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Preliminary approach related to the multifaceted decision support analysis of risk assessment in the process of transporting feed by railroad using the FMEA method

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Abstract: The article presents selected aspects regarding transporting goods intended for animal feeding. The transport of this type of cargo must meet trade safety requirements and be monitored at every stage of the transport chain. The safety of transport of this type of goods is given priority because possible contamination of feed could affect the quality of food products and threaten human health. The authors referred to the reasons for creating an international procedure regarding, among others, the transport of this group of goods, limiting the risks mentioned above. The proposed procedure is a response to various incidents of feed contamination. It was introduced as an internal system and then developed internationally. The article points to the multi-threaded nature of topics related to the risk management process during the transport of feed intended for animal feeding by rail. This article presents an approach to this issue that considers a multi-aspect analysis of decision support. Risk assessment in transporting feed by rail is an essential factor influencing safety in trade. The article presents the FMEA method, which enables decision support analysis considering non-compliance risk. The recommended method that enables the examination of transport processes for this group of goods is the analysis of the types and effects of possible errors. The task solved using the FMEA method is fed by historical data, the transport task, and the FMEA methodology. Three elements are analyzed - the significance of non-compliance, the risk of non-compliance, and the possibility of detecting non-compliance. They enable quantification and determination of a risk priority number. If the acceptable risk level is exceeded, changes are made to the transport task. The article broadly refers to aspects of risk analysis, which allows you to manage the transport process.

Keywords: FMEA, freight process, GMP+ System

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1. Introduction

Rail transport carries goods grouped into 20 sections for statistical purposes. Each of them is characterized by its transport vulnerability, which is associated with the possibility of various adverse events. One of these sections, according to the simplified standard classification of goods for transport statistics [27], is animal feed, which is classified into the following groups: food products, beverages, and tobacco. According to data from the Central Statistical Office [8], in 2022, 2 143 thousand tons of food products, beverages, and tobacco were transported by rail in Poland, which accounted for 0,9% of the total mass transported by this mode of transportation. Although the transportation of feed by rail represents a small share of the market, this issue represents a significant challenge in the activities of transport companies. In addition, it is determined by the need for special conditions to be met throughout the transport process. The level of service provided during the handling operations of feed materials affects the quality of the food being later produced. Special conditions for storage, handling, and transportation of feed are crucial, considering the issues related to optimizing and improving the organization and quality of transportation [14,15,16,17,18,19,26]. One of the criteria for qualitative assessment may be the safety of feed transportation.

The GMP+ System, initiated in 1992 by the Dutch feed industry in response to various feed contamination incidents, is important when transporting feed cargo. It was initiated as an internal system and later expanded internationally. GMP+ International manages the system in cooperation with stakeholders from many countries. GMP+ Feed Safety Assurance (GMP+FSA) is a comprehensive module containing standards for feed safety assurance in all supply chain steps. Based on practical needs, many elements are included in the GMP+ FSA standards, such as feed safety system management requirements, traceability, prerequisite programs, comprehensive coverage of the entire feed chain, and the Early Warning System (EWS).

Among the standards of the GMP+ System is the GMP+&B4 standard for transportation [9]. The purpose of its introduction in transport companies is to improve the safety of feed circulation during their movement. A key area within the organization of feed transportation is the proper functioning of the entire process related to forwarding activities. In general, forwarding is any business activity that consists of organizing cargo movement at the request of a legal or natural person and then performing the necessary group of additional activities resulting from the specifics of this order. It includes many activities in its scope besides the transport itself, among which all activities before the shipment is sent for transportation and activities after the shipment is released can be mentioned. The services mentioned above are performed by freight forwarders (called freight brokers in the GMP+&B4 standard) on behalf of the principals and for their account, on behalf of the principals or their behalf directly, or they can only organize them by contracting specialized operators (including transport companies). An important aspect when transporting this group of cargo is the need to ensure environmental conditions in which contamination or potentially dangerous substances cannot jeopardize the safety of transporting feedstuffs. If a particular environment poses a risk to the transportation of feed, then the forwarder or carrier must demonstrate, through a risk analysis, that any risks are controlled. The forwarder or carrier must ensure that the cargo holds [9]:

– were made of proper materials that can be effectively cleaned and serviced to prevent feed contamination,
– were in good condition,
– were fit for their intended use and functioned following their intended use,
– enabled good hygienic practices,
– were properly inspected to detect residues of previous loads.

As the author of the paper [10] points out, it is essential to have the right approach to rail traffic planning and to support the decision-maker with the proper method for risk assessment in rail traffic planning. The author gives an overview of the methods that can be used for each stage of the method and classifies them into two types: strongly recommended to use and recommended to use.

Considering the above, the article points out the multifaceted nature of issues related to risk management during the transportation of selected commodities for animal nutrition (feed) by rail transport. This article aims to present an approach that considers the multifaceted analysis of decision support for risk assessment in transporting feedstuffs by rail transport. The recommended method that enables the study of transport processes for this group of goods is the analysis of the types and consequences of possible errors. This method quantified elements such as the importance of non-compliance, the risks of non-compliance, and the possibility of detecting non-compliance. The entire content of the article is divided into three main parts. The first discusses the basic regulations and standards relating to the rail transport safety system and risk management methods that can be applied during the implementation of rail freight transport. The second part covers issues related to the essence of the organization of rail freight transport and the risk management process, with a detailed description of each stage and an indication of risk assessment methods. The last part includes a multifaceted analysis of impact factors using the method of analyzing the types and consequences of possible errors during the implementation of feed rail transportation.

2. Selected research areas related to the organization of rail transport of goods for animal feed

2.1. Selected legislation related to the safety of the rail transport system

Safety in the rail transport system is the subject of many national and European legal acts. The primary documents at the European Union level, which directly describe the most important regulations related to rail transport, include:

– The Railway Safety Directive [3],
– Directive on the interoperability of the railroad system [2],
– Single Railway Area Directive [4].

On the other hand, specific guidelines and requirements for a system approach to safety management for railroad companies, infrastructure managers, entities in charge of maintenance, manufacturers, and users of sidings have been defined, among others, in [3,29].

A critical regulation defining the process related to risk management and independent change in rail transportation is presented in [0]. The document presents a multi-step approach to the following activities, in which we can distinguish, among other things, such elements as criteria for determining the significance of the change (consequences of failure, innovation used in the introduction of the change, complexity of the change, monitoring, reversibility of the change, additionality), definition of the system and identification and classification of risks, selection of risk acceptance rules, management of risks, valuation of risks, indication of compliance with safety requirements and independent evaluation.

In the case of transporting feed by rail, the correct interpretation of the law is of vital importance. All participating transport and shipping companies are obliged to perform their tasks following legal acts and internal regulations and procedures.

2.2. Feed transport standards by road and rail

GMP+ International provides feed market participants with practical and valuable documents in the form of databases, guidelines, and newsletters. Certification organizations can implement the GMP+ standard independently. Together with GMP+ partners, GMP+ International develops precise requirements for the Feed Certification system. GMP+ International GMP+ B4 standard is part of the overall GMP+ standard for transportation. Implementing the GMP+ B4 standard aims to build a feed transportation management system that ensures the safety and quality of services related to transporting this group of goods. The standard considers all applicable feed laws, the principles of feed safety, and standards generally accepted in the feed sector for producing and delivering safe feed. Certification of a feed safety system according to the requirements of this standard does not guarantee full compliance or non-compliance with sector requirements. It indicates that the participant has an effective feed safety system to achieve and maintain compliance with the law and safety requirements [9].

In the case of feed contamination, risk management, and adverse event monitoring should enable the recall of the commodity appropriately and notify customers of the reasons for non-delivery or delayed delivery. In such a context, supervision of service delivery includes [9]:

1. Monitoring the service status – the forwarder or carrier provides information regarding the name of suppliers and customers, delivery date, number of products, batch number (if provided), identification, and handling point code. The forwarder or carrier should have a documented procedure for a system of (early) detection and response to signals indicating that feed safety does not meet legal requirements, GMP+ FSA module standards, or customary commercial quality, which may cause damage downstream. If it is detected that the feed does not comply with the legal requirements for feed safety or customary commercial quality, then the supervisor/principal should be notified immediately.
2. Damage handling – the forwarder or carrier must describe in document form their procedure for handling customer complaints. This procedure must describe, at a minimum, the recording of the relevant elements of the complaint and the actions taken to handle the complaint. The procedure for recording and handling complaints must consist of at least the following:

- registration of complaints,
- investigation of the sources of complaints,
- recording the actions taken in response to the complaint,
- documenting communication with principals and other external parties,
- handling irregularities in transportation.

3. Internal Audit – the standard indicates the obligation of the forwarder or carrier to develop an internal audit procedure and implement a scheduled audit program to verify that internal systems are operating as intended and effectively. Internal audits should verify compliance with the following:
   - the requirements and conditions of this standard,
   - the procedures of the forwarder or carrier,
   - the requirements and conditions of the forwarder's or carrier's HACCP plan,
   - feed safety legislation,
   - special requirements of the customer.

   The internal audit program must include verification of appropriate activities at least once a year. All personnel responsible for internal audits must be competent in this area, which is achieved through proper training (internal or external). The results of internal audits must be included in a report to be forwarded to those responsible for the audited area. The audit report must include all activities and functions that do not comply with the requirements for operational activities. In case of non-compliance, corrective actions must be taken. An authorized person must sign the audit report when irregularities are corrected.
4. Loading control – this is a position, the detailed description of which can be found in the participant's quality control system. Its tasks are performed by an employee who, based on training and experience, has the knowledge and skills required for a loading controller to assess the suitability for transporting feed. If the participant does not have their loading controller, they can use the services of an independent inspection company or certification organization. The loading controller must, of course, meet the established criteria.

The forwarder or carrier must take appropriate measures to ensure effective tracking of the product at each of the stages for which it is responsible.

2.3. Risk assessment methods with multifaceted analysis

Risk assessment can be carried out using qualitative, quantitative, or qualitative-quantitative methods. Qualitative methods are the most commonly used in practice, as they are easier to apply and require much less detailed information than quantitative methods. Among qualitative risk assessment methods, the most widely used methods are those based on the relationship between the risk and the effect of the hazard and the probability of the effect generated by the hazard. Risk assessment of the implementation of rail transportation, like other transportation services, requires decision-making under the following conditions [5,31]:

- certainty – when the effects of risks are known,
- uncertainty – when the probabilities of occurrence of the effects of risks are not known, or the effects of risks are difficult to determine,

– risk – when the probabilities of hazard effects are known.

The research methods can be assigned to the various entities involved in the rail transportation system as follows [6]:

– railroad operator: event tree, Failure Mode and Effect Analysis (FMEA), Hazard and Operability Study (HAZOP), COSCO II, checklist,
– infrastructure manager: event tree, FMEA, HAZOP, COSCO II, checklist,
– siding user: event tree, FMEA,
– manufacturer: RAMS (Reliability, Availability, Maintainability, Safety),
– retrofit repair facility: RAMS.

Given the uncertainty associated with the organization of rail freight transportation, it is also necessary to perform regular analysis and risk assessment, which is part of risk management [22]. A correctly implemented and executed risk management system should [30]:

– create and protect value,
– be an integral part of all organizational processes,
– be part of decision-making,
– explicitly incorporate issues of uncertainty into accepted objectives,
– be implemented in a systematic, structured, and time-bound manner,
– be based on the best available information, and be adapted to the specifics of the organization.

Many methods exist to assess risk in the rail transportation system [25,30]. Railroad safety can be considered in terms of the subject studied, the element analyzed, the selection criteria, and the research method.

As the considerations carried out indicate, among the existing risk assessment methods, there is no one-size-fits-all method that applies to all cases. Some methods are used for preliminary risk assessment – in the early stages of the „life" of objects or processes. Other methods allow a thorough analysis at the design stage of a facility, helping to identify risks and assess their future consequences. Still, other methods are suitable for situations that require examining risks arising from a specific hazard.

3. Organization of rail transport of selected goods for animal feed in the context of the risk management process

3.1. Principles of organization of rail transport of selected goods for animal feed

Rail transportation is characterized by high complexity in terms of the implementation of transport tasks and the multifaceted nature of safety risks of these transports. The following authors present a broad spectrum of issues of risk in rail transport and methods used in risk assessment in rail transport [11,12]. The articles include, among other things, a description of the essence of planning the operations of rolling stock, a description of the method of risk assessment, the identification of risks in planning the work of rolling stock (according to the M_o_R methodology – the risk, its cause and the effect it may cause), an estimation of the impact of risk on the planning process and risk assessment. The

movement of feed by rail transport is characterized, as in the case of moving other groups of cargo, by the possibility of transporting it as a compact or distributed system, as pointed out by the paper's authors [15].

In the process of rail freight transport, the identification of risks can be associated with the following points of contact:

- point infrastructure elements, e.g., with the point of shipment, the intermediate point (train formation, including transshipment), and the point of destination,
- railroad line,
- operational processes,
- activities of other entities during the implementation of rail freight transport.

Identification of risks allows the subsequent stages of the study to analyze and evaluate risks. Threats can come from internal sources arising from the transport system under study and external sources resulting from causes inherent in its environment. One risk can consequently generate multiple adverse effects with different impacts. At the same time, one effect of risk realization may have several causes.

On the technological side, a distributed system is a complex process involving many resources compared to a compact system. It involves considerable maneuvering work. Among other things, maneuvering is performed to allow [15]:

- marshaling cars to individual tracks,
- putting together train sets,
- changing groups of wagons in trains,
- placing wagons at loading points and taking them away,
- switching wagons from one track to another,
- selecting empty wagons with unique technical parameters,
- placing wagons for additional activities, e.g., cleaning, washing, disinfecting, weighing, repairing, etc., and taking wagons back after these activities are completed,
- excluding wagons with defects from the train.

Distributed transport is much more expensive than transport in compact trainsets and requires disproportionate effort, especially in shunting and expediting. The distributed transport system is based on the so-called nodal point system, which involves the movement of individual wagons and wagon groups per established rules. Freight trains for distributed transport are compiled from appropriately selected wagon consignments in terms of their destination station. It is described by the corresponding directional station numbers of the destination station and movement (in the system: shunting yard – marshaling yard – shunting yard).

In contrast, compact transports are cargo transports carried out using all-train transports from the station of shipment to the station of destination. In the case of appropriate parameters of loading points (length of tracks, capacity of storage yards, possibility of using loading facilities, etc.), these transports start directly from the loading point of one forwarder and end directly at the loading point of another consignee. In this case, we can speak of shipments from one forwarder to one consignee. A characteristic feature of these transports is that the entire cargo is moved by a single train, essentially using a single traction unit, without the need for costly shunting work at intermediate stations. This transport system also improves the quality of the transport and speeds up the delivery time. In addition, it makes it possible to increase consignment security. The volume of goods

shipped at the same time has a significant impact on the cost of transporting them. Thus, it includes the places of loading and unloading of goods (transshipment points). A simplified diagram showing this situation is shown in Figure 1.

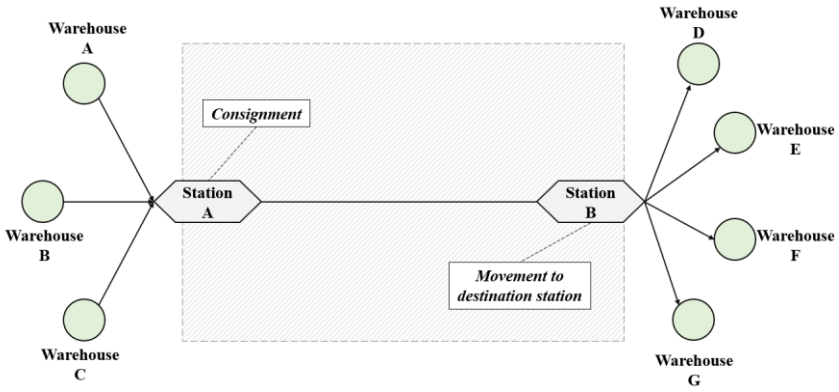

Fig. 1. General view of the freight process - places of loading and unloading of goods (source: a study based on [15])

An essential aspect of implementing the freight process is the loading and unloading of goods at the loading points. After loading, the train begins its journey from the sending station, the carriage activity takes place, and then the train arrives at the destination station. The final point in the process is the unloading activity at the place designated for it (generally, the unloading point is located on a railroad siding). This activity means that rail sidings also play an essential role in the rail freight process for feed. The GMP+&B4 standard for transportation cited in the first part of the article requires that appropriate risk assessment control parameters be maintained throughout the transportation process. From the analysis of transport technology, it is clear that compact transports make it possible to significantly improve transport safety, which is of considerable importance in feed transportation.

3.2. Essence and principles of risk management in the literature

Dedicated to any organization regardless of its type, size, and location, ISO 31000:2018 [21] presents principles and guidelines for risk management systematically and transparently within any issue and context. According to the standard mentioned above, risk management involves three main stages. The first is adopting risk management principles, the second is developing, introducing, and continuously improving the framework structure, and the last is implementing the risk management process. Although the indicated standard cannot be part of the certification, it gives guidelines for internal or external audit programs.

In contrast, according to the ISO 26000 guidelines, an organization should take responsibility for the impact of its decisions and actions on society and the environment. That means transparent and ethical behavior contributes to sustainable development, complies with applicable laws, and is consistent with international standards. It also means that social responsibility is built into the organization`s structure and practiced in its

operations, which is very important in the transportation of feed, as bad decisions can cause great damage to feed marketing. In this situation, risk management is essential.

To describe a company`s principles of conduct in the area of risk management, the so-called Deming cycle (also known as the PDCA cycle), which includes the following sequence of activities: plan, do, check, act, may be helpful. This cycle is used in many well-known management standards, such as ISO 9001, ISO 14001, OHSAS 18001, and ISO 27000. In general, risks can be divided into the following categories [7]:

- critical,
- unacceptable, requiring immediate additional action - Risk Reduction Plans and the establishment of controls and monitoring,
- significant, requiring the establishment of controls and monitoring, decisions (cost-justified) about Risk Mitigation Plans can be made,
- negligible, requiring periodic review and evaluation, and not requiring systemic controls and monitoring.

The risk management process should be formalized. Table 1 shows the key components of the risk management structure and describes the various stages of the above structure.

Table 1 Characteristics of the different stages of risk management

Stage	Description
Defining the context	It addresses the competitive environment, overall macroeconomic trends, regulatory requirements, voluntary industry commitments, and key risks.
Risk identification	Risk identification results in a risk register or scenarios and the links (potential couplings and interactions) between them in different parts of the organization. This stage should be carried out as part of a dialogue with different relevant stakeholders (e.g., employees, customers, local communities, etc.), using moderated workshops, brainstorming, expert assessment (Delphi method), checklists, interviews, etc.
Risk analysis	The purpose of risk analysis is to determine the probability and impact (consequences) of identified risks on strategic objectives. One type of risk can affect several of the organization's financial and non-financial objectives, such as environmental and social, including labor issues. Quantitative risk analysis typically involves estimating both an undesirable event's frequency (or probability) and the associated consequences (or validity). However, in cases where calculations indicate that the consequences are negligible or the frequency is shallow, it may be sufficient to estimate the value of one of the parameters.
Risk evaluation	The purpose of an evaluation is to support the decision-making process by assigning recommended actions to risks to reduce the likelihood of their occurrence or negate their effects.
Dealing risk	The purpose of this stage is to develop detailed recommendations and select one or more complementary courses of action. This should lead to risk minimization, i.e., reducing the likelihood or limiting negative consequences in the case of risks, and increasing the likelihood and maximizing positive consequences in the case of opportunities.

Source: study based on [7]

Identifying and understanding the proper context of the issue under review is a prerequisite for counterparties to perceive the risk management process as adding real value. One method of determining this is through dialogue with the environment, identifying the expectations of strategic customers, and the organizational and market conditions in which the company operates. The next step is to identify the risks, which should relate to negative and positive aspects (they can also be seen in terms of threats and

opportunities). A risk analysis is then carried out, resulting in a risk register updated with probability values and quantifiable financial and non-financial consequences.

Risk analysis should include [7]:

- the initiating investigation of an event or circumstance,
- identification of root causes,
- the sequence and combination of events considered,
- the possible risk scenarios,
- all circumstances that mitigate the nature and reduce the frequency of possible harmful consequences of the identified risks.

We can prioritize risks according to a combination of probability and potential impact, or by a combination of vulnerability and impact, or regarding either of these parameters. It is also essential to determine which risks require financial inputs and which do not and how the organization responds to a given risk. When the value of probability is not the only criterion for prioritization or when it is impossible to determine it, it is advisable to determine the organization's exposure to risk, obtaining a matrix showing the vulnerability and impact of the hazard.

The next stage includes risk evaluation, which involves comparing the level of risk estimated at the "risk analysis" stage with the risk criteria agreed upon at the "setting the context" stage. It sometimes happens that the conclusion of the risk evaluation is the need to undertake further in-depth analysis or the advisability of maintaining the currently used control measures, safeguards, and ways of monitoring their effectiveness. At this stage, risk aggregation and composition should occur, sometimes called consolidation, which involves comparing the total assessment of identified risks in a given area with the established risk appetite related to, for example, failure to achieve the assumed financial goals. The risk register may describe selected risk management options (risk responses or risk minimization plans), and detailed studies may be treated as attachments. At this stage, the risk owner decides how to deal with the risk. The response may consist of accepting the risk (no action is taken, observing whether the risk level persists or not) or, rejecting the risk and implementing remedial actions (in response to the risk). It is essential that a risk decision was undertaken formally and that it was properly documented.

Risk management is a cyclical process that should take into account [7]:

- assessment of a given method of dealing with risk and determining whether the level of risk after implementing control measures is at an acceptable level,
- developing a new, more effective risk management plan when the risk level after implementing control or security measures is unacceptable,
- assessment of the effectiveness of implemented control measures and the effectiveness of security measures.

Risk management should, on the one hand, guarantee the achievement of the assumed goals and, on the other hand, help minimize discrepancies in the expectations of individual stakeholder groups. Its role is to ensure stable growth in results and constant improvement of the effectiveness of strategic and operational processes. Persons responsible for risk management are therefore obliged to accurately identify all situations that are a source of threats as quickly as possible, prepare the organization for various scenarios of development, and create conditions for making optimal decisions in a situation of variability and uncertainty. Comprehensive risk management becomes particularly important in the case of such a sensitive product as animal feed.

4. Application of analysis of types and effects of possible errors during the implementation of railway transport of feed

4.1. General assumptions

One of the methods supporting the multi-aspect analysis of decision support in the process of transporting feed by rail is the analysis of the types and effects of possible errors (Failure Mode and Effect Analysis (FMEA). It involves systematically identifying process errors and eliminating or minimizing effects. The basis for developing the FMEA analysis was the experimental observation that approximately 75% of errors originate in the early stages of service implementation, but their detection at these stages is low. Analyzing the types and effects of possible errors facilitates evaluating a transportation process or design. It allows you to eliminate and prevent the effects of errors or organizational oversights, which can be achieved by establishing cause-and-effect relationships of potential process errors, taking into account risk factors. That enables continuous process improvement through systematic analysis and introduction of corrections that eliminate sources of errors/threats and improve process properties. The FMEA method enables the detection of potential factors that could later hinder or even prevent the functioning of processes. As part of the FMEA methodology, three stages are carried out, which lead to the definition of an indicator, the value of which determines the behavior within the entire transport process. A detailed description of the individual stages is provided in Table 2.

Based on the dependencies presented in the stage of determining potential defects that are likely to occur in the process, an indicator is calculated – RPN (Risk Priority Number), denoted as P and described by the formula:

$$P = R \times W \times Z \tag{1}$$

Table 2. FMEA methodology – stages

Stage	Description
Establishing a team	The team includes representatives of various company departments and experts in a given field. It appoints a person responsible for managing and coordinating the team's work. The team prepares the assumptions needed for the proper analysis by selecting the operations to be analyzed. The FMEA method uses a systems approach in which each process is a system that includes subsystems. Each element of the system performs specific functions. The team's next task is to define the system's boundaries and isolate the degrees and number of subsystems within it.
Determining potential defects that are likely to occur in the process	The defect's cause is that the subsystem's operation is inconsistent with the assumptions, disrupting the system. Cause and effect relationships are identified and then assessed according to three criteria on a scale from 1 to 10: – probability (frequency) of damage/defect/cause occurrence – R number, – ability to detect the cause before it causes a defect – number W, importance of the defect for the user of the product – Z number.
Determining proposals for introducing preventive actions to reduce or eliminate the risk of defects identified as critical	If it is impossible to eliminate the defect, actions should be proposed to increase detection or reduce the adverse effects of their occurrence. Implementing preventive and corrective actions should be continuously monitored, and results should be verified using the FMEA method.

Source: own study based on [28].

Proposals are made to introduce preventive and corrective actions to reduce or eliminate the risk of defects identified as critical. If it is impossible to eliminate the defect completely, actions should be proposed to increase detection or reduce the negative effects of their occurrence. Implementing preventive and corrective actions should be continuously monitored, and their results should be verified using the FMEA method.

IEC 60812:2018-12 [13] explains how a failure modes and effects analysis (FMEA) can be planned, implemented, documented, and sustained, including its variants, failure modes, effects, and criticality analysis (FMECA). FMEA can be used in safety analysis, supervision, and other purposes, but the indicated document, which is a general standard, does not provide specific guidance for safety applications. PKP PLK S.A. uses the FMEA procedure for technical and operational risk assessment. Risk numbers R take the value from 1 to 1000 and are determined by the product of three factors [20]:

- P – the probability of the materialization of a hazard resulting from the source of a given risk. The "P" number takes an integer value from 1 to 10,
- W – the probability of detecting the hazard with the risk control measures used. The number "W" takes an integer value from 1 to 10,
- S – the number that determines the value of consequences per event and, if more than one event occurs in the period under evaluation, the average value for the consequences resulting from a given hazard. The number „S" takes an integer value from 1 to 10.

Given the risk areas specific to the line infrastructure manager, the spectrum of which covers the entire rail network, this article chooses to use the general FMEA methodology.

4.2. Analysis of the significance of non-compliance, the risk of non-compliance and the detection of non-compliance

The course of the analysis of the types and effects of possible errors can be recorded using a form adapted to assess the significance of non-compliance and its impact (Table 3). The risk of non-compliance can be described as shown in Table 4. The possibility of detecting non-compliance can be described as shown in Table 5.

Table 3. Estimated numerical values of the non-compliance significance criterion (ZN)

Description of the meaning of the non-compliance	The meaning of non-compliance	Estimated numerical value	Symbol
The non-compliance has a negligible impact. The safety risk is negligible.	Very small	1	ZN^{bm}
The discrepancy is of little consequence. The difficulties are minor. The safety risk is low.	Small	2-3	ZN^{m}
The inconsistency has a limited but noticeable significance. The process cannot be completed efficiently or on time. Noticeable security risk.	Average	4-6	ZN^{p}
Mismatch matters a lot. The process may not be completed, or its implementation may be complicated. The security risk is significant.	Big	7-8	ZN^{d}
Inconsistency is significant. The trial will probably not take place. The safety risk is unacceptable.	Very big	9-10	ZN^{bd}

Source: own study based on [23].

Table 4. Numerical values of the criterion for determining the risk of non-compliance (RWN)

Description of the risk of non-compliance	Risk of non-compliance	Estimated numerical value	Symbol
Improbable	Improbable	1	RWN^{n}
Very low	Very rare	2	RWN^{br}
Relatively low	Rare	3	RWN^{r}
Occasional	Average	4-6	RWN^{p}
Cyclical, quite frequent	Often	7-8	RWN^{c}
Non-compliance almost impossible to avoid	Very often	9-10	RWN^{bc}

Source: own study based on [23].

Table 5. Numerical values of the non-compliance detection criterion (MWN)

Description of the possibility of detecting non-compliance by control mechanisms	Ability to detect non-compliance	Estimated numerical value	Symbol
Certainty of detection	Very high	1	MWN^{bw}
High probability of detection	High	2	MWN^{w}
Possibility of detection	Average	3	MWN^{p}
High probability of being undetected	Low	4-6	MWN^{n}
Little chance of detection	Very low	7-8	MWN^{bn}
Certainty of being undetected	Extremely low	9-10	MWN^{en}

Source: own study based on [23].

4.3. Procedure for managing threats when organizing rail transport

The described procedure is based fundamentally on analyzing the consequences of possible errors, which are recorded using a form for assessing the significance of non-compliance. The GMP+ B4 standard was prepared to limit the materialization of threats that may arise during feed transport. Above all, it is about preventing the contamination of feedstuffs that may arise during transport. The level of generality in dealing with adverse events in the process of transporting freight by rail often results in an inadequate response to the upsetting of the acceptable level of risk by those involved in the process. It is common practice to react to adverse railway events' consequences rather than prevent their occurrence [24]. The following approaches can be taken to deal with undesirable incidents during transport, including during the transport of feed:

- Prevention – dealing with significant adverse events that may occur frequently, which is a hedging approach, succeeded by the solutions to reduce the risk. The policy should outline the company's plans for control activities to mitigate the devastating impact of adverse events.
- Tolerance – consent to current difficulties. The adverse event tolerance approach refers to dealing with external events, e.g., weather. The adopted tolerance policy should specify the rules for coming to terms with undesirable events.
- Monitoring – concerns dealing with minor but frequent events. This approach implies the obligation to provide a detailed solution through organizational measures.

The GMP+ &B4 standard prevents the occurrence of adverse events by specifying specific procedures for the transport of feed. The following principles of the feed transport safety system must be taken into account:

1. Conducting a threat analysis, which includes: identification of all threats to transport safety and assessing whether these hazards may constitute a risk to transport safety.
2. Identify control measures for each hazard, including:
   - identification of critical control points,
   - establishing critical limits,
   - development and implementation of a monitoring system,
   - defining remedial actions,
   - approval and verification of the feed transport safety plan,
   - documentation and recording of the feed transport safety plan.

The GMP+ standard defines the requirements for feed safety management. The forwarder or carrier must develop, document, implement, and maintain a feed safety management system. It must be adapted to changes in law or other changes affecting feed safety. It is assumed that the system guarantees that all activities that may affect the safety of transported feed are carried out, defined, implemented, and consistently maintained in the company. The forwarder or carrier must define and document the scope of the safety management system by designating which products are to be transported, the loading bays, and the locations covered. The system must, in all cases, record, inter alia, feed transports as well as all feed-related activities for which the forwarder or carrier is responsible. The freight forwarder or carrier must specify the following:

- the part of the chain for which the forwarder or carrier is responsible (it begins where the responsibility of the previous link ends and ends where the responsibility of the next link begins),
- all activities related to the transport of feed (also includes activities subcontracted to third parties),
- all means of transport used,
- all locations (this also applies to places where relevant administrative tasks are carried out),
- if a freight forwarder or carrier decides to outsource an activity that may affect feed safety, he must ensure that such activity is carried out following the requirements of this standard.

The forwarder or carrier must take all possible measures to prevent birds, animals, and pests from entering the premises and preventing their presence. The forwarder or carrier should take appropriate measures to prevent the presence of pests in industrial premises, buildings, or holds loaded with feed products. They should develop, implement, and document a pest prevention and control program. Pest control activities must be planned, conducted, and documented. Documents relating to control activities must demonstrate compliance with the requirements and conditions [9].

According to the standard, a freight forwarder or carrier must establish, collect, and analyze relevant data at least annually to demonstrate that the feed safety system is appropriate and effective and to assess whether further improvements to the effectiveness of the feed safety system are possible. The assessment should cover at least the following issues:

- assessment of the ex-ante conditional program,
- evaluation of analysis results (cleaning and disinfection),
- verification of threat analysis (if applicable),

– assessment of the level of knowledge of employees,
– results of supplier evaluation (e.g., suppliers of cleaning products, etc.),
– complaint analysis (from customers),
– assessment of the implementation of legal provisions and regulations,
– results of internal and external audits,
– changes that may affect the safety of feed transport.

5. Summary

The task solved using the FMEA method is fed by historical data, the transport task, and the FMEA methodology. Three elements are analyzed – the significance of non-compliance, the risk of non-compliance, and the possibility of detecting non-compliance. They enable quantification and determination of a risk priority number. If the acceptable risk level is exceeded, changes are made to the transport task. The above situation is illustrated in Figure 2.

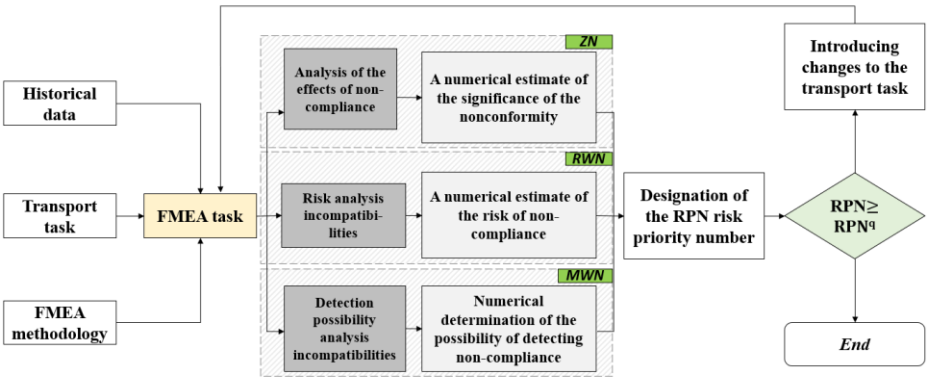

Fig. 2. Algorithm for analyzing the effects and causes of defects when determining values for rail transport of feed (source: own study)

There is no single effective risk management system. The level of detail of the collected risk information should, therefore, be adapted to the complexity of the organization's structure, processes, specificity of the industry, product, or communication processes with stakeholders. The risk is closely related to the safety of feed trade. The forwarder or carrier remains responsible for the feed's safety and for checking the compliance of his activities with the requirements. By complying with the requirements of this standard, a forwarder or carrier can demonstrate to third parties the safety and quality of its services [9].

Thanks to the FMEA method, it is possible to quantify the fundamental values necessary to estimate the risk of transporting feed by rail. The identified threats are perceived as undesirable factors that may affect many elements of the transport process, from loading at the loading point through transport to unloading at the loading point.

All process elements should be defined in accordance with the FMEA methodology, and if the acceptable values for the risk priority number are exceeded, the entities involved in the process should react immediately. Transporting feed by rail is monitored, which

allows for collecting information about any disruptions. They constitute a database that allows you to determine the limit ranges for the levels defined using FMEA.

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