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PROBLEMS OF WOOD-BASED SUPPLY CHAIN MANAGEMENT IN THE CONTEXT OF RESILIENCE - A CASE STUDY

Problematyka zarządzania łańcuchem dostaw z branży materiałów drewnopochodnych w kontekście odporności na zagrożenia – studium przypadku

Abstract: *This paper outlines the main challenges faced by the supply chain in the wood-based materials sector in the context of building resilience. The research work carried out made it possible to identify the main problems in the selected supply chain from the wood-based industry. They are associated with the occurrence of negative effects, including the destruction of the pallet, aging of goods in the warehouse, high packaging costs, and inefficient transport processes realization, including the processes of handling pallet units. In the context of external risks, a particular challenge is the shortage of raw materials on the market. The analyzed case study is based on the supply chain resilience assessment with regard to resilience potentials evaluation.*
Keywords: resilience, supply chain, the wood-based materials industry

Streszczenie: *W artykule zostały przedstawione główne wyzwania z jakimi mierzy się łańcuch dostaw w sektorze materiałów drewnopochodnych w kontekście budowania odporności na zagrożenia. Przeprowadzone prace badawcze pozwoliły na zidentyfikowanie podstawowych problemów w wybranym łańcuchu dostaw z branży drewnopochodnej. Związane są one z występowaniem negatywnych skutków, obejmujących m.in. zniszczenie palety, zaleganie towaru w magazynie, wysokie koszty opakowania, nieefektywną realizację procesów transportowych, w tym procesów manipulacji jednostkami paletowymi. Jednocześnie, w kontekście zagrożeń zewnętrznych szczególnym wyzwaniem jest obecnie brak surowca drewna na rynku. W analizowanym studium przypadku skupiono się na*

analizie odporności na zagrożenia łańcucha dostaw w odniesieniu do oceny potencjałów odporności na zagrożenia.
Słowa kluczowe: odporność na zagrożenia, łańcuch dostaw, przemysł materiałów drewnopochodnych

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1. Introduction

Today's supply chains face many challenges related to, among other things, the geopolitical situation, demand uncertainty, volatile economic and operational conditions, or cyber threats [1]. This means that supply chains operating in an uncertain environment can be disrupted in many ways. This is the case in all economic sectors, regardless of the level of chain integration. The only difference is the type of adverse events that should be the subject of risk analyses carried out for individual logistics chain participants.

In this context, it is currently difficult to effectively manage a supply chain without regularly analyzing adverse events/threats that occur and implementing solutions focused on risk management and resilience. Particularly in the context of building resilient supply chains, the analyses should focus on issues arising from the uncertainty and volatility of the economic environment [2].

An example of an industry where effective supply chain planning is a significant challenge is the wood-based materials industry. In the wood industry sector, the specification of the raw material and the characteristics of the wood-based products limit or even determine the solutions considered in the area of supply chain resilience management. In this context, the question arises - How to properly manage the supply chain in the industry under study to ensure its reliability and resilience to threats [3].

As a result, this study aims to present the characteristics and problems faced by supply chain logistics in the wood-based products industry. The analysis was based on data from a company specializing in the production of wood-based materials, in particular particleboard. A group of undesirable events in the chain was distinguished, which were considered critical events for the analyzed company. The analysis was based on the concept of resilience potentials proposed by Hollnagel [4].

In summary, the discussion successively presents the basic definitions of supply chain resilience and the Hollnagel concept in the context of building resilient supply chains. The third section then characterizes the studied supply chain from the wood-based materials industry regarding the observed key logistical issues and challenges. The basic resilience potentials of the chain are discussed, and the main directions for further research work are defined. The paper concludes with a summary.

2. Supply chain resilience assessment based on resilience potentials approach

The concept of resilience (resilience) is now widely analyzed in many research areas, such as engineering, social sciences, and economics [5]. An overview of definitions and concepts related to resilience and so-called resilience engineering can be found, among others, in [6]–[11]. An analysis of the relationship between concepts such as vulnerability, resilience, and adaptive ability is included, among others, in [12], [13].

Concerning supply chains, the concept of resilience is defined in terms of - its flexibility, agility, speed of adaptation, transparency, and redundancy (see, e.g. [14], [15]). In [10], the authors provide a comprehensive overview of the definition of this concept concerning four perspectives: the elementary event, the performance level of the chain, the speed of adaptation, and adaptation determinants. The issue of supply chain resilience in the context of risk management for chain infrastructure and the ability to reconfigure chain resources is discussed in detail in [16]. At the same time, in the paper [17], the authors define a three-level model of resilience for the employee, the organization, and the logistics network structure. Furthermore, an interesting approach to analyzing supply chain resilience is presented in the paper [18], where the authors propose a network approach based on a graph-theoretic perspective.

Due to the importance of the issue under study and the spectrum of research conducted, many publications have been published in recent years focusing on summarising the literature on supply chain resilience (e.g., works [6], [11], [19]). The issues of analysis and assessment based on measurement systems of functioning supply chains have been analyzed in works [20], [21]. The issues of modeling and evaluation were studied, among others, in [22]–[25].

Resilience engineering developed today must also consider the complexity of technical systems and supply chains [26]. It is important to remember that complex supply chains and production systems are nowadays closely connected to human factors, the environment, or the challenges of the Industry 4.0 concept (especially cyber-physical systems and cyber-security). This implies the need to implement a comprehensive and holistic approach to the problem of ensuring the resilience of logistics networks and chains under analysis. In this context, reference can be made to the NAS (National Academies of Sciences) report, which identifies four incident management cycles in the context of a resilient organization [4]:

- **Planning and Preparation:** setting the basement for maintaining service availability and resource function during any disruptive event,
- **Absorbing:** maintaining the most critical resource functions and service availability while repelling or isolating the disruption,
- **Recovery:** restoring all resource functions and service availability to their full functionality,
- **Adaptation:** using the knowledge gained about the course of the event, change procedures, system configuration, how staff are trained, or other aspects to achieve a higher level of resilience.

Sheffi and Rice [27] define building a resilient business as a strategic invention that changes how a business operates and increases its competitiveness. They suggest that resilience in an enterprise can be achieved by reducing its vulnerability to the risk of disruption, creating redundant infrastructure, and increasing the flexibility of the operational processes in place. Sheffi and Rice [27] also describe resilience as a function of a company's competitive position and the responsiveness of its supply chain. Disruptive events are defined as random events caused by internal and external factors that affect the system, negatively impact its performance, and generate short- or long-term consequences.

In light of the concept presented, it is possible to propose a definition of supply chain resilience as *its ability to prepare for, plan for, absorb, and recover operational capability in adapting to actual or potentially adverse events*. We can relate the assessment of supply chain resilience defined in this way to the resilience potentials described in the work [28] (Fig. 1):

- **P1 - Potential to respond:** the ability to respond appropriately to any threat or hazard by activating adequately planned and prepared activities, adjusting the required functional mode, or introducing new activities, procedures, or processes,
- **Potential to monitor:** the ability to monitor all signals from the internal and external environment that may affect the organization's performance in the short or long term,
- **P3 - Potential to learn:** the ability to learn from experience, particularly '*learning the right lessons from the right experiences*.' It also includes changing the goals the organization is aiming for, depending on the type of change in the situation,
- **P4 - Potential to anticipate:** knowledge of what to expect and the ability to anticipate future developments, particularly the occurrence of potential disruptions, constraints, and changing operating conditions.

The first potential involves the problem of defining a response appropriate to the situation and considering the limited level of resources available. In this context, responses should only be prepared for a limited number of disruptive events or conditions. At the same time, for events and situations that occur frequently, it is appropriate to prepare a specific type of response/reaction, but for unlikely events, the proper response will be to try to ensure an adequate level of availability for the whole system. In designing a given supply chain capability, the main problem is to answer two fundamental questions: when to respond and how to respond. As the trigger signal must be external to the response subsystem, the stop rule should be internal to the response (e.g., as part of a procedure). In addition, reaction time can be a critical parameter in many cases. The response must be neither too early nor too late. As responding is often a complex and aggregated process, proper timing and synchronization of all necessary resources can also be critical in creating the capacity to respond.

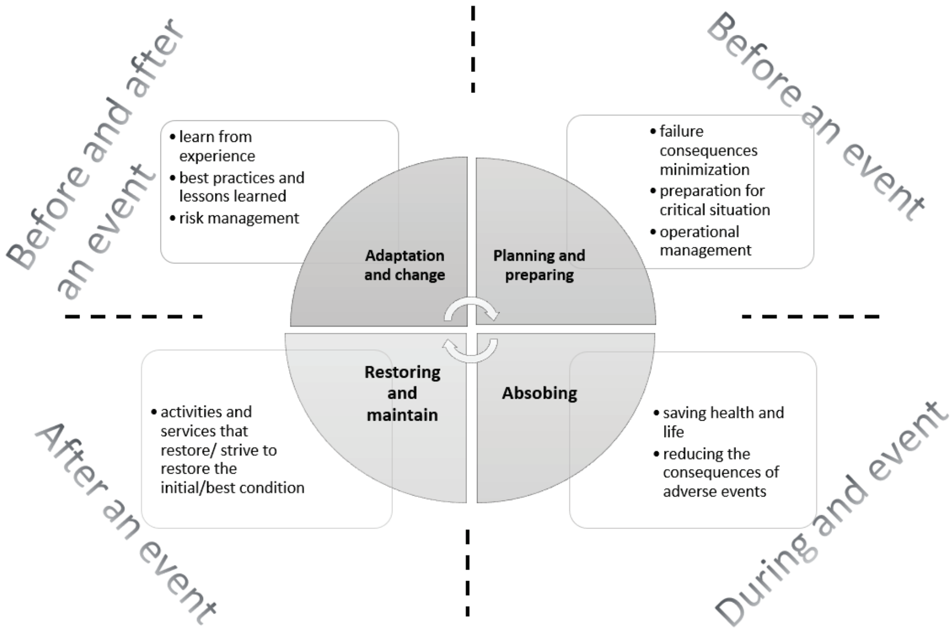

Fig. 1. Supply chain resilience potentials in the context of a cycle of continuous monitoring and learning, source: own contribution based [29]

The main objective of monitoring is to increase the organization's capacity to deal with possible threats and hazards. A proactive monitoring process ensures adequate effectiveness, which means ensuring that upcoming risks can be identified based on current operational information. At the same time, the monitoring system must be based on an appropriate set of operational indicators that allow the diagnosis of the current functional state of a supply chain. A change in the level of a selected indicator in a significant way (above an assumed acceptance level) is a signal to initiate action within the first potential.

Monitoring should be performed continuously, but the measurement frequency may vary depending on the situation. There are three basic types of indicators monitored:

- Ex-post indicators that refer to data collected in the past. These can be individual data or aggregated in such a way as to discover possible trends in their changes. At the same time, they should refer to aspects such as safety, availability, or reliability.
- Current indicators which refer to data occurring at a given time. They describe the current state of the monitored system and can be used to correct performance during operation (so-called feedback control).
- Leading indicators which refer to the interpretation of measurements of current and past data concerning what might happen in the future. They can, therefore, be seen as predictors of the future rather than typical status indicators. Information based on these indicators is subject to the most significant uncertainty, which should be considered in decision-making.

It should be noted that in practice, a compromise between efficiency and accuracy of measurements is necessary. Therefore, when using monitoring results, it is important to be aware of the uncertainty resulting from this compromise.

The next potential is responsible for organizational learning, understood as the active and deliberate modification of processes and procedures that describe the organization's behavior in specific situations. The main objective of learning is to improve the organization's ability to respond, monitor and anticipate. Every organization should learn from everything that happens from both negative and positive examples. In general, adverse situations are rare and irregular, so learning, in this case, is a reaction to some unusual event or situation (e.g., a disturbance or accident). The typical principle for starting the learning process is to find that some event or signal significantly differs from expectations. This type of learning is called reactive learning.

Building the potential to anticipate in an organization is conducive to supporting predictive thinking. Where monitoring is about observing and looking at something to see if it undergoes significant change, anticipation is more about thinking and imagining beyond the event horizon. The primary purpose of anticipation is to imagine alternative scenarios and predict what could happen. Anticipation, therefore, depends on the assumptions about the future and the models used for anticipation. In practice, three basic types of modeling are used, namely deterministic, probabilistic, and realistic. The first is based on the assumption that the future is a simple reflection of the past regarding the similarity of magnitude and frequency of occurrence. The basis of the probabilistic approach is the assumption that the unknown future is an extrapolation of the known past, taking into account randomness. The third method is based on the assumption that understanding past events and their relationships makes it possible to predict the possible course of events in the future, considering the uncertainty that such prediction is subject to. In this context, we may have to deal with three types of events in the supply chain - the white swan, the grey swan, and the black swan [30]. A brief characterization is given in Table 1.

The fundamental relationships between the discussed hazard resilience potentials and the phases of the disruption cycle triggered by the occurrence of a specific hazard in the supply chain (according to the disruption profile proposed in the work [27]) are presented in Table 2. The next section of the work presents an example of the analysis of hazard resilience potentials for a selected supply chain from the wood-based products industry.

Table 1

The main types of adverse events that can occur in a supply chain

Incident	Definition	Characteristics	Response to disruption/approach
White swan	An event occurring at random, described by a known probability distribution (based on historical data)	• Minor uncertainty • Extensive knowledge of the incident	**(readiness)/** autonomous decision-making based on deep learning

Table 1 cont.

Incident	Definition	Characteristics	Response to disruption/approach
Grey swan	Dynamic event, partially predictable based on available knowledge	• Medium level of uncertainty • Limited knowledge about the event	(**robustness**)/ decision making based on risk analysis
Black swan	The dynamic event, unpredictable based on available knowledge	• Deep uncertainty • Ignorance/lack of data	**(recovery, resourcefulness)/** decision-making based on resilience

Table 2

Resilience potentials of supply chains

PHASES →	**Action ↓**	**PRE-DISRUPTION**	**DISRUPTION**		**POST-DISRUPTION**
Potentials ↓		**PP – Prepare & Prevent**	**AR – Absorb & Retain**	**RS – Recover & Sustain**	**AI – Adapt & Improve**
Anticipate	1.1 Planning	X			
	1.2. Identifying	X			
	1.3 Predicting	X			X
Monitor	2.1 Supervision	X	X	X	X
	2.2 Detecting	X	X	X	X
	2.3 Recognizing	X	X	X	X
Respond	3.1 Protecting	X			
	3.2 Absorbing		X		
	3.3 Repairing			X	X
Learn	4.1 Analyzing	X	X	X	X
	4.2 Adapting				X
	4.3 Evolving				X

3. Resilience of wood-based supply chain – a case study

The issue of resilience is particularly relevant to the operation of wood-based material supply chains, which are highly vulnerable to all kinds of external and internal threats.

Wood-based materials are products for production in which so-called wood waste is used, i.e., waste generated during obtaining timber (e.g., chips, sawdust, shavings) and round wood, which is processed. Wood-based products are mainly (Fig. 2):

- laminated boards are impregnated boards permanently bonded with melamine resin and covered with decorative paper on the surface;
- chipboards made from wood chips of specific dimensions, bonded together with an adhesive under pressure;
- worktops (kitchen worktops) are made of chipboard and decorative HPL.

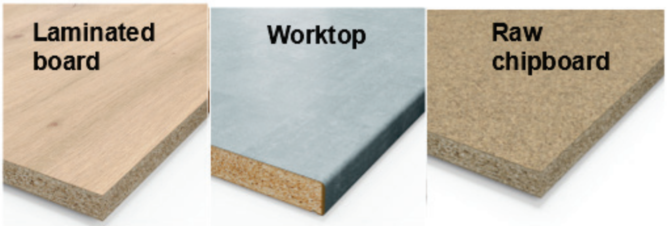

Fig. 2. Examples of wood-based materials, source: company's materials

Currently, we can encounter different types of supply chains related to the wood industry in the literature. First are the so-called forest supply chain, wood supply chain, and wood-based supply chain. The first term - forest supply chain - refers to a sequence of activities and processes covering activities from harvesting timber from forest areas through the processes of transforming the wood raw material into final forest products to the delivery of the final product to the end user [31]. In a given supply chain, raw wood can be transformed into products such as logs, roundwood, sawn timber, panels, construction wood, pulp, paper, biomass, or bioenergy (for electricity and heat). The literature emphasizes that this type of supply chain mainly focuses on meeting industrial needs in an environmentally sustainable way [32].

The wood supply chain (wood supply chain) in the literature mainly refers to the supply chain management of roundwood, which is used, among other things, as biomass or for industrial production [33].

The terms forest supply chain and wood supply chain are used interchangeably in the literature, and sometimes their boundary is blurred.

Wood-based supply chain refers to wood-based products' networks and supply chains, including the boards discussed in this article. The operation of such a supply chain can be illustrated in general terms using the example of the wood-based company studied, operating in the global market.

The wood-based materials supply chain starts during forest harvesting (Fig. 3). It includes planning, storage, and transport. Harvesting timber from the forest requires proper planning, considering aspects such as the harvestable volume and the tree's age. The roundwood is then stored and transported to the locations where it is processed, such as sawmills.

Waste from wood processing is a raw material for the wood-based products industry. Products that result from wood processing, such as sawn timber, also undergo further processing. During further production, waste is also generated, which is used as raw material for the wood-based products industry.

The municipal waste recycling industry is increasingly important in sourcing raw materials in view of the environmental crisis and the lower availability of roundwood on the market. Factories buy municipal waste, e.g., furniture, and turn it into an input.

From a supply chain perspective, the main difference between roundwood and municipal waste is the raw material's processing time - roundwood has to be stored and dried, which lengthens the whole process. The price of roundwood and municipal waste differs depending on many factors, e.g., the price of coal. In addition, dynamic changes in the raw material market (timber, municipal waste, recycled waste) result in a lack of a constant percentage share, affecting weight and often inefficiently scheduled shipments of wood-based boards.

The finished product, wood-based board, is mainly used for furniture production and in the construction industry.

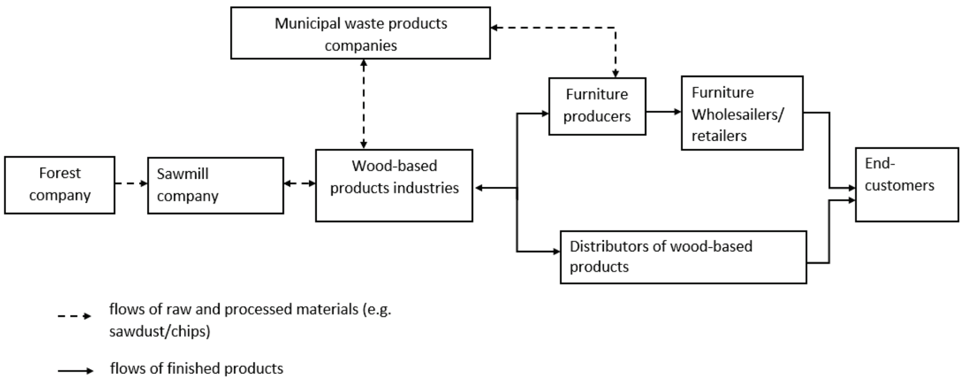

Fig. 3. Wood-based supply chain for the case company

The main problems that the wood-based products supply chain faces are:

- high transport prices concerning the products served,
- the problem of sourcing raw materials on the market,
- tonnage,
- product dimensions,
- diversified assortment,
- packaging costs regarding the value of the product.

The problems identified are primarily related. For example, product size, tonnage, and price severely limit efficient transport planning. A diverse product range also limits the ability to provide transport processes in accordance with the 5Rs rule. At the same time, rising transport service prices translate into the disadvantageous effect of a high product-to-transport price ratio.

Another problem concerns the possibility of sourcing raw materials for production. Sourcing raw roundwood, or waste or recycled products, is currently becoming a significant challenge. On the one hand, this is related to the political situation in the East (warfare and the impossibility of sourcing raw material from across the eastern border (Belarus) due to sanctions imposed by the EU) and the high price of coal, which translates, among other things, into an increasing demand for pellets. On the other hand, the pandemic triggered increased demand for wood products and the need to find new sources of raw materials. Remote working and lockdown made Poles more likely to renovate their homes, translating into increased demand for building materials and raw materials [34].

The enormous tonnage and unusual dimensions of raw materials and products contribute to the difficulties involved in handling, transport, and storage operations. On the one hand, the problem of operator safety and the environment during handling operations must be considered. On the other hand, the costs and time of storage processes and internal transport operations are high. They involve multiple handling operations, which increases the time of the transport process and the cost of material flows (practically very limited possibilities to implement the FIFO principle). In addition, it should be noted that the costs of damage to materials and products arising during storage and internal transport operations can reach an average of 3% of the value of all stocks held in the company.

This problem is further complicated by the company's diverse product range under analysis. At present, the vast range of product decors, both in terms of dimensions, structures, and material finishes, dramatically limits the possibility of storing products efficiently in the warehouse.

In addition, packaging is an important part of the supply chain in the wood-based panel industry, which is related to its cost intensity. At a basic level, packaging should protect the product during pallet handling, storage, and transport. For example, due to the value of the final product, each pallet of worktops is wrapped in foil to protect against contamination, among other things. Other products are packaged without foil, which reduces the total cost of packaging concerning the product's value. An example of packaging for laminated boards is shown in Fig. 4. At the same time, the high cost of packaging in relation to the value of the packaged product means that it is common practice to limit the use of packaging materials. This lowers the level of protection of products during handling and transport, which also, as one factor, translates into a high amount of handling damage (Fig. 5).

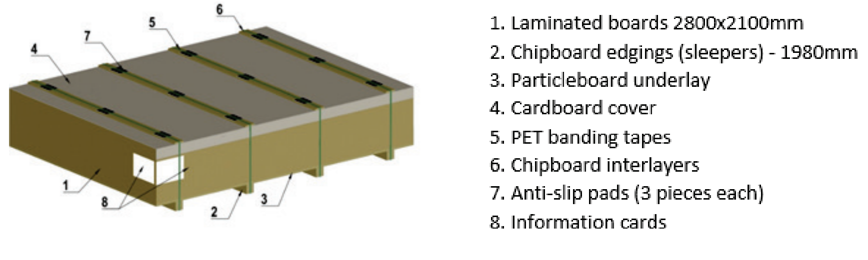

Fig. 4. An example of a packing scheme for a laminated board

The problems identified translate directly and indirectly into emerging disruptions in the company's supply chain under review.

For example, the need for additional handling operations translates directly into material damage occurring and thus into delays in fulfilling the company's customer orders. Also, delays on the producer-customer line are generated by problems in the area of raw material supply. The magnitude of the importance of a given problem can be shown, among other things, by a summary of the amount of material damage observed in 2018-2021 (Fig. 5).

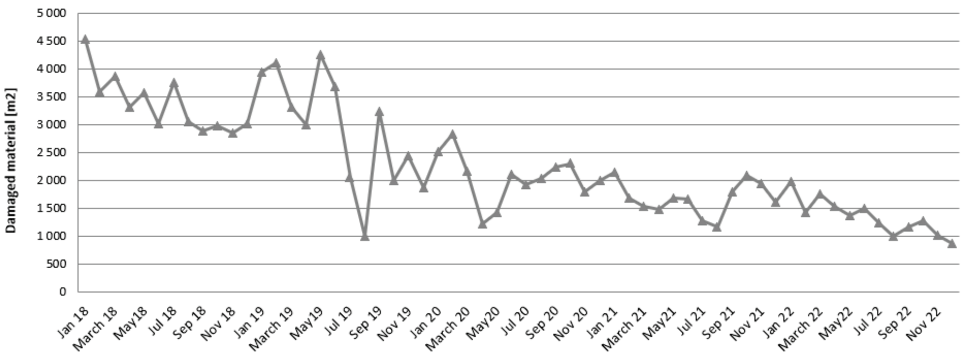

Fig. 5. Summary of the amount of material damage observed, expressed in square meters

During the period under review, an average of 1,691 m^2 of products suffered mechanical damage primarily due to improper handling operations. In terms of the number of 2.8x2.1m2 chipboard panels, on average, the company recorded 288 panels per month, which represented the company's operating loss due to damage occurring. At the same time, the maximum level of stock that can be stored in the company is 52,000 m^3, while the operational stock, at which handling operations can be carried out in a safe, efficient manner and with the quality of processes and materials, is 45,000 m^3. During the period under review, the average stock varied between 27.1 and 54.0 thousand m^3.

In turn, the indirect impact on the performance of the company's supply chain under study in a disruption may be related to the company's inability to react quickly in the context of the disruption occurring (minimizing the impact of the threat). For example, the inability to source raw materials or high transport prices limit the company's flexibility in the context of the large fluctuations in demand that occur.

At the same time, it is possible to relate the company's operational management problem to the uncertainty of disruptions occurring. In this context, three types of events can be distinguished, with different uncertainty levels (as shown in Table 1). The first event - the so-called white swan - is an event about which the company has very extensive knowledge, usually based on operational data and previous experience. An example would be the occurrence of high stock levels due to a large assortment of products stored in the warehouse. This type of situation happens very often in the company studied, which has allowed the manufacturer to develop mechanisms to deal with such a situation.

The second type of event - the grey swan (Table 1) - is characterized by a medium level of uncertainty. Here, we can include events that we know may occur in practice. Still, due to high variability (e.g., the influence of external conditions), the characteristics and parameters of these events are not predictable. An example would be the occurrence of a difference in the defined and actual weight of harvested raw material. In the timber industry, the calculated weight of the raw material/product will often differ from its actual weight. The weight of the wood depends, among other things, on the humidity or the raw material used. Due to the fact that it is not possible to define the weight of the raw material/product correctly - for example, a tolerance of 5% of the weight of the goods must be taken into account when planning transports.

The third event - the so-called 'black swan' (Table 1) - is characterized by a profound lack of knowledge about its occurrence's consequences and/or probability. In this case, corporate decision-making is carried out based on determining the so-called 'least risk' and maximizing potential operational benefits. An example is the pandemic period, during which a vast and sudden increase in customer orders was recorded. Basic reactive measures include, for example, an increase in employment or the search for new suppliers for the necessary raw materials.

The discussed examples of adverse events that may occur in the wood-based product supply chain indicate the possibility of building a resilient system based on the resilience potentials approach discussed earlier. Below are examples of adverse events and the procedures adopted in accordance with Hollnagell's approach [28]. For the company under study, three examples of the most common problems were defined, and the fundamental behavior of the company, indicating the building of resilience potentials, was identified.

The first capability, P1 - the potential to respond, involves developing an effective system to respond to the threats that occur (Fig. 6).

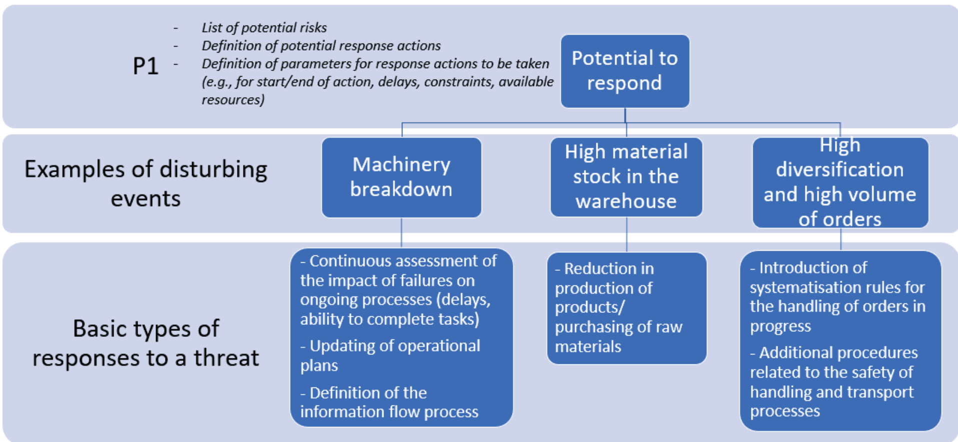

Fig. 6. Potential to respond in the analyzed supply chain

Three events are indicated to discuss a given potential: machinery breakdown, high material stock in the warehouse, and significant order quantities. The figure also shows the basic response types to the indicated risks within the response potential. These are primarily aimed at immediately identifying the potential impact of a given hazard and counteracting its occurrence. For example, a high material stock in the warehouse is particularly dangerous for the bulky and non-standard goods industry, as there is an increased risk of exceeding the permissible load capacity of the warehouse. In the case of the company surveyed, maximum stock levels in the warehouse are exceeded on average once a month (weekends) due to the lack of synchronization between production and distribution of products to customers. This situation results, among other things, in damage due to the handling of pallets or the need to rent external storage space close to production facilities, which is not always possible.

Another potential - P2 - the potential for monitoring in a given supply chain primarily involves developing an effective system to monitor operational processes to detect potential risks (Fig. 7).

To discuss a given potential, three events were identified - a problem with the availability of raw material and waste for recycling, a high material stock in the warehouse, and an inefficient loading plan due to a change in the density and weight of the final product. As in the previous case, the figure also shows the basic types of activities undertaken in the company to monitor the operational processes carried out. For example, to identify error in the form of high stock levels, daily monitoring of stock levels and stock inventory indicators is carried out concerning the so-called safety indicators established in the company.

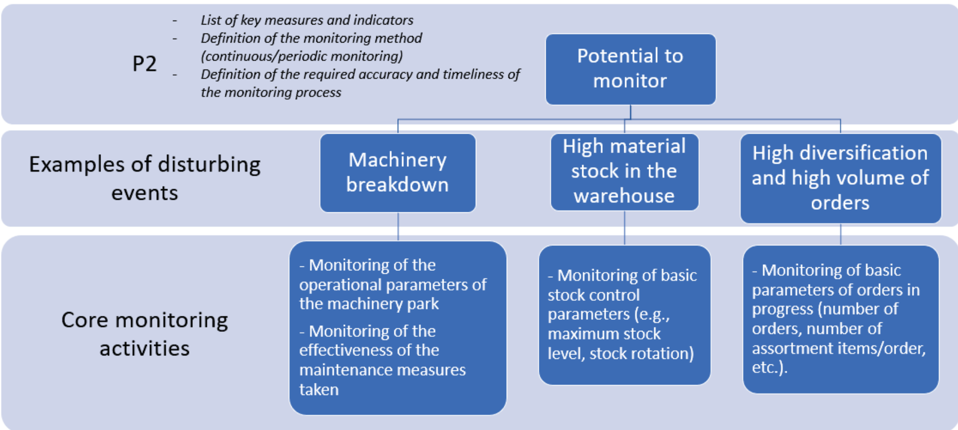

Fig. 7. Potential to monitor in the analyzed supply chain

The third potential - P3 - the potential to learn in a given supply chain involves the development of assumptions and conditions in the organization's continuous improvement process (Fig. 8). Three events are indicated to discuss the given potential: machinery park failure, high warehouse material stock, and reported complaints. As in the previous case, the figure also shows the basic types of organizational learning activities undertaken in the company. Reporting on machine breakdowns, for example, should be done in an agile way. Each link in the supply chain should know the scale of the failure and the extent of the delays, as it is time-consuming to get the machinery up and running. Complaint analysis, on the other hand, is geared towards answering questions such as: What was the cause of the complaint? Was it a manufacturing defect or damage during transport? Is the complaint about the entire batch or one single item? Will the return transport costs be within the margin? When dealing with a complaint, the costs of the complaint, disposal, and transport must be considered.

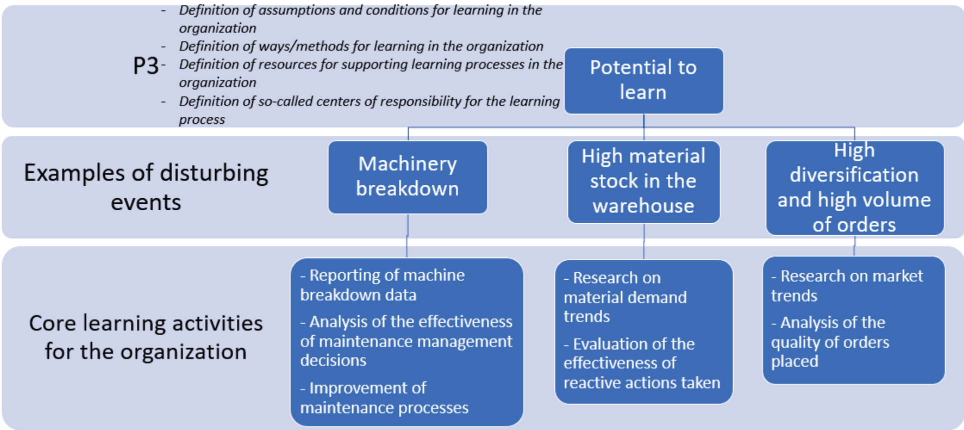

Fig. 8. Potential to learn in the analyzed supply chain

The last potential - P4 - the potential to anticipate primarily refers to building an effective forecasting system for the organization's operations (Fig. 9). Three events are indicated to discuss the given potential: mismatched market offerings due to market dynamics and changing market trends, inefficient transport processes due to variability in raw material availability, and reduced operating profit due to high components and finished goods prices. As in the previous case, the figure also shows the basic types of actions taken in the company for predictive learning. For example, the availability of raw materials depends on energy prices, coal prices, and the general economic situation. The last factor, particularly, has negatively affected the wood-based products industry in the previous year. EU sanctions banning the import of wood and wood products from Belarus and Russia have particularly hit Polish producers. For example, Belarus was Poland's largest foreign supplier of firewood and wood-based panels until April 2022. The sanctions introduced meant that new supply markets had to be sought.

The high sensitivity to the indicated factors influences the market prices for available raw materials. At the same time, the type of raw material used (municipal waste, roundwood, sawn wood) for the production of final products directly affects the density of the finished product, which in turn affects the weight of loading, i.e., the efficiency of transport. In turn, the operating profit generated depends on the price of the finished product. The finished products' prices directly rely on raw materials' availability. On the other hand, the company operates in a competitive market, so the offer prices must be adjusted to the prevailing market prices to maintain/acquire new customers. This situation translates, for example, into the level of margins and, as a result, the company's profit.

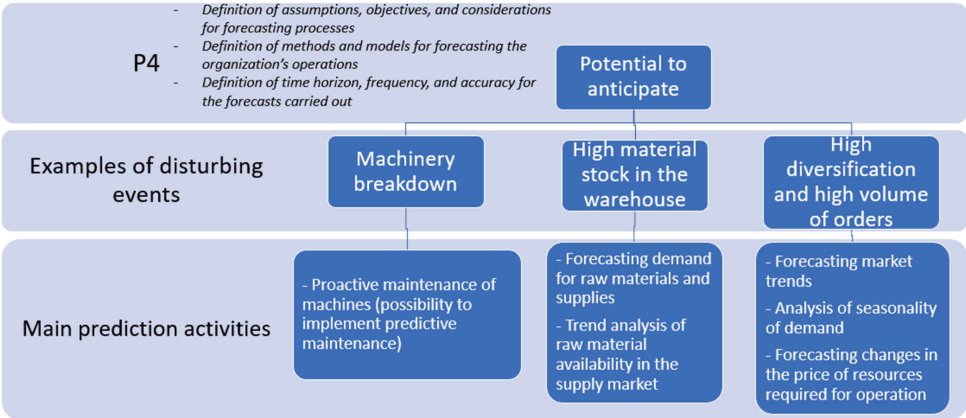

Fig. 9. Potential to anticipate in the analyzed supply chain

The presented examples of the indicated activities in the context of realizing hazard resilience potentials according to the Hollnagel concept [28] allow an initial assessment of whether a company operates according to the hazard resilience concept in its operational activities and considers supply chain risk management issues. At the same time, a comprehensive view of the problem of building resilience in the supply chain using the concept of potential is presented for one example of an adverse event - a machinery failure (Table 4). This was based on the relationships between the discussed hazard resilience potentials and the phases of the disruption cycle triggered by the occurrence of a specific supply chain hazard (as shown in Table 2). In this context, the basic activities for building hazard resilience in the studied chain, depending on the phase of the disruption cycle triggered by the damage to the machinery park, were identified. At the same time, the actions adopted in each stage correspond to the theoretical assumptions defined in Holnagell's general concept. The potential to respond requires a definition of the type of response to a threat in terms of answering the questions: When to respond? How to respond? How to manage the available resources? In turn, within the definition of actions for the potential to monitor, it should be remembered that the recommendations indicated are based on using current and leading indicators in the pre-disruption and disruption phases.

In contrast, the actions after the disruption phase should be based on the ex-post indicators defined in the company. Then, the potential for anticipation primarily includes activities in the pre-disruption phase, and all actions should be geared towards identifying potential threats and building scenarios for dealing with the threat. At the same time, it should be noted that there are three types of events in each activity (Table 1). The activities undertaken should identify potential hazards, classify them (Table 1), and choose the type of modeling (deterministic, probabilistic, realistic) accordingly. The last potential - the learning capability - the recommended actions should, on the one hand, correspond to the adopted learning strategy of the organization; on the other hand, this potential report on the actions taken in the organization in relation to the existing risks. The information produced under this potential provides the necessary documentation for the four resilience potentials.

Table 3

Resilience potentials for the company under study using the example of an adverse event - machinery failure

<table>
<tr><th>PHASES →</th><th rowspan="2">Action ↓</th><th>PRE-DISRUPTION</th><th colspan="2">DISRUPTION</th><th>POST-DISRUPTION</th></tr>
<tr><th>Potentials ↓</th><th>PP – Prepare & Prevent</th><th>AR – Absorb & Retain</th><th>RS – Recover & Sustain</th><th>AI – Adapt & Improve</th></tr>
<tr><td rowspan="3">Anticipate</td><td>1.1 Planning</td><td>Maintenance planning and scheduling for potential failures</td><td></td><td></td><td></td></tr>
<tr><td>1.2. Identifying</td><td>List of potential failures</td><td></td><td></td><td></td></tr>
<tr><td>1.3 Predicting</td><td>Building predictive models for potential failures</td><td></td><td></td><td>Updating of predictive models based on failure reports</td></tr>
<tr><td rowspan="3">Monitor</td><td>2.1 Supervision</td><td>Monitoring of machine operating parameters</td><td>Monitoring of the effectiveness of the emergency response (speed/effectiveness of actions taken)</td><td>Monitoring the effectiveness of corrective actions taken</td><td>Monitoring of the level of supply chain operational parameters once the threat has been removed (recovery time)</td></tr>
<tr><td>2.2 Detecting</td><td>Detection of potential failure symptoms</td><td colspan="2">Detection of potential inefficiencies (discrepancy between targeted and achieved levels for implemented processes)</td><td>Detection of inconsistencies between targeted and achieved levels of supply chain operational parameters</td></tr>
<tr><td>2.3 Recognizing</td><td>Identification of failure type</td><td colspan="2">Identification of fundamental consequences of failure in the context of operational decisions taken</td><td>Identification of potential negative consequences for the supply chain once the threat has been removed</td></tr>
</table>

Table 3 cont.

PHASES →	**Action ↓**	**PRE-DISRUPTION**	**DISRUPTION**		**POST-DISRUPTION**
Potentials ↓		**PP – Prepare & Prevent**	**AR – Absorb & Retain**	**RS – Recover & Sustain**	**AI – Adapt & Improve**
Respond	3.1 Protecting	Implementation of maintenance schedules			
	3.2 Absorbing		Provision of resources required to preserve/maintain operational capability; definition of information flow process		
	3.3 Repairing			Failure removal	Updating operational plans
Learn	4.1 Analyzing	Maintenance management reporting and data analysis	Reporting and analysis of data on operational actions taken	Reporting and analysis of data on corrective actions carried out	Reporting and analysis of data on causes and effects of disruption occurring
	4.2 Adapting				Updating machinery maintenance management procedures
	4.3 Evolving				Improvement of maintenance processes

4. Conclusions

Today's supply chains face several challenges, external (variability of demand, availability of resources) and internal (operational efficiency). Supply chains for wood-based products are primarily characterized by the transport process's high cost relative to the product's price, the variability in the dimensions of the weight and density of the final products, or the dynamically changing availability of raw materials.

This paper presents these main challenges of wood-based product supply chains in the context of assessing the resilience of supply chains. An approach based on Hollnagel's concept of potential assessment [28] is proposed. Its appropriate use in a company is based on the need to monitor and analyze its performance in areas such as the current operational level and knowledge of possible disruptions, the ability to learn from acquired experience, or the ability to anticipate the occurrence of undesirable events in the future. The case study presented here exemplifies how processes based on resilience thinking can be defined within a company. Traditional risk management focuses on planning for and mitigating supply chain vulnerabilities. Resilience management places additional emphasis on recovery processes and enabling adaptation to changing operational conditions. Thus, the concept of resilience can be seen as a new way of dealing with risk in a complex environment.

To sum up, the paper presents the preliminary results of a study on developing a resilience method for supply chains in the wood-based products industry, which the authors will develop in their future research. At the same time, parallel analyses are carried out to identify the underlying risks present throughout the company's supply chain under study and assess in which part of the chain these disruptions are most significant (in terms of impact).

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