specific case, a more detailed assessment should be made depending largely on the classification of the dangerous goods being transported. The risk assessment should be taken as the basis for determining accident prevention strategies.

REFERENCES

1. Bačkalov I. An analysis of accidents in inland navigation in context of autonomous shipping. Proceedings of the 1st International Conference on the Stability and Safety of Ships and Ocean Vehicles, Glasgow, 2021.
2. Bačkalov I., Vidić M., Rudaković S. Lessons learned from accidents on some major European inland waterways, Ocean Engineering, Vol 273, 2023.
3. Baryshnikova N., Li I. Safety analysis of routing and planning of the transportation of dangerous goods by water transport. International Symposium "Earth sciences: history, contemporary issues and prospects", 2021.
4. Berg H.P. Human Factors and Safety Culture in Maritime Safety (revised), TransNav - the International Journal on Marine Navigation and Safety of Sea Transportation, Vol 7, No 3, September 2013.
5. Cheng Z., Li Y., Wu B. Early warning method and model of inland ship collision risk based on coordinated collision-avoidance actions. Journal of Advanced Transportation, 2020.
6. Ciecińska B. Identification of Defects Causes: Ishikawa Diagram and 5 Whys in Theoretical and Practical Terms. Quality Control and Quality Assurance - Techniques and Applications. 2023
7. Galieriková A., Sosedová J. Inland waterway transportation of dangerous goods: risk assessment and decision-making strategies. 18 th International Scientific Conference Globalization and Its Socio-Economic Consequences, University of Zilina, 2018.
8. Galieriková A. The human factor and maritime safety. Transportation Research Procedia, Vol 40, 2019.
9. Huang, X., Wen, Y., Zhang, F., Sui, Z., Cheng, X. A Comprehensive Risk Assessment Framework for Inland Waterway Transportation of Dangerous Goods. Journal of Marine Science and Engineering. 2021.
10. Jerzyło P. , Rekowska P., Kujawski A. Shipping safety management on Polish inland waterways. Archives of Transport System Telematics, Vol 11, iss 4, 2018.
11. Luca L. A new model of Ishikawa diagram for quality assessment. IOP Conference Series: Materials Science and Engineering, Volume 161, 20th Innovative Manufacturing Engineering and Energy Conference. 2016.
12. Mia, Md. J., Uddin, Md. I., Awal, Z. I., & Abdullah, A. An era of inland water transport accidents and casualties: the case of a low-income country. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5(2), 2021.
13. Molero G.D., Santarremigia F.E., Aragonés-Beltrán P., Pastor-Ferrando J.P. Design of inland container terminals with dangerous goods. Total Safety and the Productivity Challenge, 1st Edition, 2019.
14. Oluseye O.O., Ogunseye O.O. Human Factors as Determinants of Marine Accidents in Maritime Companies in Nigeria. Journal of Maritime Research, Vol XIII. No. III, 2016.
15. Pacana A., Siwiec D. Improving the process of analysing the causes of problem by integrating the Ishikawa diagram and FAHP method. Scientific Papers of Silesian University of Technology Organization and Management Series No. 143, 2020.

16. Publikacja Informacyjna Nr 19/1, Metodyka Formalnej Oceny Bezpieczeństwa Żeglugi. Polski Rejestr Statków, Gdańsk 2002.
17. Stefanova M. Cause-and-effect diagram of logistics services. International Journal of Business & Management Studies. Vol 02; Issue 07, 2021.
18. Thunyaphun, T., Umeda, S., Yuhi, M. Sediment Budget and Net Sediment Transport on a Coast Dominated by Waves and Offshore Currents: A Case Study on the Ishikawa Coast and Its Surrounding Areas in Japan. Journal of Marine Science and Engineering, 11(3), 2023.
19. Wróblewski D. Zarządzanie ryzykiem – przegląd wybranych metodyk. CNBOP-PIB, Józefów 2018.