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Investigating the Impact of Information Distortions on the Resilience of Land-sea Transport Chains Under Business-environment Instability Conditions

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Abstract
Possessing reliable information is the basis for making accurate decisions when planning land-sea transport chains. Modern transport chains create increasingly complicated networks, which affect the decisions made when planning these chains. It should be noted, however, that information distortions may arise at individual stages of the transport process within complex transport chains. The article aims to examine the sources of hazards and risks occurring in land-sea transport chains, to determine the information distortion indicators that may be processed by transport and logistics industry enterprises under conditions of business environment instability, as well as to determine the levels of these chains' resilience to possible information distortions. The article presents the selected types of managerial decision errors. An approach to assessing the impact of distorted information on the decision-making process has been proposed. Information distortion indicators processed by transport and logistics industry enterprises in conditions of business-environment instability were also identified. An attempt was made to determine the possible levels of resilience of these chains to the symptoms of business-environment instability. It was found that, depending on the degree of distortion of the information used by the manager, their decision may be erroneous to a varying degree, while the degree of managerial decisions' incorrectness can be assessed by the number of decision-making cycles required to make and implement an effective decision.

Keywords
land-sea transport chain, information distortion indicators, decision-making, supply planning, transport management

1 Introduction

The efficiency of transport task execution depends to a large extent on the reliability of the information provided within the various links of the supply chains (Lee et al., 1997). This information concerns, among others, customer requirements, deadlines included in the transport work schedule, environmental conditions, etc. Based on this information, decisions are made and activities related to the delivery of goods and services are planned (Xiao et al., 2023).

Nowadays, the access to reliable information is becoming a prerequisite for ensuring high efficiency of transport fleet usage and transport task execution (Chandra and Balasubramanian, 2023). Therefore, information becomes one of the most valuable resources, the value of which will exceed the value of manufactured goods in the near future (Cao et al., 2021; Cover and Thomas, 2006).

Changes in reliability of information processed by managers of transport and logistics (T&L) industry companies can be caused by business-environment instability. Recently observed changes in business-environment conditions were caused by the COVID-19 pandemic, the war in Ukraine, as well as sharp increase in fuel prices (Milewska, 2022). Political, economic, social and technological challenges can impact transport chain planning and execution (He and Yao, 2022; Sibindi and Samuel, 2019). Moreover, the investments in transport infrastructure development may result in changes in access to transport services that should be considered by managers planning the transport tasks (Filina-Dawidowicz and Durczak, 2023). The coincidence in time of different changes in business environment has contributed, on the

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one hand, to the volatility of needs in T&L services and, on the other hand, to the exacerbation of the problem of streamlining the traffic flows between contractors and subcontractors of these services and the tightening of requirements for the reliability of information provided to the participants of transport chains.

Transport processes are usually susceptible to various hazards, i.e. potential accidents, breakdowns, or weather phenomena, that can have a negative impact on the achievement of the intended objectives established by managers of T&L industry companies (Filina-Dawidowicz et al., 2022), and consequently cause both material and financial, as well as image losses (Hines and Samuel, 2007). For example, decision-making challenges were observed during the COVID-19 pandemic (Staniuk et al., 2022), and various threats, including cybersecurity threats (Netcomplex, 2018), also accompanied the transport and supply chain planning process in Central European countries.

It was noted that in unstable business-environment conditions, the practical aspects of land-sea transport chain (LSTC) operation, linking road, rail, maritime, inland navigation transport modes, etc., should be examined (Jacyna, 1998). Currently, the creation of these chains takes place as part of developing sustainable transport systems (Jacyna et al., 2014, Muślewski et al., 2011). However, failure to comply with the rules of shaping and subsequent use of information support may lead to significant consequences for the planning of LSTC when handling Polish trade and transit.

Based on the analysis of the available literature, it can be concluded that information sharing is very important in management of transport chains and whole supply chains (Cao and Chen, 2021, Tang et al., 2021, Xue et al., 2021). It was revealed that information uncertainty occurs (Lee et al., 1997, Jacyna and Semenov, 2020), therefore, it is important to structure the available information in order to facilitate accurate decision making (Semenov et al., 2020). It was also noted that when planning transport chains, both distortions of information may occur (Semenov et al., 2021), as well as its asymmetry (Shen et al., 2019, Teniwut et al., 2018). The authors of the publications reviewed also noticed the methods which can be applied to analyze the impact of information distortions on the operation of transport and supply chains (Kudekar and Urbanke, 2008, Pawar et al., 2016), together with the interactions between information sharing, supply chain structure and performance (Zhang et al., 2019).

In order to ensure effective ways of using collected information, it is necessary to provide a new approach to information management that will ensure:

- reducing the risk of making incorrect decisions during LSTC planning,
- considering changes taking place both in the internal and external environment of LSTC,
- effective usage of IT techniques and technologies together with the soft skills of managers of T&L industry companies,
- improving the process of transport service management by ensuring LSTC resilience against disruptions.

The objectives of the present article are:

- to examine the sources of hazards and risks occurring in the LSTC,
- to determine the information distortion indicators under conditions of unstable business environment,
- to determine the levels of these chains' resilience to possible information distortions.

The article discusses the role of information in the LSTC planning process under conditions of business-environment instability, as well as the sources of threats related to transport activity (Section 2). The specifics of the decision-making process during LSTC planning are analyzed in Section 3. Section 3 consists of three subsections focusing on the division of errors made by managers of T&L industry companies, the analysis of the impact of distorted information on the quality of the decision-making process, and the problems of ensuring the resilience of the LSTC to the symptoms of business-environment instability. In order to sum up the conclusions are drawn.

2 The role of information in the LSTC planning process

2.1 Planning LSTC under conditions of business-environment instability

The planning process of cargo transport within LSTC has very complex dynamics and must be based on reliable information characterized by a number of features (Lee et al., 2002). However, the available research results show that at the beginning of the 21st century, the management of T&L industry companies gave the greatest attention to the relevancy, objectivity, and security of the collected information. As transport and supply chain transparency issues were addressed, the efforts to digitize LSTC management process were directed towards providing access to reliable information on both transport demand and supply. The importance of the cooperation of entities in these chains was highlighted (Holweg et al., 2005).

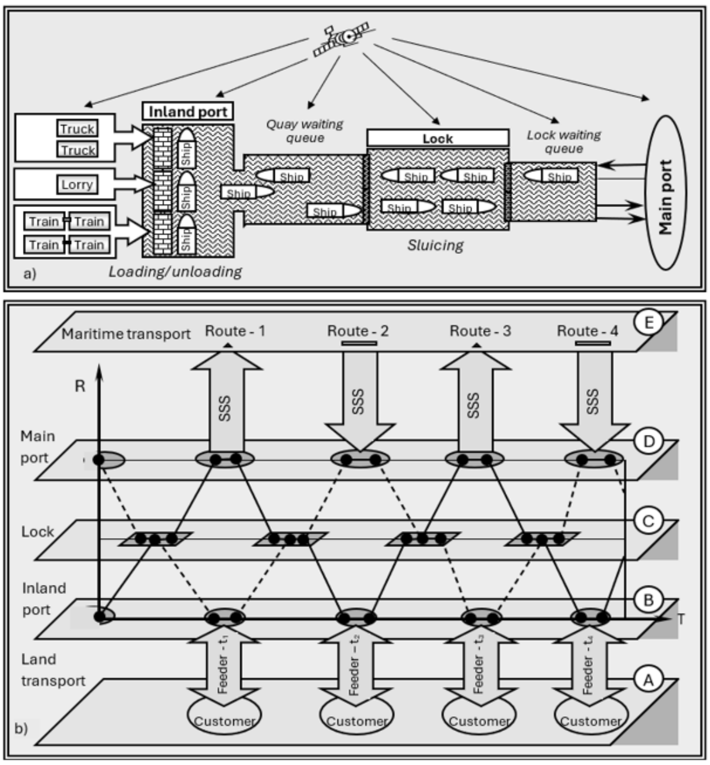
The results of a study conducted between the end of March 2020 and mid-April 2022 within 113 supply chain leaders worldwide from different industries (Alicke et al., 2022) indicated that the most important priority for investment in digital technologies were the systems providing support for both demand and supply planning, as mentioned by over 74% and 69% of the companies surveyed in 2022, respectively. Changing priorities from striving for "greater visibility" to "improving planning" of supply chain indicates the increasing interest of enterprises in exchanging reliable (credible) information supporting processes preformed in these chains (Semenov et al., 2021). It should also be noted that in more than half of the surveyed companies (58%) inventory optimization is still a priority.

According to the aforementioned research results (Alicke et al., 2022), companies are more often implementing long-term strategies to increase their resilience against disruptions, for example, applying a dual-sourcing strategy. In 2020, 55% of the surveyed companies implemented supplies from two suppliers, in turn, in 2022 this number increased by about 30%. It is also noteworthy that out of the companies' group using dual-sourcing strategy, up to 85% believe that such a strategy will be important in the future, while a significant number of companies (44%) develop regional supply chains, that are performed using, i.e., LSTC.

The priorities in behaviors of supply chain participants impact transport chain planning and organization. The part of LSTC performed using inland navigation according to the "*multi-points*" mode is presented in Fig. 1. While LSTC planning different infrastructure points may be connected, considering business-environment conditions, then consistently information reliability and possibility to perform the transport processes one by one. To improve the information sharing and integrate the participants of transport chain the digital solutions may be applied.

LSTC planning under conditions of business-environment instability includes the following steps:

- identification of requirements needed to implement the transport tasks,
- identification of business-environment conditions,



Legend	
Truck/train	A wheeled vehicle for moving the cargo
Ship	A seagoing or inland vessel
SSS (Short Sea Shipping)	Shipping of goods on ship over short distances
Inland port	A harbor on an inland waterway, where cargo may be loaded on and unloaded from a ship
Main port	A node of convergence for different transport modes, e.g. seaport/ logistics center
Lock	A watertight chamber connecting the upper and lower canals, large enough to enclose one or more vessels
Route	A way from a dispatch point to a place of cargo destination
Feeder ($t_1 \div t_4$)	A land transport that connects customers and inland port
Customer	A company purchasing/selling a commodity
Area A	The area of land transportation risks within LSTC
Area B	The area of inland port transshipment risks within LSTC
Area C	The area of transportation risks in measurement and control points within LSTC (e.g. locks)
Area D	The area of seaports transshipment risks within LSTC
Area E	The area of maritime transportation risks within LSTC
Parameter R	The transport distance
Parameter T	The time of process performance

Fig. 1 Examples of LSTC fragments, organized according to the "*multi-points*" mode, where: a) LSTC descriptive model; b) LSTC functional model (source: own elaboration), where in Fig. 1 b): solid line – selected connection to perform the transport service, dashed line – possible connection to perform the transport service

- identification of the type of information needed for LSTC planning,
- identification of threats and risks related to transport activities,
- analysis of possible types of managerial decision errors,
- examining the impact of distorted information on decision making process,
- determining the way to perform LSTC,
- estimation of LSTC resilience to symptoms of business-environment instability.

2.2 Sources of threats and risks related to transport activities

Various threats may appear during the LSTC planning and implementation (Rosochacki and Filina-Dawidowicz, 2021; Swinney and Netessine, 2009). Despite the progress made on digitization, many companies operating in the T&L industry in the European Union still do not have a developed approach to assessing the risk of making inappropriate management decisions in complex, multi-level supply networks (Khatri, 2020).

The severe shortage of managers – logisticians and the positive trend of increasing the number of information distortions received from various sources are holding back some T&L industry companies in their efforts to accelerate digitization and implement advanced planning systems. The analysis of available literature sources demonstrates that information distortions affect almost every supply chain performed with the use of LSTC (Hendriks, 2010). These chains are affected by different threats (Fig. 2).

In order to mitigate the effects of this phenomenon, more than half of manufacturing enterprises use a certain number of preventive measures such as increasing stocks, using various sources of supply and their regionalization.

Managers responsible for planning and managing LSTC believe that detecting unreliable information and replacing it with up-to-date and complete information is the crucial issue for improving the processes of making the correct decisions. Each such process is burdened with the need to take into account the risks associated with transport activities (Table 1).

3 Decision making in LSTC planning tasks

3.1 Types of managerial decisions errors

Let's assume that the experienced LSTC manager can avoid making errors (mistakes), that are mentioned in Table 2. Then the degree of inaccuracy of the decision can be assessed by the number of management cycles that are sufficient to make a rational decision. The assessment of the degree of decision incorrectness is influenced by the quality of the input information, which can be structured and divided into 4 categories, including incomplete and correct, partially correct, incomplete and incorrect, as well as completely distorted. A wide range of information distortions increases the number of required managerial decision-making cycles to no less than three. While monitoring the decision implementation, the manager may note that the results obtained are different from the planned ones, which gives grounds to conclude that the information received was incorrect. In this way, one cycle of managing the collected information will pass.

Let's assume that the manager succeeds to identify and eliminate distorted information within a single cycle. In this way, the second information management cycle begins, followed by the next cycle.

While planning LSTC, even a set of three cycles requires quite a substantial amount of time and provided improvements.

3.2 The impact of distorted information on decision-making process

The decision-making process is very sensitive to the reliability of the information used, i.e., the divergence of decisions made based on unreliable information will increase as the unreliability level of the preliminary information increases.

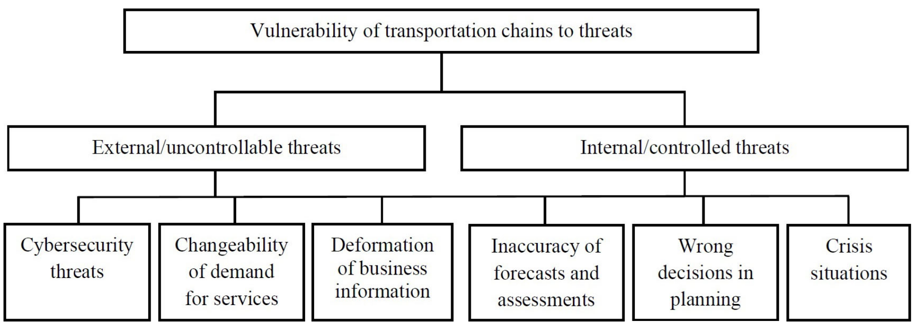


Fig. 2 Sources of threats in a land-sea transport chain (source: own elaboration)

Table 1 Risk related to transport activities carried out in LSTC (source: own elaboration)

Subject of risk	Risks related to transport activities		
	Preparation of transport works	Cargo transportation	Loading, unloading operations
Transport means (ships, trucks, handling equipment, etc.)	Errors in the transport process design, route planning or work schedule. *Reasons*: non-compliance with conditions set in agreement, unreliable information, etc.	Damage, total or partial destruction. *Reasons*: fire, breakdown, low level of driver qualifications, illegal actions of third parties, etc.	Damage, total or partial destruction. *Reasons*: staff errors (drivers, loaders), weather conditions, etc.
Transported goods (liquid and bulk cargo; general cargo, perishable products, etc.)	Incorrect threat identification; incorrect assessment of various risk types, improper organization of transport processes. *Reasons*: information distortion; failure to check; knowledge gaps, non-compliance with regulations and procedures, etc.	Damage, total or partial loss of goods. *Reasons*: use of defective containers and/or reusable packaging, improper cargo securing, unlawful actions of third parties, crew members' errors, etc.	Damage, thefts, value loss. *Reasons*: personnel errors, failure of handling equipment; technology and handling procedure violation, etc.
Personnel (managers and employees, incl. crane operators, warehousemen, drivers, ship's crew members, etc.)	Errors in the transport process organization; conflicts, irresponsibility, gaps in knowledge and training. *Reasons*: Employment of persons without appropriate qualifications or experience needed to perform professional tasks; legal omissions, etc.	Causing damage to the life and health of the driver, ship's crew members. *Reasons*: health problems, accidents, legal omissions, unlawful actions of third parties, etc.	Damage to the life and health of equipment (forklifts and overhead cranes) operators, warehousemen. *Reasons*: violation of safety regulations and procedures, improper area marking, etc.

Table 2 Mistakes made when planning land-sea transport chains (source: own elaboration based on Wu et al. (2022))

Error type	Characteristics	Possible causes	Precondition
Slip	Decisions are distinguished by unintentional ambiguity	Inattention, routine, time lacks	Excessive task number
Lapse	Decisions are distinguished by intentional ambiguity	Misunderstanding of the requirements contained in the task	Lack of input information verification
Mistake on rules	Voluntary decisions were made	Non-compliance with rules, errors in the rule's application, procedures ignorance	Low competences, over complicated standards
Mistake on knowledge	Decisions were made incompetently	Insufficient knowledge and experience	High level of information uncertainty
Routine violation	Decisions were made in procedures violation	Actions under time pressure	Consciously underestimating the risk, non-applying the standards
Exceptional violation	Refusal to perform the task, acting for the benefit of another company	Making decisions in crisis situations	Employer and employee conflicts

Let us set Ω as the area of space R^n containing the beginning of the trajectory of the decision-making process occurring in the time horizon T, where $T = [0, \tau]$, and τ means the end coordinates of the decision-making process trajectory.

Let's consider the course of the decision-making process in the following form:

$$x = f(x,t),\ x \in R^n,\ f : T \times \Omega,\ f(t_0) = 0. \tag{1}$$

Equation (1) shows that for each i-th trajectory of the decision-making process (t_i, x_i), there is only one trivial solution $< x_0 >$, that meets the initial conditions $(t = 0, x = 0)$.

Let's mark $< \varepsilon >$ as the variable depending on the distortion level of information held by the manager. Then, according to Lyapunov (Giesl and Hafstein, 2015), a trivial decision $x = 0$ is called a stable decision if for any starting moment of the decision-making process t_0 and distortion level of the information possessed $< \varepsilon >$ there is such a variable $< \delta >$, the value of which depends only on ε and t_0, as well as does not depend on the course of the decision-making process along the entire processtrajectory (t_i, x_i). At the same time, for each subsequent decision $< x_i >$, made in moments $t > t_0$, the following condition is met (Eq. (2)):

$$\left[x(t)\right] < \varepsilon. \tag{2}$$

This statement can be also presented in the following form (Eq. (3)):

$$\begin{aligned}&(\forall \varepsilon > 0),\ (\forall t \in T),\ \left[\exists \delta(t_0 \varepsilon) > 0\right],\\&(\forall x_0 \in X)(\forall t \geq t_0 t \in T) \rightarrow \left[x(t)\right] < \varepsilon.\end{aligned} \tag{3}$$

Any small change in the current decision-making process trajectory can lead to a significant change in its future behavior. It has been proven that the last two properties imply sensitivity to initial conditions.

3.3 Resilience of LSTC to symptoms of business-environment instability

Traditionally, transport and supply chains were supposed to be efficient, not resistant. During the last years many manufacturing and trading companies were forced to address gaps in their supply chains, changing the concept application from maximizing efficiency to maximizing resilience. Studies on supply chain implementation practices have revealed a significant discrepancy between achieving maximum resilience and perceiving the importance of digitalization in process planning and the quality of information collected for this purpose. Addressing these two issues is critical for companies seeking for the ways to improve the resilience of transport and supply chain planning and execution.

In order to analyze this problem, it is necessary to systematize the threats affecting the services provided. More and more often, the sources of such threats include non-compliance with safety and security rules during information processing and storing, inappropriate knowledge regarding the rules of working with information or IT systems, imperfection of information support organization procedures, use of defective software, behavioural factors causing information distortions, etc. In this approach, the threats caused by information distortion play an important role, because making any decisions based on distorted information becomes particularly difficult and unsafe.

Let's analyze how the use of distorted information affects the decision's accuracy. Let's assume that the LSTC planning process is implemented in six stages of the decision-making cycle, including information gathering, analysis, forecasting, planning, implementation, and control. According to the experience of the authors of the presented articles, one of the most important stages of the LSTC planning process is the first stage, during which the manager collects necessary information. If this step is carried out incorrectly, incorrect decisions will be made, which in turn will lead to irregularities during their implementation.

In transport work planning practice, the above-mentioned problem is getting worse as managers need not only current reliable information, but also information about possible events that may occur in the short term. The inaccuracy of such information is the result of possible changes in the LSTC business environment. Therefore, any information distortions at this planning stage will lead to greater inaccuracies of the information held. To avoid this problem, before starting the first stage of transport work planning, information collected in text, graphic or tabular form should be:

- verified (mandatory for information obtained from unknown sources),
- subjected to prognostic analysis to check its validity during the planned period of transport task execution,
- interpreted in time.

Each transport work plan assumes the implementation of the set tasks and the achievement of predetermined indicators. As a result of the information distortion at the stage of preliminary data analysis (during LSTC planning), these indicators will either be incorrectly selected or unattainable at all. Therefore, during the plan implementation, the discrepancies between the actual indicators and the planned ones may take place, which will result in need to introduce appropriate adjustments by the manager. Otherwise, the implementation of the plan will bring an inevitable negative result, such as unplanned financial, social or image consequences. In this case, chaos theory postulate could be designated, according to which complex systems are extremely dependent on initial conditions, and even the smallest changes in the decision-making environment can lead to unpredictable consequences.

Let us formulate the following assumptions:

1. If at least one fact is missing, incomplete information takes place.
2. If even one fact is not true, false or erroneous information takes place.

Then, let's shape the matrix of all possible information distortions, assuming that its quality is assessed by two factors – incompleteness and lack of credibility (Table 3). Let's mark the information lack as "0", complete information as "1", and unreliable (incomplete) as "2".

Taking into account that the combinations of indicators (0/1) and (1/0) are identical (Table 3), it can be concluded that there are six distortion degrees. Information may be

Table 3 Matrix of information distortion indicators (source: own elaboration)

Information distortion indicators		Information completeness		
		0	1	2
Information credibility	0	0/0	0/1	0/2
	1	1/0	1/1	1/2
	2	2/0	2/1	2/2

complete and reliable (indicator = (1/1)), incomplete but reliable (indicator = (1/0 or 0/1)), partially reliable and complete (indicator = (1/2 or 2/1)), incomplete and unreliable (indicator = (0/2 or 2/0)), completely unreliable (indicator = (2/2)), or missing (indicator = (0/0)). The negative impact of distorted information deals with the fact that it is one of the main reasons for the manager to make incorrect decisions during LSTC planning. Such an impact may be exerted by information with a low distortion degree, e.g., partially reliable and incomplete. Based on the above statements, it is possible to determine the levels of LSTC resilience to information distortions during transport chain planning considering the risk of business-environment instability (Table 4).

In conclusion, it can be stated that depending on the degree of the information distortion used by the managers, their decisions could be erroneous to varying degrees. The degree of incorrectness of a decision can be assessed by the number of decision-making cycles required to make and implement an effective decision.

4 Conclusions

In the presented research study, the impact of information distortions on the land-sea transport chains resilience under business-environment instability conditions was analyzed. LSTC planning process was considered, as well as the sources of hazards and selected areas of risk were investigated. The types of managerial decision errors were discussed and an approach to assessing the impact of distorted information on the decision-making process was proposed. The matrix of information distortion indicators was proposed, as well as the levels of LSTC resilience against possible information distortion were identified. After analyzing the results of the conducted research, it was found that:

- variability of the business environment and information disruptions will continue to occur, which means that the problem of ensuring the planned LSTC resilience to disruptions remains a crucial issue in the long-term perspective,
- the most difficult task is to detect sources of information distortion that interact, creating a synergy effect.

The results obtained may be of interest to managers of T&L industry companies who have to assess the quality of information collected, and may also be useful when planning goods deliveries, supporting the processes of making the right decisions, especially in conditions of business-environment instability.

Future directions of the authors' research will focus on the assessment of information distortions and analysis of selected distortions occurring within LSTC. Methods of adapting supply management systems to conditions of information disruption will be analyzed, as well as the ways to prevent their negative impact on transport processes will be examined.

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Table 4 Levels of LSTC resilience to information distortions during transport chains planning considering risk of business-environment instability (source: own elaboration on based on Kiritz et al., 2019)

Risk tiers of business-environment instability	Information distortion indicator	LSTC resilience to information distortions
First tier (Unlikely risk)	Complete and reliable information/Indicator = (1/1)	The resilience is completely assured
Second tier (Rare risk)	Incomplete but reliable information/Indicator = (1/0 or 0/1)	The resilience depends on external factors, e.g., suppliers (i.e., vendor lock-in)
Third tier (Moderate risk)	Reliable and partially complete information/Indicator = (1/2 or 2/1)	The resilience is ensured by possessed information checking with reliable sources
Fourth tier (Serious risk)	Incomplete and unreliable information/Indicator = (0/2 or 2/0)	The resilience is ensured through usage of specific strategies, e.g., "*Max Spare Components*" strategy
Fifth tier (Critical risk)	Completely unreliable information/Indicator = (2/2)	The resilience is ensured through feedback loops to make changes and adjustments to decisions made
Sixth tier (Disruption risk)	Missing information/Indicator = (0/0)	The resilience is missing

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