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SELECTED ORGANIZATIONAL AND TECHNICAL SOLUTIONS USED IN THE SAFETY OF WAREHOUSE PROCESSES

ABSTRACT: This paper addresses the complex and dynamic nature of warehouse operations, highlighting the critical role they play in the overall supply chain. Warehouses are exposed to a variety of static and dynamic processes that operate in a turbulent environment, where both internal and external threats can significantly impact performance and productivity. Effective risk management and security measures are crucial to maintaining the smooth functioning of these operations, as errors can lead to financial losses, waste, and damage to the reputation of a company. The research explores the challenges in decision-making related to resource management and safety procedures within warehouses, focusing on identifying potential threats, understanding the causes of inventory discrepancies, and evaluating the effectiveness of existing safety systems. The study, grounded in extensive national and international literature and ongoing research initiated in 2015, aims to assess the impact of technical and non-technical systems on warehouse management amidst various threats. The findings, derived from surveys conducted in Polish warehouses, are presented through tables, diagrams, and annotations, providing insights into enhancing safety and operational efficiency in this critical area of the supply chain. The publication addresses the research question: How do technical and non-technical systems impact warehouse management amid various threats? Its goal is to evaluate the effectiveness of methods and strategies that enhance safety in Polish warehouses.

KEYWORDS: warehouse, warehouse processes, security measures, security systems, threats

WYBRANE ROZWIĄZANIA ORGANIZACYJNO-TECHNICZNE WYKORZYSTYWANE W BEZPIECZEŃSTWIE PROCESÓW MAGAZYNOWYCH

ABSTRAKT: Niniejszy artykuł dotyczy złożonej i dynamicznej natury operacji magazynowych, podkreślając ich kluczową rolę w całym łańcuchu dostaw. Magazyny są narażone na różnorodne procesy statyczne i dynamiczne, które działają w burzliwym środowisku, gdzie zarówno zagrożenia wewnętrzne, jak i zewnętrzne mogą znacząco wpłynąć na wydajność i produktywność. Skuteczne zarządzanie ryzykiem i środki bezpieczeństwa są kluczowe dla utrzymania płynności tych operacji, ponieważ błędy mogą prowadzić do strat finansowych, marnotrawstwa i uszczerbku na reputacji firmy. Badanie eksploruje wyzwania związane z podejmowaniem decyzji dotyczących zarządzania zasobami i procedurami bezpieczeństwa w magazynach, koncentrując się na identyfikacji potencjalnych zagrożeń, zrozumieniu przyczyn rozbieżności w inwentarzu oraz ocenie skuteczności istniejących systemów bezpieczeństwa. Badanie, oparte na szerokiej literaturze krajowej i międzynarodowej oraz trwających badaniach zapoczątkowanych w 2015 roku, ma na celu ocenę wpływu systemów technicznych i nietechnicznych na zarządzanie magazynami w obliczu różnych zagrożeń. Wyniki, pochodzące z ankiet przeprowadzonych w polskich magazynach, są przedstawione za pomocą tabel, diagramów i adnotacji, oferując wgląd w poprawę bezpieczeństwa i efektywności operacyjnej w tym kluczowym obszarze łańcucha dostaw. Publikacja odpowiada na pytanie badawcze: Jak systemy techniczne i nietechniczne wpływają na zarządzanie magazynami w obliczu różnych zagrożeń? Jej celem jest ocena skuteczności metod i strategii poprawiających bezpieczeństwo w polskich magazynach.

SŁOWA KLUCZOWE: magazyn, procesy magazynowe, środki bezpieczeństwa, zagrożenie, wypadek



INTRODUCTION

Each warehouse carries out processes (reception, movement, picking, shipping) that are static and dynamic and take place in a variable, turbulent environment. It is important to recognize that the performance and productivity of warehouse operations, which include the storage and management of goods, have a significant impact on the smooth functioning of the subsequent and preceding stages of the supply chain. This, in turn, influences profitability and the perception of the company by its clients (both suppliers and buyers). Errors in these operations can lead to financial losses, unnecessary waste, and damage to the reputation of the company.

Every warehouse process in real conditions is exposed to unplanned situations and threats. An effective tool in such situations is to ensure the safety of operations in the warehouse. It serves to identify and prevent threats, ensure survival conditions, and pursue interests by using effective risk minimization potential when an unplanned situation occurs.

Security is a dynamic phenomenon that changes in time, space, and dimension. Security architecture is a knowledge-based and practical activity and covers a wide spectrum of forms and ways of organizing appropriate conditions for the operation of a security warehouse by ensuring its existence (survival) and the ability to achieve goals.

It should be emphasized that even the best-planned activities do not guarantee their full implementation due to the turbulence of the environment, which may change as a result of internal and external threats. It is often impossible to predict all the factors on which warehouse security depends. Examples of such situations may be: the COVID-19 pandemic, the war in Ukraine, the current inflation, or the energy crisis.

It is very problematic to make decisions regarding collected resources and procedures so that the processes implemented as part of warehouse management ensure security at the required level. This is due, among other things, to the fact that many questions have been answered, which allow for a logical and rational solution to the problem. These questions may include the following:

- What external and internal (technical and non-technical) threats exist in the warehouse?
- What are the main causes of incorrect inventory recording (theft, assembly, delivery delays, complaints, returns, loss of goods) in the warehouse?
- Are there technical systems in place in the warehouse that support safety, and if so, what are they?
- Are there management systems in place in the warehouse?
- What solutions related to the implementation of safety assumptions have been implemented in the warehouse over the last three years?
- Are the costs associated with ensuring safety in the warehouse analyzed?

Understanding the responses to these inquiries helps to maintain a satisfactory standard of safety within the warehouse, but does not provide absolute certainty. This is because in the

event of a flood, it is challenging to accurately predict the extent and timing of the breach of alarm thresholds, as well as the potential damage and associated expenses that can arise.

The identified issues and previous analyzes carried out in Poland highlight the need for additional investigation in this domain. The content detailed in this publication stems from ongoing research initiated by the author in 2015, as documented in various works by both the author and collaborators. The material draws upon a comprehensive array of national and international literature, with contributions from scholars such as Sowa, 2018; Schuetz 2022; Brown, 2023; Szymonik, Stanisławski, 2022; Larco, de Koster, Roodbergen, Dul, 2013; Forcin, Falcone, 2021.

The publication outlined the following:

- a research problem formulated as a question: How significantly do operational technical and non-technical systems impact the management of warehouses amidst a variety of threats?
- goal: To pinpoint and evaluate the efficacy of methods and strategies that contribute to enhancing safety within Polish warehouses.

The study was executed via surveys using a bespoke questionnaire designed to examine the risks and elements that influence the safety of the warehouse. The findings were depicted through a series of tables, diagrams, and concise annotations.

WAREHOUSE FUNCTIONS

A warehouse serves as both a functional entity and an organizational space, deliberately designed to facilitate various logistics activities such as receiving, unloading, storing, sorting, and distributing goods. These processes are dynamic and subject to evolution. Often, the ultimate outcome deviates from the original plan, influenced by the fluctuating conditions under which the flow of materials and information occurs within the warehouse.

Simply portraying the warehouse through its internal configurations (both organizational and functional) is insufficient. It is also crucial to consider the ongoing dynamic shifts that occur within and around the warehouse, as these significantly influence operational processes, such as order picking, or dispatching. Consequently, an accurate representation of a warehouse's operations should integrate both static and dynamic elements, which is instrumental in crafting logistic simulation studies.

The operation of a warehouse encompasses several aspects:

- Facility: This refers to the various processes executed with the stored inventory.
- User: This element represents the entities interacting with the facility, such as manufacturing or service businesses or individual consumers.
- Environment: The facility and its users are connected through their interactions with external factors, such as transportation within the logistics sector, which can have either a positive or negative effect on their actions and the overall efficiency of warehouse operations.
- Relationships: These are the capabilities to maintain the operational integrity of the facility (through warehouse processes) and the user (such as a business), as well as to

forge connections with the external environment, like the online marketplace of suppliers and customers, thereby influencing the scenarios that unfold.

A warehouse as a logistics entity is characterized by several key features, including:

- **Stable Environmental Integration:** This involves the capacity to maintain consistent interactions with the external environment, such as ensuring the production line is supplied with the necessary items according to the schedule, or addressing and mitigating crises like floods or fires.
- **Influential Connectivity:** It possesses the ability to interact with the surrounding environment and shape the outcomes of evolving scenarios, which could involve conducting market analysis and predicting demand and supply trends, or assessing requirements for threat mitigation.
- **Interconnectedness with Related Phenomena:** The facility has the ability to forge links with related events and its environment, enabling it to identify specific factors that influence the efficiency of its operations, such as evaluating customer satisfaction levels or the extent of complaints.

Interactions with the environment can stem from a facility's internal factors (for instance, the dimensions of ordered parts are contingent on the consumer demand for the products produced) or can be influenced by external factors that necessitate or dictate these interactions (such as a downturn in the market, economic downturns, or competitive endeavors).

The description of an object, generally speaking, may concern its three aspects¹:

- **functioning** (warehouse processes) – executing the user's scheduled activities, such as securing the necessary space and time, managing the flow of materials, that is, transporting everything to its destination within the whole production system;
- **morphology** (structure) – the organization's framework, the arrangement of components, the interlinkages between these components, and their individual characteristics, for instance, the administrative, operational, and storage infrastructures to form a unified entity, resulting in what is known as an automated warehouse;
- **organization** (information and decision-making processes), including the flow of information, the interplay of control algorithms, such as those for inventory tracking, storage, order picking, shipping, and overall work management².

The internal properties of a warehouse, just like any system (object), can be analyzed in the context of such quantities as³:

- capacity for particular types of resources;

¹ S. Paszkowski, *Podstawy teorii systemów i analizy systemowej*, Warszawa 1999, p. 19.

² J. O'Donnell, *Definition warehouse management system (WMS)*, https://www-techtargget-com.translate.googleusercontent.com/searchp/definition/warehouse-management-system-WMS?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (03.03.2023).

³ *How to make a warehouse efficient: From space optimization to cost reduction*, https://www-modula-eu.translate.googleusercontent.com/blog/how-to-make-a-warehouse-efficient-from-space-optimization-to-cost-reduction/?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (17.03.2023).

- optimization of warehouse stock/resources;
- efficiency (economy, productivity) of warehouse work (receipt, storage, release, records, etc.);
- resistance to disruptions in ongoing processes;
- operational technical performance indicators;
- costs of warehousing activities;
- staff satisfaction and safety;
- other.

CLASSIFICATION AND TYPES OF THREATS

Maintaining operational security within a warehouse requires the deployment of human, physical, and financial resources. The extent and nature of the resources dedicated to safeguarding the warehouse are contingent upon:

- external threats coming from it;
- internal threats that are ‘cumulative’ within itself;
- the warehouse's resistance to threats – Its reliability⁴;
- available management, executive, and information-decision-making potential.

It should be emphasized that, in general terms, warehouse security is related to: risk (R), reliability (P_o), and threats (Z). To assess these values, we use quantitative or qualitative measures, remembering a uniform approach for a specific logistics system, such as a warehouse.

The risk value (R) depends on: probability determining the possibility of a threat occurrence (P), reliability – resistance to disruptions caused by threats (P_o), frequency of threat occurrence (C), value of possible losses (S), exposure factor determining the degree to which the warehouse is important from the point of view of the threat (E). R – in the warehouse we can write as⁵:

$$R = P \times P_o \times C \times S \times E \dots\dots(1)$$

Recognizing threats is crucial for assessing risks, thus predicting their emergence using past data is essential. Additionally, it is important to monitor and recognize these threats to implement appropriate measures for recovery.

To evaluate the potential impact of threats on warehouse security, a valuable approach involves thoroughly identifying and categorizing them into two groups. This comprehensive classification enables better understanding and facilitates targeted mitigation strategies.

⁴ A. Pyster, D. Olwell, *System Reliability, Availability, and Maintainability*, https://sebokwiki.org/wiki/System_Reliability,_Availability,_and_Maintainability (23.03.2023).

⁵ P. Sienkiewicz, H. Świeboda, *Ryzyko w inżynierii systemów bezpieczeństwa*, [in:] *Inżynieria systemów bezpieczeństwa*, (red.) P. Sienkiewicz, Warszawa 2015, pp. 9, 41; P. Zaskórski, *Informacja ciągłości działania determinantą bezpieczeństwa organizacji*, [in:] *Nie-bezpieczny świat. Systemy. Informacja. Bezpieczeństwo*, Warszawa 2015, p. 449.

FIRST GROUP

Threats to the functioning of warehouse management can be divided into five groups⁶:

- The initial category consists of natural threats such as various disasters, including floods, hurricanes, and other catastrophic events. Within this category, we can also identify incidents resulting from deliberate actions or human error, like equipment malfunctions, fires, thefts, industrial accidents, communication breakdowns, electrical grid outages, and the corruption or manipulation of data crucial for warehouse operations.
- The second category encompasses civilization-related incidents, with examples being cyber-assaults, exposure to electromagnetic fields, lifestyle-related illnesses, mismanagement of environmental and economic resources leading to financial downturns, environmental pollution affecting soil, air, and water, inefficient disposal of waste, microbial hazards, and widespread health emergencies like epidemics and pandemics.
- The third category is composed of social threats that challenge the fundamental laws of nations, including acts of terrorism, blockades, unauthorized protests, racial disputes, and large-scale population shifts.
- The fourth category pertains to psychological threats stemming from mental health problems such as stress, persistent exhaustion, circadian rhythm disturbances, and depression. These are often linked to suboptimal work environment choices, non-adherence to workplace health and safety standards, ergonomic failures, and job-related exhaustion.
- The fifth group involves technical malfunctions, which cover scenarios such as the breakdown or ruination of warehousing facilities, disruptions in energy and water services, IT system outages, and malfunctions of technical equipment or systems.

SECOND GROUP

Threats can also be divided into four groups for research purposes.

- external threats:
 - natural: these include environmental hazards such as natural disasters;
 - civilizational: encompasses societal and cultural factors;
 - social: pertains to threats arising from human interactions;
 - personality: relates to individual behaviors and actions;
 - technical: involves failures in technical systems.
- internal threats:
 - record keeping: issues with maintaining accurate records;
 - picking errors: mistakes during order picking;

⁶ R. Brown, *6 potential threats to warehouse facilities*, https://thebossmagazine-com.translate.goog/potential-threats-to-warehouse-facilities/?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (27.02.2023); *Warehouse Risk Management: Is Your Facility Secure?*, https://www-clearrisk-com.translate.goog/risk-management-blog/is-your-warehouse-secure?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (04.01.2023); *Main warehouse risks: keep them under control*, https://www-mecalux-com.translate.goog/blog/main-risks-warehouses?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (07.03.2023).

- theft: unauthorized removal of goods;
- delivery delays: timeliness challenges;
- financial liquidity: cash flow problems;
- work accidents: safety incidents;
- supply chain interruption: disruptions in the supply chain.
- technical threats:
 - IT system failures: malfunctions in information technology;
 - internal transport issues: problems with warehouse vehicles;
 - air conditioning breakdowns: failures in climate control;
 - power supply disruptions: electrical outages;
 - monitoring system failures: issues with surveillance and monitoring.
- organizational and legal challenges:
 - regulatory gaps: lack of up-to-date regulations;
 - training deficiencies: insufficient employee training.

The outlined categories of disruptions highlight the extensive and multifaceted nature of adverse events that can impact warehouse management. When considering functions and management levels, disruptions in warehouse processes may arise from the following:

- strategic planning and assessment: incorrect assumptions during strategic planning; flawed evaluation of strategic options;
- reputation and social responsibility: damage to reputation due to sustained criticism from government or international media; failure to uphold social responsibility standards;
- internal processes and technologies: reliance on inappropriate or unreliable internal processes and technologies;
- operational challenges: issues related to storage, distribution, and employee actions; malfunctioning processes within the warehouse;
- external factors: unpredictable actions of customers, suppliers, competitors, and new market entrants; changes in the external environment;
- stakeholder relations and organizational structure: poor relations with stakeholders; inadequate organizational structure for delegating responsibilities; lack of appropriate conduct rules for employees and managers;
- compliance and security: non-compliance with laws, internal regulations, and contractual obligations; insufficient physical security for assets and personnel;
- information technology challenges: outdated ICT resources and technologies; inconsistent ICT strategy; disruptions in ICT infrastructure;
- environmental impact: permanent environmental destruction; loss of commercial, recreational, or conservation value, leading to significant financial consequences for supply chain participants.

These multifaceted threats underscore the need for proactive risk management and robust strategies within warehouse operations.

FACTORS AFFECTING WAREHOUSE SECURITY

Warehouse safety encompasses a set of guidelines and optimal practices dedicated to creating a secure work environment. Given that warehouse operations heavily rely on human labor and the utilization of proper machinery, adhering to established safety protocols and regulations is essential⁷.

Warehouse security also represents a state that provides assurance and guarantees in several dimensions: process implementation (ensuring the effective execution of warehouse processes), information flow (facilitating the flow of information for logistics planning and management), protection and survival: safeguarding against threats and ensuring survival during hazardous situations, adaptation to change.

A specific level of warehouse security can be achieved in many ways - not only by ensuring specific effectiveness of direct counteraction to occurring events.

In the context of warehouse security, we consider controllable quantities represented by various factors. These factors influence the overall level of security within the warehouse. Specifically, we focus on the following aspects⁸:

- preventing security threats,
- readiness for threat activation,
- resource allocation for threat mitigation,
- mitigating consequences.

It should be considered that, from a systemic perspective, warehouse security is associated with threats, reliability, and risk. To evaluate these magnitudes, we apply quantitative or qualitative measures, keeping in mind a uniform approach for a specific warehouse.

An important area for the functioning of a warehouse is its security, which we can treat on the basis of system analysis as⁹:

- susceptibility to dangerous situations: this property of the warehouse relates to its ability to withstand and respond to hazardous situations or threats; specifically, it emphasizes the unreliability of the warehouse's safety measures, the degree to which it may be vulnerable to adverse events;
- external threat protection: another critical aspect is the warehouse's capacity to safeguard its inventory and infrastructure from external threats; this includes implementing measures to prevent unauthorized access, theft, damage, or any other risks posed by external factors.

⁷ J. Piłatowska, *10 best warehouse safety tips*, https://linkercloud-com.translate.google/blog/warehousing/10-best-warehouse-safety-tips?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (17.01.2023).

⁸ E. Kołodziński, *Istota inżynierii systemów zarządzania bezpieczeństwem*, <http://www.uwm.edu.pl> (10.08.2022).

⁹ P. Sienkiewicz, H. Świeboda, *Ryzyko w inżynierii...*, *op.cit.*, pp. 9, 41.

Safety in a warehouse depends on three groups of factors, i.e. technical, more broadly in research, legal, and personal (see Table 1).

Table 1. Factors determining safety in the warehouse

Factor	Contents
Technical	Warehouse equipment and infrastructure (more in research)
Legal (organizational)	Documentation and its implementation, as well as procedures minimizing the risk of accidents or material losses.
Personnel	Competencies, qualifications and experience, professional development of staff.

Source: own study.

Safety considerations in warehouses hinge on the availability of suitable equipment and facilities, which are crucial for ensuring the correct handling, storage, and processing of the items. This includes the safekeeping of the premises and the commodities within.

Ensuring safety in a warehouse is possible if internal and external protection is well organized through the use of such devices¹⁰:

- security cameras;
- lighting;
- alarm systems;
- access control systems with remote backups;
- anti-burglary doors and windows;
- smoke detectors;
- proximity warning sensor;
- virtual reality (VR) or augmented reality (AR) systems that enable employees to conduct practical training in a safe environment (Impact of Upgraded Technology on Warehouse Safety);
- ESFR (Early Suppression Fast Response) sprinkler system, hydrants, fire extinguishers, ventilation openings, emergency exits;
- emergency power supply (generators, batteries);
- fire alarm system.

In today's digital age, overlooking the significance of technology and electronic systems would be remiss. Specifically, the inclusion of equipment that facilitates real-time online inventory management and monitoring is indispensable. This technology allows precise tracking of stock levels, valuation, product categories, and expiration dates, ensuring efficient and accurate warehouse operations.

¹⁰ 8 *Types of Warehouse Security Measures*, https://www-the fulfillmentlab-com.translate.goog/blog/warehouse-security?_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (03.03.2023).

Some helpful tools and instruments in this regard include¹¹:

- Internet of Things (IoT) – RFID technology combined with sensors, software and other technologies that allow you to track inventories via the Internet, with extensive use of cloud computing and big data, 5G, blockchain, machine learning;
- warehouse management systems WMS (Warehouse Management System) – an IT system supporting the management of warehouse processes using appropriate IT tools¹²;
- material flow management system MFMS (Material Flow Management System) – an extension of the traditional warehouse management system;
- warehouse automation systems – the use of various control systems to operate with minimal or reduced human intervention in the implementation of warehouse processes.

Technical factors affecting warehouse security include:

- mechanical security, which are all types of permanent partitions (structures, walls, gates, fire-proof doors, anti-burglary doors), and their additional task is to protect particularly important (valuable or dangerous) supplies stored there;
- electronic security, which includes alarm systems and closed-circuit television.

During the COVID-19 pandemic, the emphasis on securing premises, particularly unoccupied warehouse spaces, intensified. This was due to a rise in the preference for remote work, which extended to areas such as warehouses and logistics hubs.

The security measures currently in use include¹³:

- access control systems,
- entry management systems,
- the intrusion detection system (IDS)¹⁴,
- perimeter defense systems,
- omnipresent surveillance cameras operating round-the-clock,
- proximity sensors,
- fire detection systems,
- audible alert systems,
- permanent fire suppression installations.

¹¹ *Ibidem.*

¹² Y. Zhang, *Warehouse Management System Based on RFID and Internet of Things Technology*, [in:] 2nd International Conference on Networking, Communications and Information Technology, Manchester, United Kingdom, 26-27.12.2022, Manchester 2022, pp. 489-492.

¹³ *Systemy zabezpieczeń osób i mienia - najważniejsze trendy. Postęp w systemach zabezpieczeń dzięki pandemii*, <https://obiektykomercyjne.muratorplus.pl/instalacje/systemy-zabezpiecen-osob-i-mienia-rozwoj-branzy-najnowsze-rozwiązania-aa-THDp-1b9V-q4GR.html> (30.03.2023).

¹⁴ *Sygnalizacja włamaniowa i napadu*, https://miwsc-eu.translate.google.com/burglary-and-robbery-signaling/?lang=en&_x_tr_sl=en&_x_tr_tl=pl&_x_tr_hl=pl&_x_tr_pto=sc (28.01.2023).

In the context of an organization, legal factors encompass the creation and execution of documentation, alongside the establishment of procedures. Ensuring rigorous compliance with these procedures is essential to reduce the likelihood of incidents or financial losses¹⁵.

During the preparation of warehouse documentation, it is essential to account for inventory (types of supplies and reserves) and adhere to the legal standards and rules that define storage conditions. Documentation should cover: warehouse worker responsibilities; fire prevention guidelines; safety and health protocols; warehouse data sheet; maintenance procedures; guidelines for using humidity and temperature gauges; ventilation protocols; use of emergency signals and their varieties; a plan for evacuating stored goods; details of the emergency response team; inventory of warehouse assets; equipment placement blueprint; up-to-date warehouse particulars; procedures for handling hazardous material spills; warehouse operational rules; a list of individuals with document approval authority; temperature and humidity logs (including digital versions); examples of seals; a registry of warehouse visitors; a log of warehouse checks; a record of items sent for repair or maintenance; a deposit ledger; and other necessary documents.

It is vital that warehouse operations have established protocols that not only proactively prevent potential hazards, but also offer prompt and effective responses to any imminent risks, thus mitigating their negative impact. These measures are crucial for maintaining the integrity and smooth operation.

Typical organizational procedures related to the operation of a warehouse include¹⁶: technical conditions of operation of the warehouse and its equipment, fire protection, protection against burglary, work safety of staff, receiving and issuing material goods, inventory of stocks, arrangement of stocks in the warehouse, warehouse records, documents of receipt and issue of goods, and other information activities.

Warehouse procedures must be designed to reduce the likelihood of accidents, which can arise from various factors such as malfunctioning lifts, employee recklessness, urgency due to tight schedules, disorganized work processes, non-adherence to work policies, delayed responses to unforeseen incidents, misconduct by colleagues or drivers, uncomfortable forklift operation postures, or physical strain due to poor ergonomic practices that lead to tiredness or loss of control.

In large warehouses, logistics operations are streamlined through the use of a WMS (Warehouse Management System), an IT system that facilitates various tasks. These tasks include¹⁷: tracking incoming goods from external sources and returns, as well as outgoing shipments; maintaining and adjusting inventory according to specific guidelines; allocating storage spaces for incoming stock and organizing order fulfillment; creating necessary paperwork for

¹⁵ J. de Vries, R. de Koster, D. Stam, *Safety does not happen by accident: antecedents to a safer warehouse*, "Production and operations management" 2016, 25, (8), pp. 1377-1390.

¹⁶ C. Skowronek, Z. Sarjusz-Wolski, *Logistyka w przedsiębiorstwie*, Warszawa 2008, p. 141.

¹⁷ *Instrukcja o zasadach i organizacji przechowywania oraz konserwacji uzbrojenia i sprzętu wojskowego DD/4.22.8*, Bydgoszcz 2013, p. 30.

deliveries and dispatches; processing orders; ensuring the accuracy of deliveries against documentation; overseeing the loading of transport vehicles; monitoring warehouse transactions; identifying and pinpointing the location of items; conducting inventory audits; and choosing appropriate transportation methods for delivery.

The procedures developed that regulate the material responsibility of employees for entrusted property are significant for the safety of the warehouse. The legal bases concerning liability are contained in the labor code and three regulations.

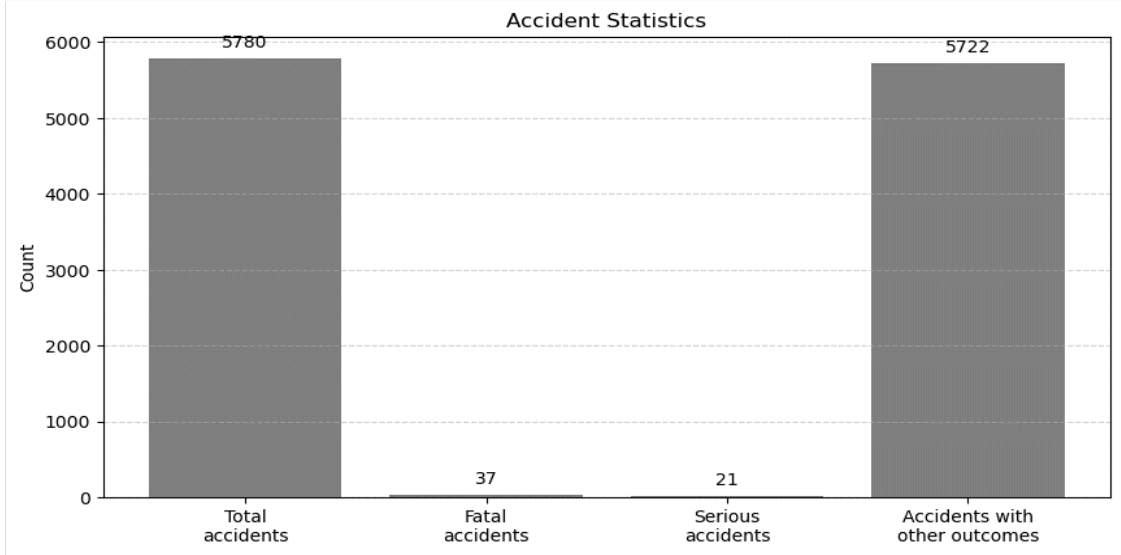


Chart 1. Accidents in 2021 in transportation and warehouse management – numerical summary
 Source: Wypadki przy pracy w 2021, GUS, Warszawa 2022, p. 4.

For the safety of warehouses, the procedures included in warehouse physical protection of warehouses are essential. A prime approach involves the participation of specialized firms such as SASF (Specialized Armed Security Formations) to safeguard individuals and assets, with a mandatory collaboration with law enforcement agencies including the Police, the State Fire Service, and the Municipal Guard. SASF personnel are authorized, during their duties, to perform checks (within designated zones) and detain individuals, apply physical force for direct compulsion, and utilize tools of direct coercion such as nightsticks, handcuffs, disabling gas, tasers, and more, including the use of firearms. These company representatives maintain continuous oversight of warehouse staff and visitor movements, as well as vehicular flow into and out of the warehouse premises.

The security of a warehouse is significantly influenced by the personnel employed within. These individuals form a collective that participates in tasks intimately related to the warehouse’s functioning. The roles designated for warehouse operations, as per the job classification system, encompass positions such as warehouse manager, chief storekeeper, inventory controller, and general warehouse staff. The size of the workforce and the skill level required depend on the warehouse’s specific objectives and dimensions of the warehouse. In the hiring process,

it is essential to consider factors like skills, credentials, and prior experience, and upon their recruitment, it is crucial to continually invest in their career advancement.

Ensuring safety within a warehouse critically hinges on adherence to occupational health and safety standards by employees and users of the facility, such as drivers handling the delivery and collection of logistics loads. Statistical evidence (referenced as Chart 1 and Chart 2), compiled by the Central Statistical Office regarding accident analysis in transportation and storage, underscores the gravity of this issue from both a societal and economic perspective.

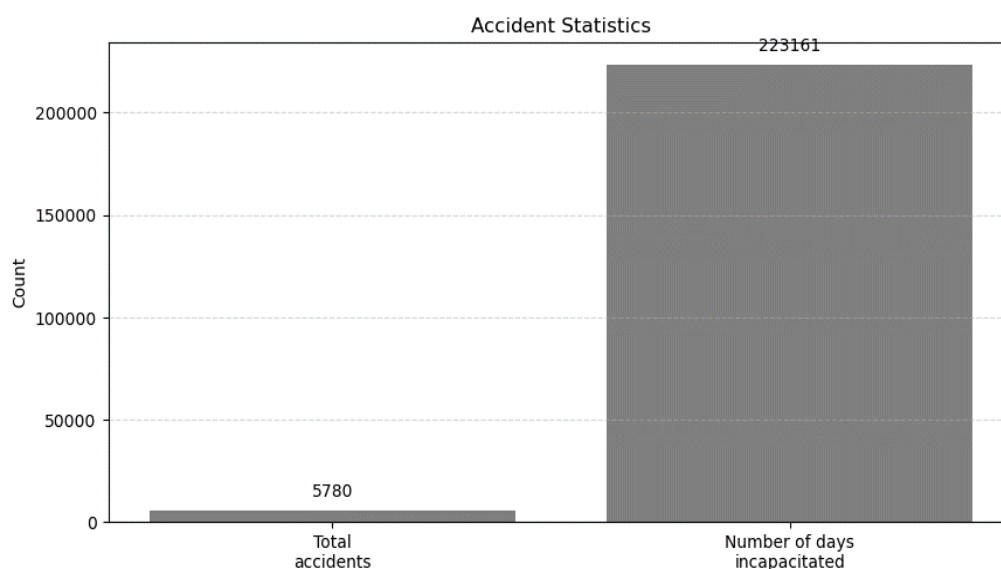


Chart 2. Accidents in 2021 in transport and warehousing – number of days of inability to work caused by accidents in total

Source: Wypadki przy pracy w 2021, GUS, Warszawa 2022, p. 2.

With a total of 5,780 accidents in the transport and storage sector, and 223,161 days lost due to work-related incapacity, it is evident that significant improvements are needed in the organizational and procedural aspects of occupational health and safety. However, it is encouraging to note that there has been a steady improvement in these conditions over the years, a trend supported by data from the Central Statistical Office.

Effective fire safety measures play a crucial role in protecting both people and stored goods within a warehouse. Carefully crafted guidelines, properly maintained firefighting equipment, and regular training instill confidence in preventing and managing potential fires.

Table 2. Number of fires in warehouse facilities in 2018–2021

Years	2018	2019	2020	2021
Warehouse facilities	1025	1053	993	924

Source: Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2021, Komenda Główna PSP, Warszawa 2022, p. 66; Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2020, Komenda Główna PSP, Warszawa 2021, p. 72; Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2019, Komenda Główna PSP, Warszawa 2020, p. 56.

Table 3. Summary of the size of fires in warehouse facilities in 2019–2021

Specification	2019	2020	2021
Overall, including:	1053	993	924
Small	827	778	723
Medium	174	168	147
Large	40	33	36
very large	12	14	18

*Explanation: Types of fire: small - counts on areas up to 70 m² in area or up to 350 m³ in volume; medium – from a small fire up to 300 m² of area or up to 1500 m³ of volume; large – we count from medium fire up to 1000 m² or up to 5000 m³ volume; very large – more than 1000 m² or more than 5000 m³ in volume, (Typy pożarów, 2023).

Source: Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2021, Komenda Główna PSP, Warszawa 2022, p. 67; Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2020, Komenda Główna PSP, Warszawa 2021, p. 73; Biuletyn informacyjny Państwowej Straży Pożarnej za rok 2019, Komenda Główna PSP, Warszawa 2020, p. 57.

Fire incidents can result from various factors, including arson by disgruntled employees, competitive motives, non-compliance with fire safety regulations, faulty electrical or HVAC systems, spontaneous combustion, and lightning strikes. The frequency and scale of fires are detailed in Table 2 and Table 3.

Information about warehouse fires highlights several critical points. First, fires pose risks both to human safety and to goods stored there. Second, they result in significant losses and disrupt warehouse management processes, including supply chains. In Poland, an average of 1,000 warehouse fires occur annually between 2019 and 2021, with approximately 20% of these being very large fires covering areas exceeding 1,000 square meters.

SAFETY IN THE WAREHOUSE – OWN RESEARCH

THE RESEARCH METHOD

The study began with a literature analysis (using the literature review method) to formulate the research problem. Based on the material obtained, it became evident that warehouse safety in Poland is not adequately appreciated, as indicated by the limited publications and scientific research in this field. This situation suggested that further research is necessary in this area.

These conclusions led the author to formulate two research gaps related to assessing the significance of safety practices implemented in warehouse operations.

The first theoretical gap pertains to the lack of model solutions for the application of modern safety measures in Polish warehouses.

The second practical (empirical) gap is related to the absence of research on the use, assessment, and recommendations of safety-related solutions affecting warehouse management.

The research aimed to identify and classify the safety practices implemented in warehouse management. Surveys were conducted using a specially prepared questionnaire. In the actual research:

- The sample selection process began with identifying 600 companies engaged in warehouse management. Subsequently, 160 firms were randomly selected for the study, and completed questionnaires were obtained from 130 companies.
- Techniques such as CAWI (Computer-Assisted Web Interviewing), auditory interviews, and individual surveys were used.

CHARACTERISTICS OF THE RESEARCH SAMPLE

The research for the article was conducted in 2022 and covered the years 2019-2022. The entities participating in the study were companies that own or manage warehouses. The study included companies with various parameters. For instance, due to: employment size, storage height, mechanization level.

The research was conducted in the following provinces, distributed as follows: Dolnośląskie – 16 (12.3%), Kujawsko-Pomorskie – 9 (6.9%), Lubelskie – 10 (7.7%), Łódzkie – 24 (18.6%), Małopolskie – 6 (4.7%), Mazowieckie – 21 (16.3%), Opolskie – 12 (9.1%), Pomorskie – 13 (10%), Śląskie – 11 (8.1%), Warmińsko-Mazurskie – 4 (3.1%), Wielkopolskie – 3 (2.1%).

According to the analysis, the majority of research was conducted in the following provinces: Łódzkie: 18.3% (ranking 5th among the wealthiest provinces in 2021), Mazowieckie: 16.3% (ranking 7th among the wealthiest provinces in 2021), Dolnośląskie: 12.3% (ranking 1st among the wealthiest provinces in 2021).

The questions included in the survey were divided into three groups¹⁸.

The first group was related to threats that can occur in warehouse management. These included external threats, non-technical internal threats, and technical internal threats.

The second group focused on technical factors that affect the safety of warehouses. Questions addressed equipment, infrastructure ensuring proper storage, internal transport, order picking, sorting, dispatch, and facility protection.

The third group dealt with organizational and legal issues related to warehouse safety.

Analysis and assessment of threats included in the first group.

External threats that affect warehouse safety fall into five distinct categories. During the past three years, the most common threats have been natural hazards (including heatwaves, floods, heavy rain, droughts, and pandemics) and technical hazards. Among the natural hazards, they consistently impacted 60 companies, while technical hazards were reported 56 times.

Among the least frequent external threats were civilizational risks (never or occurring only once, totaling 116 cases), personality-related risks (117 cases with similar infrequency), and social risks (129 cases with minimal occurrence). This outcome suggests that warehouse

¹⁸ The results of the survey with questions included in the second and third groups will be analyzed in a separate subsequent material (chapter, article).

managers carry out their responsibilities, adhering to legal requirements, and benefiting from the country’s favorable economic conditions of the country.

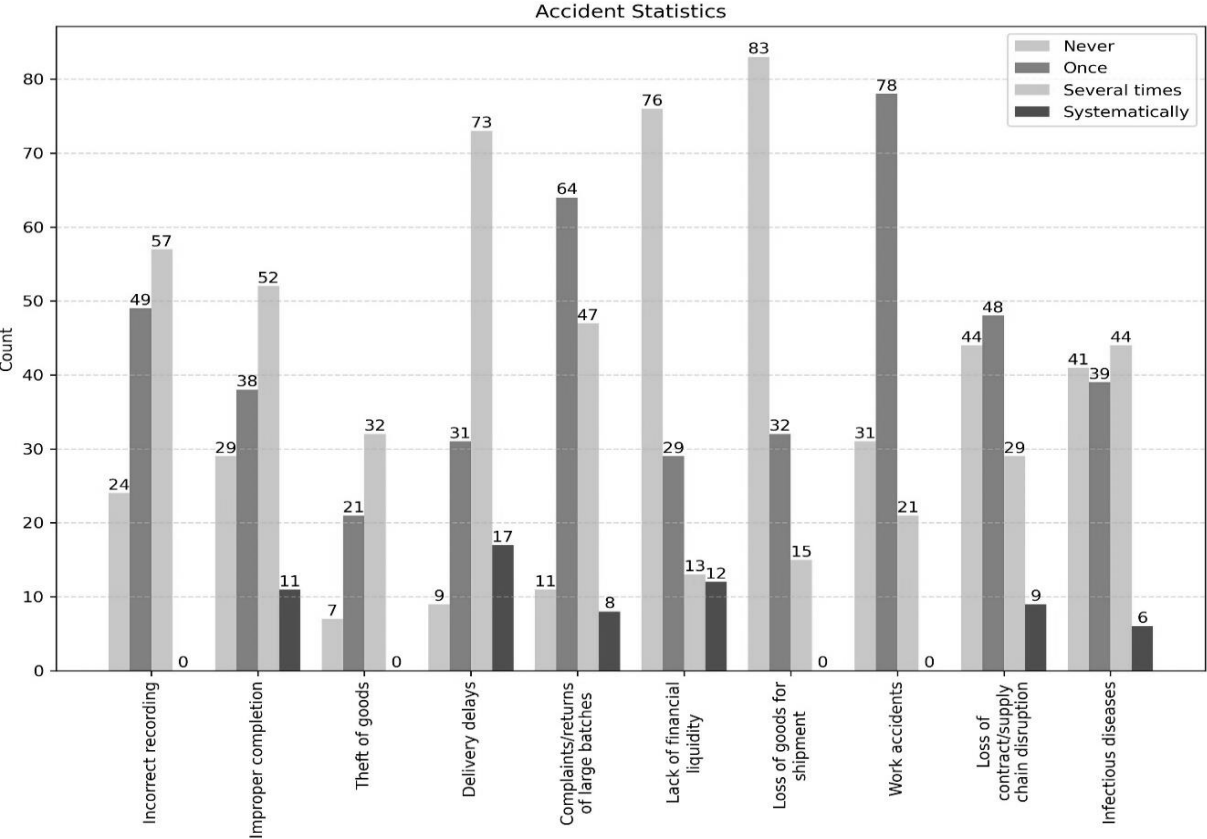


Chart 3. Internal, non-technical threats in the warehouse
Source: Based on survey analysis

Examining the survey results reveals the varying degrees of negative effects on warehouse management. Notably, natural hazards had the most significant impact (63 cases classified as large or very large). The following closely were personal hazards (28 cases), while technical hazards ranked third (11 cases). Additionally, civilization-related risks (8 cases) and social risks (7 cases) also contributed to the overall impact.

In summary, among the five types of external threats, natural hazards are both the most burdensome and the most frequent.

ANALYSIS OF INTERNAL, NON-TECHNICAL THREATS IN THE WAREHOUSE

Challenges in the execution of the warehouse process should not be attributed solely to external threats. Analyzing the responses to the question about non-technical internal hazards that occurred in your warehouse over the past three years reveals that, alongside external risks, there are other factors influencing logistics processes. According to Chart 3 on warehouse threats, those that have never occurred relate to:

- Lost Shipments: 83 cases (63%);
- Financial Liquidity Issues: 76 cases (59.7%);



- Contract Loss/Supply Chain Disruption: 44 cases (33.9%).

The warehouse safety threats that occurred ‘several times’ or ‘systematically’ pertain to:

- Delivery Delays: 90 cases (70%)
- Incorrect Picking: 63 cases (48%)
- Complaints/Returns of Large Batches: 55 cases.

Among the threats mentioned above, delivery delays and incorrect picking are the result of internal organizational errors within the warehouse. The third threat is a consequence of these two factors. To enhance customer service quality, warehouses must focus on improving their internal systems to mitigate these negative effects. This can be achieved through two distinct approaches:

1. Human Factor Optimization: Enhance the efficiency and effectiveness of human resources by making appropriate personnel adjustments.
2. Implementing Support Tools: Deploy tools and instruments that align with warehouse policies, aiming to eliminate errors and streamline logistics activities. Examples include warehouse automation through various IT systems designed to enhance warehouse management processes.

Another aspect concerns evaluating the significance of these internal non-technical threats in the context of their negative impact on warehouse operations. The analysis indicates that the level of negative impact on warehouse functioning, considering non-technical internal hazards, is lowest in the following categories: ‘none’, ‘very small’ and ‘small’:

- loss of goods – 112 cases (86%);
- lack of financial liquidity – 104 cases (80%);
- registration errors – 80 cases (61%).

When assessing the impact of threats in the ‘medium’, ‘large’, and ‘very large’ categories, the highest impact occurs in the following situations:

- Theft of Goods: 71 cases (54%)
- Infectious Diseases: 57 cases (43%)
- Complaints/Returns of Large Batches: 55 cases (42%).

From the analysis of these two groups of non-technical hazards, two conclusions emerge:

1. Lost Shipments and Financial Liquidity Issues: These align in terms of frequency and impact on logistics processes. They occur infrequently and have a low impact on warehouse functioning.
2. Complaints/Returns of Large Batches: These incidents, occurring ‘several times’ or ‘systematically’, correlate with the assessment of their impact on warehouse management.

ANALYSIS OF INTERNAL THREATS OF A TECHNICAL NATURE IN THE WAREHOUSE

When evaluating disruptions in warehouse processes, it is essential to consider not only nontechnical internal hazards. Analyzing responses to the question *What internal technical threats have occurred in your warehouse in the last three years?* clearly shows that, alongside

non-technical risks, there are other factors influencing logistics processes with a technical nature. These factors include:

- System Failures: Technical issues related to the warehouse’s IT systems;
- Floods: Risks associated with water damage due to flooding;
- Warehouse Fires: Fire hazards within the warehouse;
- Mechanical Damage to Goods: Accidental damage to goods caused by mechanical factors;
- Internal Transport Equipment Failures: Issues with forklifts, pallet jacks, or other internal transport vehicles;
- Technical System Failures: Problems with internal technical systems (such as electrical or ventilation systems).

Addressing these technical risks is crucial to maintaining warehouse safety and efficient operations.

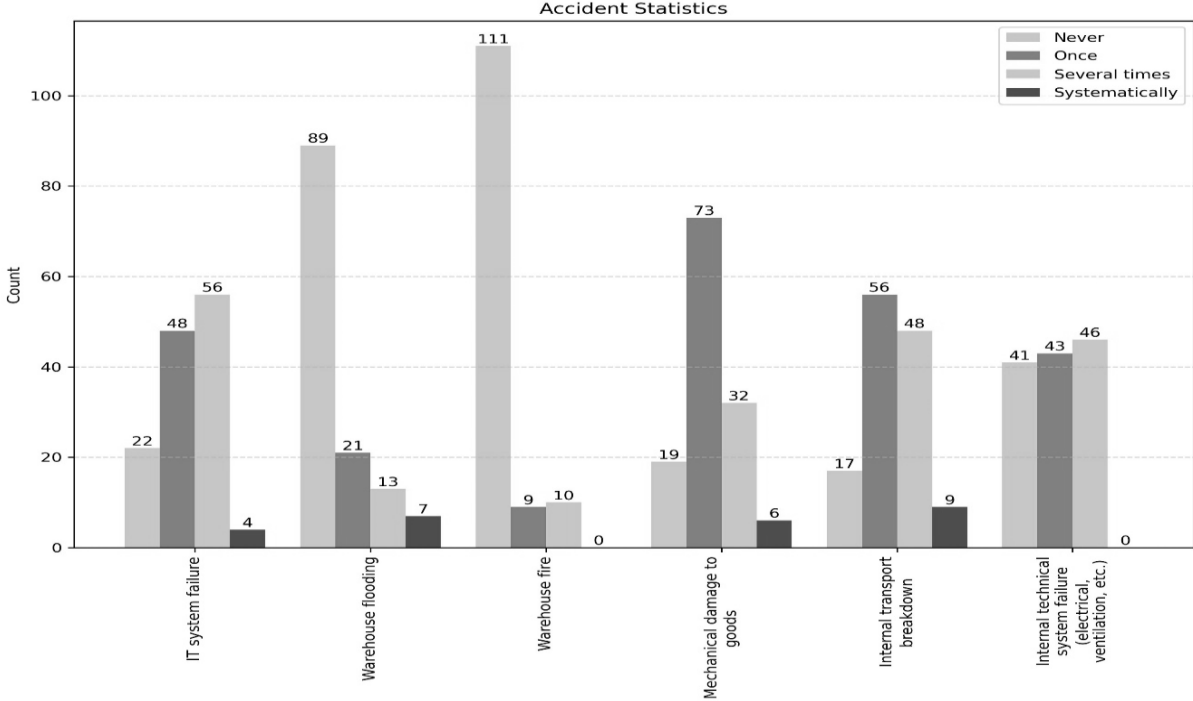


Chart 4. Frequency of internal threats of a technical nature in the warehouse

Source: Based on survey analysis

According to the analysis in Chart 4, warehouse safety threats that have ‘never occurred’ or occurred only ‘once’ relate to:

- Warehouse Fires: 120 cases (92.3%);
- Floods: 110 cases (84.6%);
- Mechanical Damage to Goods: 92 cases (70.8%).

On the other hand, threats that occurred ‘several times’ or ‘systematically’ pertain to:

- IT System Failures: 60 cases (46.1%);
- Internal Transport Equipment Failures: 57 cases (43.8%);
- Internal Technical System Failures (electrical, ventilation, etc.): 46 cases (35.4%).

Based on the survey analysis, it can be concluded that the level of negative impact on warehouse functioning, considering technical internal hazards, is lowest in the following categories: ‘none,’ ‘very small,’ and ‘small’:

- Warehouse Fires: 130 cases (100.0%);
- Flooding of the warehouse: 122 cases (93.8%);
- Mechanical Damage to Goods: 92 cases (70.8%).

Summarizing the impact of internal technical hazards across three categories: ‘medium’, ‘large’, and ‘very large’, the highest negative impact on warehouse functioning, as perceived by managers, can be attributed to the following failures:

- IT System Failures: 71 cases (54.6%);
- Internal Transport Equipment Failures: 52 cases (40%);
- Internal Technical System Failures (electrical, ventilation, etc.): 40 cases (30.8%).

These risks underscore the importance of effective risk management and preventive measures in warehouses. Ensuring proper maintenance and safety procedures can mitigate these hazards and enhance overall warehouse safety.

The results analyzed with respect to the negative impact on warehouse operation due to internal technical hazards clearly confirm that the frequency of technical threats correlates with its impact on warehouse operations. The more (or less) frequently they occur, the greater (or smaller) the resulting losses. Three notable examples of such risks are warehouse fires, floods, and mechanical damage to goods.

CONCLUSIONS

Warehouses serve as fundamental components in supply chain operations. Without them, it is challenging to envision the functioning of business processes related to procurement, production/services, and distribution. It is essential to recognize that all warehouses, including Class A¹⁹ facilities, are susceptible to various risks originating from human actions or natural events.

Events such as the COVID-19 pandemic, energy crises, inflation, the war in Ukraine, worsening climate conditions (heatwaves, floods), increasing material costs, and demand-supply fluctuations require the exploration of new organizational and technical solutions in warehouse management. These challenges drive the search for innovative approaches to enhance safety, efficiency, and adaptability in warehouse operations.

The research results presented in this paper allow us to address the research problem, revealing the extent to which technical and non-technical systems impact warehouse management in unplanned situations. The survey analysis categorized risks into three groups: external, non-technical

¹⁹ Depending on various parameters, warehouses are typically classified into four primary classes (A, B, C, D) and two additional classes (A+ and B+). The best-prepared warehouses, considering inventory management, fall into the A and A+ categories. These classifications help ensure efficient storage and logistics operations.

internal, and technical. Notably, natural hazards are both the most severe in terms of consequences and the most frequent. Following these are personal and technical risks.

In the second group, internal non-technical threats, the human factor plays a crucial role. It is directly related to actions such as proper completion, theft, or infectious diseases. Therefore, it becomes necessary to eliminate these threats by taking appropriate corrective actions and raising awareness among personnel about their importance in the entire process of ensuring safety in warehouse management. In the third group, internal technical threats, three types are most commonly identified: warehouse fires, flooding, and mechanical damage to goods, which directly impact the losses incurred in the warehouse.

The presentation of these three theoretical subsections and one practical subsection allowed us to achieve the goal set in the article, as we identified and evaluated tools and practices that positively affect safety in warehouses in Poland.

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