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GRESILIENT SUPPLY CHAIN – A CASE STUDY OF GLOBAL FLOWS

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Purpose: Nowadays there is still low awareness of creating specific supply chain hybrids in a planned manner. This paper focuses on a hybrid of the gresilient chain, which reflects the trend to act for the well-being of the environmental to eliminate disruptions in the flow of goods. The aim of the study is to determine the interdependence of the factors shaping the resilience of the supply chain and to determine which of them contribute the most to the creation of a green chain.
Design/methodology/approach: AHP and DAMATEL were used as research tools. A study focused on the cognitive chain is extremely interesting, because it is a global chain in which the main coordinator is relatively small. The subject of the research is the international supply chain of a company that conducts research on engine oils, coolants and fuels for gas engines driving turbines, electric and wind turbines, hydraulic transmissions, etc.
Findings: As a result, among other things, it was established, that speed is the factor that is most sensitive to the influence of other factors and, at the same time, the most important from the point of view of recipients. In addition, it was proven that redundancy is essential for creating resilience in the analyzed chain, while transparency is necessary for creating the green chain. It has also been shown that redundancy and cooperation work simultaneously to a great extent for the benefit of both chains.
Research limitations/implications: Every supply chain requires a separate study.
Practical implications: The results can help managers in implementing the gresilient strategy or in modifying it if it has already been implemented. The work carried out may contribute to the creation of a general matrix containing paths to the expected types of supply chains, taking into account the specificity of input and output connections.
Social implications: Gresilient chains are part of the idea of corporate social responsibility.
Originality/value: From the standpoint of building up resilience, this is an interesting case, because it is the discussed case does not fit into the concepts of popular models in which agility is promoted as the one that guarantees the resilience of the chain. The study is an expanding knowledge in the field of the gresilient chain, in which research is lacking due to the initial stage of science in this area.

Keywords: Transportation, Logistics, Resilient Supply Chain; Green; AHP, DEMATEL
Category of the paper: research paper, case study.

1. Introduction

In the context of the recent financial, pandemic or geopolitical crises, the trend of making chains more resistant is of particular importance. This is to lead to eliminating disruptions in the flow of goods. The literature emphasizes that, above all, agility, flexibility and transparency are the factors that make it possible to strengthen chains.

The second strong trend in the supply chain is its greening, i.e. striving to ensure that the processes are carried out keeping the well-being of the environment in mind. On the basis of comprehensive research covering a wide spectrum of activities, it can be seen that the measures taken relate primarily to the shortening of supply chains at the entrance in order to reduce CO2 emissions. Efforts are made to optimize the level of inventory in the context of their environmental impact, and environmental certificates are required from suppliers. The growing pressure to decarbonize operations and reduce the carbon footprint, the need to adapt to the Fit for 55 program further intensifies the discussed phenomena among the links of supply chains and the transport and logistics industry that supports them.

There is therefore a need to consider these trends simultaneously and implement chains of so-called gresilient.

2. Literature review and identifying the research gap

Currently, research on chains of this type is at an early stage of development. Among others Sen, Datta & Mahapatra (2017) and Xiong et al. (2020) proposed a decision support framework to address supplier selection issues while considering ecological and resilience criteria. Azevedo et al. (2013) developed the Ecosilient index for environmental and resilience performance and illustrated its application with a case study on the automotive supply chain. Souza, Bloemhof-Ruwaard and Borsato (2019) on the other hand, noticed, from a case study of the sugar beet supply chain, that the strategy of minimizing environmental impacts also increases the fragility of the chain. The authors showed how changes in the chain configuration affect the elasticity and durability of the chain in economic and environmental terms.

Nasrollah et al. (2023) understood the problem of designing a supply chain network on the example of an oxygen concentrator device, taking into account the two spheres discussed. The authors have proven that the increase in disruptions in the supply chain causes an increase

in carbon dioxide emissions. Ghomi-Avili et al. (2018), based on a case study of the filter industry, also referred to this issue. The authors concluded that it is important for competitiveness to anticipate the risk of disturbances in flows, as well as to reduce C02 emissions by implementing appropriate production processes. In turn, Yavari and Ajalli (2021) found that the amount of released CO2, cost and lost demand in the resilient model are far less than the non-resilient model. For the downstream supply chain, using multi-sourcing has a slight improvement in the performance of the supply chain under disruption risks. The authors focussed their attention on the milk supply chain.

Hasani, Mokhtari and Fattahi (2021) showed, however, that the centralization of points in the supply chain is beneficial due to the reduction of CO2 emissions. This is due to the shorter distance between objects. The research was carried out on the example of a manufacturer of medical devices. The scattering of points that can reinforce a chain is therefore in conflict with environmental issues. Foroozesh, Karimi and Mousavi (2022) also addressed the issue of carbon intensity and resilience on the example of the food supply chain.

Warmbier and Kinra (2022) extended the research by combining the issues of a resilient and sustainable chain. Based on the literature review, the authors revealed the great potential of combining the two discussed research domains. They determined that they should be considered along four dimensions: supply chain capabilities, practices, risk and performance. A similar research team (Warmbier, Kinra, Ivanov, 2022). found that there are many common activities for the development of these chains. It was also found that, for example, redundancy is the element that creates contradictions between both chains. Similar thematic studies were conducted by Negri et al. (2021). The authors recognized that research on immunity is less mature and that the relationship between the two topics is often inconsistent. In their opinion, it is not clear what practices could jointly contribute to the development of both areas. The time horizon of the conducted research is also important. Some authors, in this broader context, focus on selected processes, such as supplier selection (Amindoust, 2018).

Considerations of both types of chains are also conducted in the comparison of agile and lean chains. For example, Sharma and co-authors (2021) in research on various chain hybrids, including the hybrid in question, noted that the types of chains should be studied through the prism of the production strategies (Make-To-Stock – MTS, Made-To-Order – MTO, Assemble to Order – ATO, Engineer to order - ETO) and that the applied chain measures affect the choice of given hybrids. Studies of this type may be an inspiration to introduce moderators in the analysis of gresilient chains.

Summing up, it can be concluded that there is a large research gap in the field of gresilient chains. In the few studies mentioned earlier, problems resulting from reconciling the creation of resistant and green chains were shown. In particular, it was pointed out that attempts to strengthen the chains lead to worse environmental effects. This is especially important in a situation where we are dealing with economic, natural, epidemiological or geopolitical crises.

Then, it is critical for enterprises to maintain liquidity in the flow of goods and profitability, while pro-environmental issues remain in the background.

It is therefore vital to determine which of the factors, important from the point of view of the resilience of a given supply chain, is also important for greening IT. Therefore, the aim of the study was:

- to give an indication of the strength of the interaction of the factors increasing the resistance of the chain, from among those that are most important for a given, specific case,
- to determine which of these factors and to what extent, positively correlate with the creation of green chains. Therefore, a new approach was used in this study, where the starting point was the resilience activity, which was activated first. In addition, the need to rely on a group of factors appropriate for the discussed case was emphasized, and not the one that is most often proposed in research models. A preliminary study of the relationship between the initial factors was recommended before referring them to pro-environmental aspects, and the above issues were illustrated on a configurationally stable formula for supplying materials, which, despite the turbulence in the environment, may be an attractive path to competition.

3. The subject of research and the nature of its supply chain

In the analysed supply chain, mainly engine oils are moved, which are primarily used for the operation of gas engines, electric and wind turbines, and hydraulic transmissions. It is a global chain in which individual links of the company are linked by capital and finances. Major suppliers are closely related, and this results from the need to conduct their audits and certification. As the main customers are global concerns such as Chevron, Shell, and Mobil, which are present on all continents, their service requires efficient flows in long supply chains. In total, 165,000 customers are served. The analysed company is one of the seven subsidiaries of the company that conducts laboratory tests. It is also the only link of the concern, which is located in Europe, in Poland. The other six units are located in South, Central and North America. Therefore, the supply chain is extremely specific because at the beginning of the chain comes material for analysis from Europe, North Africa and Asia from a very large number of customers. Samples from smaller customers are delivered to three consolidation sites located in Europe (Germany, Belgium, and Great Britain). This delivery mode covers 45% of the samples. Larger customers send samples directly to the Polish laboratory.

Equipment parts are also moved within international supply chains. However, reagents and small equipment (pipettes, glass, oil-absorbing mats - the so-called sorbents, etc.) and clothing are purchased from regional companies. As the laboratory is accredited based on ISO17025,

the reagents are purchased from distributors of renowned world producers, e.g. Sigma-Aldrich, and Merck. Other accessories, such as pipettes, glass, and sorbets, are supplied from commercial units. Because the company's strategy assumes the development of Asian clients and clients from the Persian Gulf region, the number of clients from outside the European Union is slowly increasing. The share of European customers and the number of ordered samples are also growing. Therefore, the role of logistics is growing, both in the context of the extension of supply chains, geographic diversification, and the volume of goods moved. This string is non-standard. It is a global chain with a large amount of material movement. At the same time, the described company constituting the epicenter of the chain is a small company, employing only a dozen or so of people, where infrastructure such as offices and warehouses, and transport units (mainly air transport units) are not owned by the enterprise. The company is small, so there is no separate logistics department, and decision-making management in the area of logistics is primarily the responsibility of the manager.

In order to diagnose weak points in material flows, an interview was conducted. IDI (Individual In-depth Interview) was used as the basic research method. The contact person for the transmission of information was the company manager who is responsible for contact with other participants in the supply chain and with companies located around the world. At the same time, the manager had the opportunity to collect information from other employees to provide reliable answers.

Based on the interview, it was found that during emergencies, for example during the pandemic, problems arise with the timely delivery of components to the machines, as well as with the supply of sufficient laboratory materials. For example, there have been disruptions in the supply of reagents, pipettes, or test tubes. Due to the necessity to obtain supplies from certified suppliers or monopolistic competition, in many cases their possible change is very difficult. Due to the complexity of the equipment, the waiting time for spare parts is extended, because in most cases the elements are imported from abroad.

These delays force an increase in the level of inventory to maintain the continuity of laboratory tests, and thus increase costs. Regional chains have a radius of up to 400 km, so disruptions occur in the availability of goods, not in the speed of transport. However, in case of materials intended for research, disturbances concern possible transportation problems, as in this case there is no alternative means of transportation. Due to the high turnover of employees, there is also a problem with the failure rate of the machines, which translates into the speed with which the material is provided. Each employee requires several months of training because the supported equipment is highly specialized. In the event of a machine failure, long service orders may occur.

To diagnose how to deal with the prevention of interruptions in the performed tasks, the relationships between individual factors were investigated in more detail using multi-criteria methods. Then, it was examined whether these factors also serve pro-environmental aspects.

4. Factors shaping resilience of the analysed supply chain – research methodology

In the literature, research on strengthening chains in models or theoretical studies is most often referred to as resilience. Nevertheless, literature items containing the terms mitigation (Barroso, Machado, Machado, 2011) or vulnerability (Ekanayake et al., 2022), or disruption/ disturbances (Ozdemir et al., 2022) also concern resistance. The study assumes that "a resistant chain is a chain that, as a result of disruptions to internal or external factors, can quickly reach the starting position or change it (through location and product configuration, links with contractors, internal reorganization, etc.) so that it will not significantly disrupt business continuity. Therefore, it is a certain ability to resist shocks that occur in the supply chain" (Maryniak, Pogorzelec-Glaser, 2022).

Based on an extensive literature review, it was determined what set of factors used to build a resilient supply chain (Maryniak, Bulhakova, Lewoniewski, 2021). Then, out of twenty selected factors, most often mentioned in the research models, it was determined which of them are adequate for the examined enterprise. The research results were published in a paper of (Maryniak, Pogorzelec-Glasser, 2022).

Model approaches emphasize that agility and flexibility are the key factors in the construction of resistant chains (Christopher, Peck, 2004; Brusset, Teller, 2017; Cui, Idota, Ota, 2019; Mohammed, 2020). However, the conducted research did not prove this.

The dependencies between individual factors (table 1) that are the subject of consideration constitute a new cognitive thread about various supply chains, both in a universal mode, and in the context of a selected research subject.

A new topic is also checking which of these factors are most conducive to building pro-environmental chains, i.e. creating gresilient chains.

Table 1.
Most important factors for resilience of the analyzed supply chain

No.	Factor	Used in
1	**Transparency** The visibility of data in the company-client relationship but not in the company-supplier relationship	Christopher, Peck, 2004; Kong, Li, 2008; Jüttner, Maklan, 2011; Johnson, Elliott, Drake, 2013; Ganguly, Kumar, 2019; Dubey et al., 2020; Ivanov, Dolgui, 2021; Ekanayake et al., 2022; Kazemian et al., 2021; Ivanov, Dolgui, 2021; Karbassi Yazdi et al., 2022.
2	**Collaboration** The durability of relationships and joint problem solving by suppliers and customers	Christopher, Peck, 2004; Barroso, Machado, Machado, 2011; Jüttner, Maklan, 2011; Johnson, Elliott, Drake, 2013; Ganguly, Kumar, 2019; Dubey et al., 2020; Belhadi et al., 2021; Ivanov, Dolgui, 2021; Johnson, Ivanov, Dolgui, 2021; Kazemian et al., 2021; Shen, Sun, 2021; Ekanayake et al., 2022; Karbassi Yazdi et al., 2022; Kaur, Singh, 2022.
3	**Redundancy** Concerns all supplies but not the efficiency of machines	Christopher, Peck, 2004; Barroso, Machado, Machado, 2011; Azadeh et al., 2013; Ganguly, Kumar 2019; Hosseini, Al Khaled, 2019; Karbassi Yazdi et al., 2022.

Cont. table 1.

4	**IT** Applies to traditional and more advanced systems	Kong, Li, 2008; Khan, Estay, 2015; Naghshineh, Lotfi, 2019; Singh, Singh, 2019; Gu, Yang, Huo, 2021; Hundal et al., 2021; Ivanov, Dolgui, 2021.
5	**Information sharing** Refers to transferring data through IT systems and 4.0 technologies	Barroso, Machado, Machado, 2011; Papadopoulos et al., 2017; Ganguly, Kumar, 2019; Naghshineh, Lotfi, 2019; Shen, Sun, 2021; Karbassi Yazdi et al., 2022; Kazemian et al., 2021; Tasnim et al., 2022.
6	**Trust** Concerns a relationship between a company and a supplier as well as between a client and a company	Kong, Li, 2008; Johnson, Elliott, Drake, 2013; Papadopoulos et al., 2017; Naghshineh, Lotfi, 2019; Johnson, Elliott, Dubey et al,. 2020.
7	**Velocity** Concerns analysis, material handling and additional services	Christopher, Peck, 2004; Jüttner, Maklan, 2011; Azadeh et al., 2013; Johnson, Elliott, Drake, 2013; Karbassi Yazdi et al., 2022; Ozdemir et al., 2022.

Source: own work based on the literature of the subject.

5. Application of the DEMATEL and AHP method in the research area

The AHP and DEMATEL techniques were used in the study. These methods belong to the group of so-called multi-criteria decision-making (MCDM) and are also used concerning supply chain research. Among other things, they are used to assess the complexity of the supply chain (Chang et al., 2016), to study the bullwhip effect (Ortiz-Barrios, 2019), supplier selection (Wu, Tsai, 2012; Hladiy, Hrytsyshyn, 2020), suppliers with two different strategic perspectives: lean and agile (Li, Diabat, Lu, 2020), ordering various parameters that affect the performance of the supply chain (Najmi, Makui, 2010).

In the context of resilient chains, these methods were used, among others, by Das et al. (2022). The authors found that cost optimization is a critical factor in the process of enhancing supply chain performance and operational capability. They also noted that this affects the sustainable development and socio-economic well-being of all stakeholders involved in the entire network. These methods were also used by Sahu et al. (2022) to study chain resistance and its balance. The authors developed a framework that serves as a decision support tool in the area of entry logistics, that is, supplier selection. These methods are also used separately in terms of chain resistance. For example, the AHP method was used to identify and analyse the drivers of resilient healthcare supply chain (HCSC) preparedness in emergency health outbreaks to prevent disruption in healthcare services delivery (Hossain, Thakur, Kazancoglu, 2022). It has also been used to assess the factors that influence the chain, as well as to take appropriate mitigation strategies to strengthen supply chains. The authors proved that suppliers of critical parts, suppliers' location and long supply chain lead times are essential to ensuring continuity of supply. It has also been shown that not only long and complex supply chains but also the practices employed by companies determine their weaknesses.

The DEMATEL method in combination with the Gray theory was applied by Rajesh & Ravi (2015). According to the authors, to increase the resilience of the supply chain, factors that enable the reduction of risk in the supply chain must be taken into account and implemented in practice. There are more papers that use these methods on green chains. This is due to the long tradition of this topic. For example, Jayant & Agarwal (2019) provided a green supplier selection decision tool. Gandhi et al. (2016) proposed a structural framework for evaluating structural funds for supply chain greening by shaping tactical, operational, and strategic flexible decision-making strategies through the combined AHP-DEMATEL approach. The use of these techniques in the study of green supply chains is also indicated in reviews (Soda, Sachdeva, Garg, 2016). In turn, Bhatia, Jakhar & Dora (2020), using AHP and DEMATEL, examined the barriers to implementing a closed supply chain (CLSC), which fits in with the idea of a green chain, whereas Huang et al. (2022) applied these methods to the implementation of a circular economy based on Blockchain technology, which is also related to pro-environmental policy in the supply chain.

6. Resilient supply chain - evaluation of the mutual relationships of factors strengthening the supply chain using the DEMATEL method

In our study, we used the DEMATEL method to assess the mutual influence of the seven selected factors, which are the basis for building the resilience of the analyzed supply chain. To extend the research, in the next step we used the AHP method to determine the importance of individual factors for the formation of a gresilient chain.

The input data were obtained from the survey in the analyzed company. As a research method, we have used a structured direct interview, supplemented with contextual data on the specifics of the supply chain.

The DEMATEL method was developed in the 1970s as a procedure to solve problems of identifying cause-and-effect relationships (Gabus, Fontela, 1972; Fontela, Gabus, 1974). With time, this method has been adapted for more general usage in multi-criteria decision-making. A detailed description of the DEMATEL method and a survey of its applications can be found in (Sheng-Li et al., 2018).

The procedure starts with n factors among which we want to identify casual relationships. Interdependencies between factors are assessed on the basis of the questionnaire. For each pair of different factors, an expert has to answer how one of them influences the other and vice versa. DEMATEL uses a 5-point scale to evaluate interdependence and feedback: from *no influence* (0), to *very high influence*. The intermediate steps are: *low influence* (1), *moderate influence* (2), and *high influence* (3). Based on the expertise, the direct relationship matrix D is constructed:

$$D = \begin{bmatrix} 0 & d_{12} & \cdots & d_{1n} \\ d_{21} & 0 & \cdots & d_{2n} \\ \vdots & \cdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & 0 \end{bmatrix} \quad (1)$$

where d_{ij} is the measure of the influence of factor i on factor j, obtained from the survey. The initial matrix is then normalized by dividing the maximal sum in rows, and one obtains matrix X:

$$X = \frac{1}{\max_i \sum_{j=1}^{n} d_{ij}} D \quad (2)$$

The "total influence matrix" T was calculated by adding all the direct and indirect effects:

$$T = X + X^2 + X^3 + \cdots \quad (3)$$

The matrix T can be calculated using the equation

$$T = X(I - X)^{-1} \quad (4)$$

To simplify the information about total influence one can use truncation and keep information only about the strongest connections between system elements. To this end, one uses a positive impact threshold θ and one eliminates the weakest connections from the structure. The reduced total impact structure is expressed by the reduced form of the total impact matrix $\bar{T}$, whose elements are determined according to the following formula:

$$\bar{t}_{ij} = \begin{cases} t_{ij}, if\ t_{ij} \geq \theta \\ 0, if\ t_{ij} < \theta \end{cases} \quad (5)$$

The threshold is calculated as an average of elements in matrix T (see, for example, Hsin-Hung, Ya-Ning, 2011; Ortiz-Barrios et al., 2019):

$$\theta = \frac{1}{n^2} \sum_{i,j=1}^{n} t_{ij} \quad (6)$$

In our case, the threshold level was equal to 1.181. The total impact matrix is given in the following table (the order of factors is the same as in Table 1):

$$\bar{T} = \begin{bmatrix} 0.000 & 0.420 & 0.387 & 0.000 & 0.205 & 0.352 & 0.470 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.188 & 0.000 & 0.366 \\ 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.227 \\ 0.275 & 0.249 & 0.000 & 0.000 & 0.273 & 0.264 & 0.432 \\ 0.255 & 0.442 & 0.349 & 0.000 & 0.000 & 0.370 & 0.484 \\ 0.000 & 0.272 & 0.000 & 0.000 & 0.000 & 0.000 & 0.224 \\ 0.000 & 0.291 & 0.000 & 0.000 & 0.000 & 0.244 & 0.000 \end{bmatrix} \quad (7)$$

At the end of the analysis, the appropriate indicators are calculated. Let r_i be the sum of all elements in row i of matrix $\bar{T}$ and c_i be the sum of column i:

$$r_i = \sum_{j=1}^{n} \bar{t}_{ij} \quad (8)$$

$$c_i = \sum_{j=1}^{n} \bar{t}_{ji} \quad (9)$$

Then one defines the importance indicator $(r_i + c_i)$ and the relation indicator $(r_i - c_i)$ of factor i. The importance indicator represents the degree of importance of factor i in the entire system. The relation indicator describes the net effect that factor i contributes to the system.

Factors with positive relation indicators ($r_i - c_i > 0$) are classified as dispatchers (causes). On the other hand, factors with negative values of this indicator are receivers (effects). The results are presented in Table 2. The R + C variable in the table signifies the total influence potential or importance of a factor, and R–C value indicates the net influence potential of a factor.

Table 2.
Importance and relation indicators of the factors

Factor	R+C	R-C-	Type	Rank
Transparency	2.363	1.304	dispatcher	3
Collaboration	2.229	-1.119	receiver	4
Redundancy	0.963	-0.510	receiver	7
IT	1.493	1.493	dispatcher	6
Information sharing	2.566	1.233	dispatcher	2
Trust	1.725	-0.733	receiver	5
Velocity	2.739	-1.669	receiver	1

As one can see, three of the factors (Transparency, IT and Information sharing) can be classified as dispatchers. The other four factors (Collaboration, Redundancy, Trust and Velocity) are receivers. The most influential causal factor is IT. On the other hand, the Velocity is the factor that is, the highest degree, influenced by others.

Figure 1 presents the graphical representation of the factors, based on the cause-and-effect group, depicting the relationship between the influence indicators and the relationship indicators

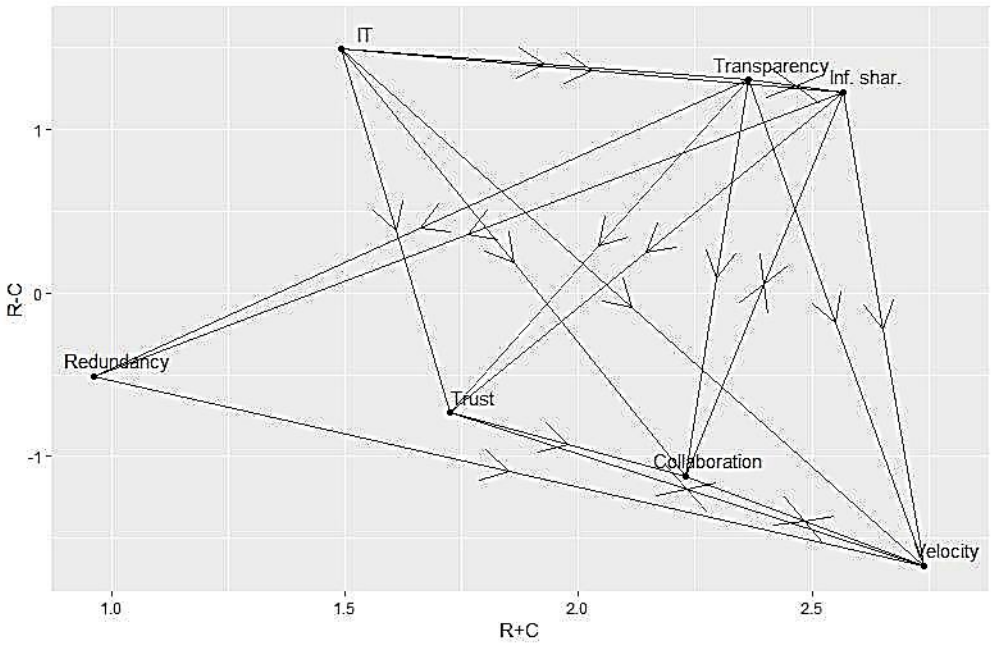

Figure 1. Impact-digraph map for seven factors of the supply chain.

The results obtained are consistent with the chain profile, as the company guarantees very short time, i.e., 48 hours, for testing the submitted samples. Equally important is the short transportation time of the samples. Therefore, the company uses airlines, despite the high costs

of transportation. Therefore, it is a critical point that influences the trust of customers and the company's brand. Due to the specific nature of the company, it is very important to cooperate both at the level of suppliers who are audited and certified and at the level of customers who, despite their often dispersed global networks, must precisely define their needs.

These two factors are influenced by transparency and information sharing, whose sources are modern IT systems and technologies. Researchers' devices and procedures are unified at the level of the entire corporation, including the tested unit, which ensures the comparability of results, regardless of the destination of the materials sent. The corporation has a Computerized Maintenance Management System (CMMS) for laboratory equipment management, periodic inspections, calibration, validation, and for the communication of messages. In turn, enterprise asset management (EAM) is used to keep devices in motion. After the tests, the algorithm collects the data and forecasts whether the parameters have changed, whether the equipment can be further used, or whether materials need to be tested more often. In addition, the company uses technologies such as cloud computing (CC), the Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML). All these technologies improve the processes of sharing information and thus increase the transparency of activities.

7. Gresilient supply chain - assessment of the importance of factors using the AHP method

The literature emphasizes that to achieve sustainable competitiveness, supply chains should not only be resilient in terms of logistics but also be pro-ecological to create image strength and increase the level of trust (Rajesh, 2019). These are the so-called gresilient chains. Therefore, there is a need to develop an integrated approach that simultaneously takes into account the need to create resilient and environmentally friendly chains (Mohammed et al., 2019). In economic reality, there are situations where sustainability initiatives and practices can affect the ability of the supply chain to deal with unforeseen disruptions. Some environmental practices can increase chain resilience, for example, by attempting to increase resource efficiency and reduce the number of warehouse points and warehouse space along the supply chain. On the other hand, for example, the limited availability of safety stocks can lead to disruptions at the moment of fluctuations in supply and demand (Fahimnia, Jabbarzadeh, 2016).

Therefore, in the next stage, it was examined whether the elements that make up the resistance model in the analyzed chain also allow for shaping the green chain. Thus, the validity of the factors was checked on a peer-to-peer basis and weights were assigned for the development of resistant chains. Then, adopting the same path, it was checked whether the identified factors also contribute to the formation of green chains. For this purpose, the AHP method was used.

AHP (Analytic Hierarchy Process) is a method proposed by Saaty (1980) to solve multi-criteria decision-making (MCDM) problems. The aim of this technique is to calculate weights of the factors and construct a ranking list of them. The AHP allows the decision-maker to simplify a complex, multi-criterial problem into one ranking list, which allows one to compare factors quantitatively. The main properties of AHP are the following:

1. AHP allows to evaluate the proposed factors according to several criteria.
2. The criteria can form a hierarchical structure (criteria and sub-criteria).
3. The comparisons between factors and between criteria at each level of the hierarchy are made pairwise and qualitatively. Decision makers compare a pair of objects (factors or criteria) each time and evaluate them descriptively. The descriptions are then transformed into numbers.
4. The final result is a linear measure of the weights for all factors.

The AHP technique is summarised in several steps (Saaty 1980), given as follows.

Step 1: Define the decision problem. Identify the goals, criteria and sub-criteria.

Step 2: Establish the hierarchy of criteria.

Step 3: Develop pairwise assessments of relative importance. This step includes collecting data to form pairwise evaluations among factors. To collect the data, one has to perform a set of questionnaires. For each pair of alternatives, i, j, one has to obtain the answer to the following two questions: (1) "Which alternative (i or j) is more important?" and (2) "How strong is this importance?". The strength of importance is measured according to the Saaty scale, as presented in Table 3.

Table 3.
The Saaty's AHP scale

Scale	Description	Interpretation
1	Equally important	alternatives i and j are equally important
3	Moderately	experience and judgment slightly favor i over j
5	Strongly	experience and judgment strongly favor i over j
7	Very strongly	experience and judgment very strongly favor i over j
9	Extremely	the evidence favoring $i$over j is of the highest possible order of affirmation
Reciprocals	Opposites	alternative j is more important than i

Source: (Saaty, 1980).

Step 4: Establish pairwise a comparison matrix. Based on the pairwise comparisons from step 3, create a square matrix $A = [a_{ij}]$, where a_{ij} is the result of the comparison of alternatives i and j, according to the scale from Table 1. The matrix A has thus the form:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{10}$$

If there exists a consistent measure of importance of factors and v_i is the weight of the alternative i, then the relative measures of importance are equal to $a_{ij} = v_i/v_j$. In this case, the vector $v = (v_1, v_2, \dots, v_n)^T$ would be the highest eigenvector of the matrix A with the eigenvalue equal to n.

Step 5: Calculate the normalized eigenvector of A, i.e. the vector $w = (w_1, w_2, \dots, w_n)^T$ that fulfills:

$$Aw = \lambda_{max} w, w_1 + w_2 + \cdots + w_n = 1 \quad (11)$$

where λ_{max} is the highest eigenvalue of A. As all elements of A are positive, according to the Frobenius-Perron theorem, the elements of w are also positive. The numbers $w_1, \dots, w_n$ are the weights of subsequent alternatives.

Step 6: Check the consistency of the assessment. The closer λ_{max} is to n, the more consistent the obtained scale is. To check it, calculate the consistency index (CI):

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (12)$$

and compare it with a random consistency index (RI), obtained from randomly generated matrices, to obtain a consistency ratio (CR):

$$CR = \frac{CI}{RI} \quad (13)$$

The values of RI are given in Table 4.

Table 4.
Random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.32	1.41	1.45	1.49

Source: (Saaty 1980).

Step 7: Integrate the assessments. If you decide that assessments are consistent enough, calculate the overall weights corresponding to each alternative by multiplying the vectors from individual matrices along with the relative weights of the criteria and the sub-criteria.

In the survey, the factors were evaluated according to two criteria: Resilience and Eco-friendliness (EF – how pro-environmental the factor is). In the survey, Resilience was indicated as a factor strongly preferred over EF, which gave the weight 83% to Resilience and 17% to EF. The CR values for the Resilience and EF criteria were 0.22 and 0.17, respectively.

The results of the analysis are presented in Table 5. As one can see, Redundancy and Collaboration are considered as the most important factors for Resilience. For creating environmental-friendly chains, the most important factors are Collaboration and Transparency.

Table 5.
Weights of the factor according to the AHP analysis

Factor	Resilience	Rank	EF	Rank	Overall	Rank
Transparency	1.8%	7	42.7%	1	8.6%	6
Collaboration	24.9%	2	20.0%	2	24.1%	2
Redundancy	38.6%	1	2.0%	6	32.5%	1
IT	9.7%	4	11.5%	4	10.0%	3
Information sharing	8.2%	5	17.0%	3	9.7%	4
Trust	6.9%	6	4.8%	5	6.6%	7
Velocity	9.9%	3	2.0%	7	8.6%	5

The importance of the different factors varies most among redundancy, transparency, and speed. The identified differences reveal that the general weights for both types of chains cannot be used as a guide when deciding to simultaneously develop competencies in the context of creating resistant and green chains. Depending on the urgency of your needs, you should decide which factors to focus on first.

In this chain, the issues of resistance and pro-environmental approach are mutually overlapping. This is because disturbances in the chain can have a significant impact on environmental aspects. The analysed company tests oils to extend the failure-free operation of machines. The company contributes to extending the life cycle of assets, minimizing the cost of repairs and replacement of parts due to the possibility of predicting the date of necessary equipment maintenance. It also provides consulting and monitoring of machines to ensure the continuity of their work. If necessary, when it is not possible to implement it by remote support, an employee of the company comes to the customer's place. Therefore, both the timely delivery of the tests' results and the possibility of quick service after the completion of the main service leads to less pollution in the form of a reduction in the number of used oils, and extends the life of often large and very expensive equipment. The tested material does not return to the contractor. Therefore, it is necessary to utilize them systematically and efficiently, and accurately register them in the so-called BDO system of a given type of waste. Waste is collected by a specialized company with a permit every three to four weeks. Waste transfer cards are also filled in electronically concerning waste in the form of oil from which energy is partially recovered.

Taking into account the analysed factors, one can perceive their simultaneous role in the creation of a gresilient chain. For example, information sharing enables one to quickly diagnose and fix problems in the flows. At the same time, information on carbon footprint and reverse logistics projects result in greater customer confidence and greater awareness of threats among all participants in the supply chain. However, some factors are clearly conducive to one type of chain or may even contribute to inhibiting the development of the other type of chain. For example, due to the fact that the company competes with speed and quality, but not with costs, it is difficult to use in this case intermodal or sea transport channels, which are more environmentally friendly.

8. Conclusions and theoretical and managerial implications

Based on the research it has been proved, despite the statements about dynamically changing external conditions and the need to act on the brink of chaos, that in economic reality there are also stable supply chains in terms of their configuration with suppliers and main customers, and in terms of the method of logistics service. In such chains, during disruptions in flows, collaboration, transparency of activities, speed of service, and redundancy of basic materials are essential. However, these activities are undertaken within the same systems, procedures and flow paths. The implementation of information technology and technology 4.0 and the unification of activities throughout the corporation accelerate processes and constitute the basis for developing cooperation and trust among business partners.

Research has established that redundancy and collaboration are important for the gresilient chain in this case.

In the future, the research perspective can be extended to the relationships of resistant chains with sustainable ones (Zahiri, Zhuang, Mohammadi, 2017), as well as to analysis in the context of the linkage of resilience aspects between dynamically integrated abilities and sustainable competitive advantage (Ponomarov, Holcomb, 2009). It is also legitimate to develop research towards multiple case studies to include various moderators in the study, such as chain complexity, geographic differentiation (Brandon-Jones et al., 2014), and a micro- and macro-economic approach (Azadegan, Dooley, 2020).

The study deliberately selected research methods (DEMATEL, AHP) that are available and appropriate for smaller companies. More advanced proposals appearing in the literature are adequate for analyses performed at the corporate level, where it is easier to find staff with sufficient competencies.

Currently, there are research models for building supply chain resilience, focused on selected elements that are generally considered important. The conducted research introduces a contextual thread regarding the specificity of the supply chain and its desired nature. This is important because, as research shows, the degree of ranking their importance varies. The conducted study contributes to the literature by:

- proving that conducting empirical research on the extraction of appropriate factors constituting a resistant chain for specific networks of links should only be an initial phase preceding deeper analyses,
- proposing simultaneous consideration of the possibility of building chains of various types using the DEMATEL and AHP methods, because in an economic reality there are usually hybrid supply chains, so separate recognition of these perspectives is not appropriate,

- proving that it is important to isolate the factors that activate work on one type of chain and at the same time contribute to the activation of work another type of chain, because some factors in this area do not correspond with each other, - expanding knowledge in the field of the gresilient chain, in which reasearch is lacking due to the initial stage of science in this area, - embedding considerations in the supply chain, which has not yet been considered in literature and is interesting due to its non-standard nature.

The work carried out may contribute to the creation of a general matrix containing paths to the expected types of supply chains, taking into account the specificity of input and output connections. The research complements our current understanding by indicating which variables can be used to formulate gresilient chains in stable links in regards to deliveries and unified relations with regular or new customers.

The obtained results show managers how the factors building the resilience of the supply chain affect each other and what the strength of the interaction between them is. In addition, they show which of the factors building the resistance of flows can, at the same time, be useful for increasing the level of its environmental friendliness. Therefore, the results can help managers in implementing the gresilient strategy or in modifying it if it has already been implemented. This is important because, as research shows, in economic reality, we usually do not compete with only one type of chain. It is also significant that not every environmentally friendly activity serves to create a resistant chain and vice versa. Therefore, the discovery of these relationships is important. It helps get to both operational and environmental performance faster. This research also raises awareness of the need to include these types of examinations in strategies, which are rarely undertaken in economic practices at the logistics level. As a rule, these are ad hoc actions in response to crises or marketing needs.

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References

1. Amindoust, A. (2018). A resilient-sustainable based supplier selection model using a hybrid intelligent method. *Computers & Industrial Engineering, 126,* 122-135, doi.org/10.1016/ j.cie.2018.09.031.

2. Azadegan, A., Dooley, K.J. (2020). A typology of supply network resilience strategies: complex collaborations in a complex world. *Journal of Supply Chain Management, 57(1),* 17-26, doi.org/10.1111/jscm.12256.
3. Azadeh, A., Atrchin, N., Salehi, V., Shojaei, H. (2013). Modelling and improvement of supply chain with imprecise transportation delays and resilience factors. *International Journal of Logistics Research and Applications, 17(4),* 269-282, doi.org/10.1080/13675567.2013.846308.
4. Azevedo, S.G., Govindan, K., Carvalho, H., Cruz-Machado, V. (2013). Ecosilient Index to assess the greenness and resilience of the upstream automotive supply chain. *Journal of Cleaner Production, 56,* 131-146, doi.org/10.1016/j.jclepro.2012.04.011.
5. Barroso, A.P., Machado, V.H., Machado, V.C. (2011). Supply chain resilience using the mapping approach. In: P. Li (ed.), *Supply chain management* (pp. 161-184). Rijeka: InTech, doi.org/10.5772/15006.
6. Belhadi, A., Mani, V., Kamble, S.S., Khan, S.A.R., Verma, S. (2021). Artificial-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: an empirical investigation. *Annals of Operations Research*, 1-26, doi.org/10.1007/s10479-021-03956-x.
7. Bhatia, M.S., Jakhar, S.K., Dora, M. (2020). *Analysis of barriers to closed-loop supply chain: A case of the Indian automotive industry*. IEEE Transactions on Engineering Management, 1-38, doi.org/10.1109/TEM.2020.2998794.
8. Brandon-Jones, E., Squire, B., Autry, C.W, Petersen, K.J. (2014). A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *Journal of Supply Chain Management, 53(3),* 55-73, doi.org/10.1111/jscm.12050.
9. Brusset, X., Teller, C. (2017). Supply chain capabilities, risks, and resilience. *International Journal of Production Economics, 184,* 59-68, doi.org/10.1016/j.ijpe.2016.09.008.
10. Chang, A.Y., Hu, K.J., Hsu, P., Hsu, C.H. (2016). *An integrated model for the evaluation of supply chain system complexity.* 2016 4th International Symposium on Computational and Business Intelligence (ISCBI), IEEE, 15-20, doi.org/10.1109/ISCBI.2016.7743253.
11. Christopher, M., Peck, H. (2004). Building the Resilient Supply Chain. *The International Journal of Logistics Management, 15(2),* 1-14, doi.org/10.1108/09574090410700275.
12. Cui, Y., Idota, H., Ota, M. (2019). *Improving Supply Chain Resilience with a Hybrid System Architecture.* International Conference on Multidisciplinary Social Networks Research. Singapore: Springer, 142-154, doi.org/10.1007/978-981-15-1758-7_12.
13. Das, D., Datta, A., Kumar, P., Kazancoglu, Y., Ram, M. (2021). Building supply chain resilience in the era of COVID-19: An AHP-DEMATEL approach. *Operations Management Research*, 1-19, doi.org/10.1007/s12063-021-00200-4.
14. Dubey, R., Gunasekaran, A., Bryde, D.J., Dwivedi, Y.K., Papadopoulos, T. (2020). Blockchain technology for enhancing swift-trust, collaboration and resilience within

a humanitarian supply chain setting. *International Journal of Production Research, 58(11),* 3381-3398, doi.org/10.1080/00207543.2020.1722860.

15. Ekanayake, E.M.A.C., Shen, G.Q., Kumaraswamy, M.M., Owusu, E.K. (2022). Identifying supply chain vulnerabilities in industrialized construction: an overview. *International Journal of Construction Management, 22(8),* 1464-1477, doi.org/10.1080/15623599. 2020.1728487.
16. Fahimnia, B., Jabbarzadeh, A. (2016). Marrying supply chain sustainability and resilience: A match made in heaven. *Transportation Research Part E: The Logistics and Transportation Review, 91,* 306-324, doi.org/10.1016/j.tre.2016.02.007.
17. Fontela, E., Gabus, A. (1974). *DEMATEL, Innovative Methods, Rep. No. 2, Structural Analysis of the World Problematique (Methods).* Geneva: Battelle Institute; Geneva Research Center.
18. Foroozesh, N., Karimi, B., Mousavi, S.M. (2022). Green-resilient supply chain network design for perishable products considering route risk and horizontal collaboration under robust interval-valued type-2 fuzzy uncertainty: A case study in food industry. *Journal of environmental management, 307,* 114470; doi.org/10.1016/j.jenvman.2022.114470
19. Gabus, A., Fontela, E. (1972). *World Problems an Invitation to Further thought within the Framework of DEMATEL.* Geneva: Batelle Institute; Geneva: Research Center,
20. Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D. (2016). A combined approach using AHP and DEMATEL for evaluating success factors in implementation of green supply chain management in Indian manufacturing industries. *International Journal of Logistics Research and Applications, 19(6),* 537-561, doi.org/10.1080/13675567.2016.1164126.
21. Ganguly, A., Kumar, C. (2019). Evaluating supply chain resiliency strategies in the Indian pharmaceutical sector: a fuzzy analytic hierarchy process (f-ahp) approach. *International Journal of the Analytic Hierarchy Process, 11(2),* 153-180, doi.org/10.13033/ijahp. v11i2.620.
22. Ghomi-Avili, M., Naeini, S.G.J., Tavakkoli-Moghaddam, R., Jabbarzadeh, A. (2018). A fuzzy pricing model for a green competitive closed-loop supply chain network design in the presence of disruptions. *Journal of Cleaner Production, 188,* 425-442; doi.org/10.1016/j.jclepro.2018.03.273.
23. Gu, M., Yang, L., Huo, B. (2021). The impact of information technology usage on supply chain resilience and performance: An ambidexterous view. *International Journal of Production Economics, 232,* 1-13, doi.org/10.1016/j.ijpe.2020.107956.
24. Hasani, A., Mokhtari, H., Fattahi, M. (2021). A multi-objective optimization approach for green and resilient supply chain network design: a real-life case study. *Journal of Cleaner Production, 278,* 123199, doi.org/10.1016/j.jclepro.2020.123199
25. Hladiy, G., Hrytsyshyn, A. (2020). *Combined Approach to Modeling Supplier Selection*. 2020 IEEE 15th International Conference on Computer Sciences and Information Technologies (CSIT), 1, 179-182, doi.org/10.1109/CSIT49958.2020.9322049.

26. Hossain, M.K., Thakur, V., Kazancoglu, Y. (2022). Developing a resilient healthcare supply chain to prevent disruption in the wake of emergency health crisis. *International Journal of Emerging Markets*, doi.org/10.1108/IJOEM-10-2021-1628.
27. Hosseini, S., Al Khaled, A. (2019). A hybrid ensemble and AHP approach for resilient supplier selection. *Journal of Intelligent Manufacturing, 30(1),* 207-228, doi.org/10.1007/s10845-016-1241-y.
28. Hsin-Hung, W., Ya-Ning, T. (2011). An integrated approach of AHP and DEMATEL methods in evaluating the criteria of auto spare parts industry. *International Journal of Systems Science, 43,* 2114-2124, doi.org/10.1080/00207721.2011.564674.
29. Huang, L., Zhen, L., Wang, J., Zhang, X. (2022). Blockchain implementation for circular supply chain management: Evaluating critical success factors. *Industrial Marketing Management, 102,* 451-464, doi.org/10.1016/j.indmarman.2022.02.009.
30. Hundal, G.S., Thiyagarajan, S., Alduraibi, M., Laux, C.M., Furterer, S.L., Cudney, E.A. Antony, J. (2021). The impact of Lean Six Sigma practices on supply chain resilience during COVID 19 disruption: a conceptual framework. *Total Quality Management & Business Excellence*, 1-19, doi.org/10.1080/14783363.2021.2014313.
31. Ivanov, D., Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control, 32(9),* 775-788, doi.org/10.1080/09537287.2020.1768450.
32. Jayant, A., Agarwal, A. (2019). A novel hybrid MCDM approach based on DEMATEL, AHP and TOPSIS to evaluate green suppliers. Jour*nal of Physics: Conference Series, 1240(1),* p. 012010, doi.org/10.1088/1742-6596/1240/1/012010.
33. Johnson, N., Elliott, D., Drake, P. (2013). Exploring the role of social capital in facilitating supply chain resilience. *Supply Chain Management, 18(3),* 324-336, doi.org/10.1108/SCM-06-2012-0203.
34. Jüttner, U., Maklan, S. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management, 16(4),* 246-259, doi.org/10.1108/13598541111139062.
35. Karbassi Yazdi, A., Mehdiabadi, A., Wanke, P.F., Monajemzadeh, N., Correa, H.L., Tan, Y. (2022). Developing supply chain resilience: a robust multi-criteria decision analysis method for transportation service provider selection under uncertainty. *International Journal of Management Science and Engineering Management,* 1-14, doi.org/10.1080/17509653.2022.2098543.
36. Kaur, H., Singh, S.P. (2022). Disaster resilient proactive and reactive intelligence procurement models for humanitarian supply chain. *Production Planning & Control, 33(6-7),* 576-89, doi.org/10.1080/09537287.2020.1834124.
37. Kazemian, I., Torabi, S.A., Zobel, C.W., Li, Y., Baghersad, M. (2021). A multi-attribute supply chain network resilience assessment framework based on SNA-inspired indicators. *Operational Research,* 1-31, doi.org/10.1007/s12351-021-00644-3.

38. Khan, O., Estay, D.A.S. (2015). Supply chain cyber-resilience: Creating an agenda for future research. *Technology Innovation Management Review, 5(4),* 6-12, doi.org/10.22215/timreview/885.
39. Kong, X.Y., Li, X.Y. (2008). *Creating the resilient supply chain: The role of knowledge management resources.* 4th International Conference on Wireless Communications, Networking and Mobile Computing, 1-4. IEEE, doi.org/10.1109/WiCom.2008.1617.
40. Li, Y., Diabat, A., Lu, C.C. (2020). Leagile supplier selection in Chinese textile industries: a DEMATEL approach. *Annals of Operations Research, 287(1),* 303-322, doi.org/10.1007/s10479-019-03453-2.
41. Maryniak, A., Bulhakova, Y., Lewoniewski, W. (2021). *Resilient supply chains 4.0-a research review.* 26th IEEE Asia-Pacific Conference on Communications (APCC), 99-104, doi.org/10.1109/APCC49754.2021.9609916.
42. Maryniak, A., Pogorzelec-Glaser, K. (2022). The nature of the intercontinental supply chain and building its resilience in a company carrying out quality analyzes of engine oils. *Scientific Journals of the Maritime University of Szczecin, 72(144),* 193-200.
43. Mohammed, A. (2020). Towards 'gresilient'supply chain management: A quantitative study. *Resources, Conservation and Recycling, 155*, 104641.
44. Mohammed, A., Harris, I., Soroka, A., Nujoom, R. (2019). A hybrid MCDA-fuzzy multi-objective programming approach for a G-Resilient supply chain network design. *Computers & Industrial Engineering, 127*, 297-312, doi.org/10.1016/j.cie.2018.09.052.
45. Naghshineh, B., Lotfi, M. (2019). Enhancing supply chain resilience: an empirical investigation. *Continuity & Resilience Review, 1(1),* 47-62, doi.org/10.1108/CRR-09-2018-0002.
46. Najmi, A., Makui, A. (2010). Providing hierarchical approach for measuring supply chain performance using AHP and DEMATEL methodologies. *International Journal of Industrial Engineering Computations, 1(2),* 199-212, doi.org/10.5267/j.ijiec.2010.02.008.
47. Nasrollah, S., Najafi, S.E., Bagherzadeh, H., Rostamy-Malkhalifeh, M. (2023). *Neural Computing and Applications, 35(3),* 2647-2678, doi.org/10.1016/j.jenvman.2022.114470.
48. Negri, M., Cagno, E., Colicchia, C., Sarkis, J. (2021). Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the environment, 30(7),* 2858-2886, doi.org/10.1002/bse.2776.
49. Ortiz-Barrios, M., Miranda-De la Hoz, C., López-Meza, P., Petrillo, A., De Felice, F. (2019). A case of food supply chain management with AHP, DEMATEL, and TOPSIS. *Journal of Multi-Criteria Decision Analysis*, 1-25, https://doi.org/10.1002/mcda.1693.
50. Ozdemir, D., Sharma, M., Dhir, A., Daim, T. (2022). Supply chain resilience during the COVID-19 pandemic. *Technology in Society, 68*, 1-10, doi.org/10.1016/j.techsoc.2021.101847.
51. Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S.J., Fosso-Wamba, S. (2017). The role of Big Data in explaining disaster resilience in supply chains for

sustainability. *Journal of Cleaner Production, 142*, 1108-1118, doi.org/10.1016/j.jclepro.2016.03.059.

52. Ponomarov, S.Y., Holcomb, M.C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management, 20(1),* 124-143, doi.org/10.1108/09574090910954873.
53. Rajesh, R., Ravi, V. (2015). Modeling enablers of supply chain risk mitigation in electronic supply chains: A Grey–DEMATEL approach. *Computers & Industrial Engineering, 87,* 126-139, doi.org/10.1016/j.cie.2015.04.028.
54. Saaty, T.L. (1980). *The Analytic Hierarchy Process*. New York: Mcgraw-Hill International.
55. Sahu, A.K., Sharma, M., Raut, R.D., Sahu, A.K., Sahu, N.K., Antony, J., Tortorella, G.L. (2022). Decision-making framework for supplier selection using an integrated MCDM approach in a lean-agile-resilient-green environment: evidence from Indian automotive sector. *The TQM Journal*, 1-43, doi.org/10.1108/TQM-12-2021-0372.
56. Sen, D.K., Datta, S., Mahapatra, S.S. (2017). Dominance based fuzzy decision support framework for g-resilient (ecosilient) supplier selection: an empirical modelling. International *Journal of Sustainable Engineering, 10(6),* 338-357, doi.org/10.1080/19397038.2017.1286410.
57. Sharma, V., Raut, R.D., Mangla, S.K., Narkhede, B.E., Luthra, S., Gokhale, R. (2021). A systematic literature review to integrate lean, agile, resilient, green and sustainable paradigms in the supply chain management. *Business Strategy and the Environment, 30(2),* 1191-1212, doi.org/10.1002/bse.2679.
58. Shen, Z.M., Sun, Y. (2021). Strengthening supply chain resilience during COVID-19: A case study of JD. com. *Journal of Operations Management, 1-2,* doi.org/10.1002/joom.1161.
59. Sheng-Li, S., Xiao-Yue, Y., Hu-Chen, L., Ping, Z. (2018). DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. *Mathematical Problems in Engineering*, 1-33, doi.org/10.1155/2018/3696457.
60. Singh, N.P., Singh, S. (2019). Building supply chain risk resilience: Role of big data analytics in supply chain disruption mitigation. *Benchmarking: An International Journal, 27(7)*, 2318-2342, doi.org/10.1108/BIJ-10-2018-0346.
61. Soda, S., Sachdeva, A., Garg, R.K. (2016). Literature review of multi-aspect research works carried out on the concept and implementation of GSCM. *International Journal of Industrial and Systems Engineering, 23(2),* 223-253, doi.org/10.1504/IJISE.2016.076404.
62. Souza, V.D., Bloemhof-Ruwaard, J., Borsato, M. (2019). Exploring ecosystem network analysis to balance resilience and performance in sustainable supply chain design. *International Journal of Advanced Operations Management, 11(1-2),* 26-45, doi.org/10.1504/IJAOM.2019.098525.

63. Tasnim, Z., Shareef, M.A., Dwivedi, Y.K., Kumar, U., Kumar, V., Malik, F.T., Raman, R. (2022). Tourism sustainability during COVID-19: developing value chain resilience. *Operations Management Research*, 1-17, doi.org/10.1007/s12063-021-00250-8.
64. Vali-Siar, M.M., Roghanian, E. (2022). *Green and Resilient Mixed Supply Chain Network Design to Reduce Environmental Impacts and Deal With Disruptions*. Research Square, doi.org/10.21203/rs.3.rs-1140812/v1.
65. Warmbier, P., Kinra, A. (2022, May). *Identifying common elements within supply chain resilience and sustainability-an exploratory study based on bibliographic analysis*. Proceedings of the 8th International Conference LDIC 2022, Dynamics in Logistics. Bremen, Germany. Cham: Springer International Publishing, pp. 65-81.
66. Warmbier, P., Kinra, A., Ivanov, D. (2022). Supply Chain Sustainability and Resilience-Relationship and Congruent Capability Analysis based on Paradox Theory. *IFAC-PapersOnLine, 55(10),* 311-316.
67. Wu, Hsin-Hung, Tsai, Ya-Ning (2012). An integrated approach of AHP and DEMATEL methods in evaluating the criteria of auto spare parts industry. *International Journal of Systems Science, 43(11),* 2114-2124, doi.org/10.1080/00207721.2011.564674.
68. Xiong, L., Zhong, S., Liu, S., Zhang, X., Li, Y. (2020). An approach for resilient-green supplier selection based on WASPAS, BWM, and TOPSIS under intuitionistic fuzzy sets. *Mathematical Problems in Engineering, Article ID 1761893*, 1-18, doi.org/10.1155/2020/1761893.
69. Yavari, M., Ajalli, P. (2021). Suppliers' coalition strategy for green-Resilient supply chain network design. *Journal of Industrial and Production Engineering, 38(3),* 197-212, doi.org/10.1080/21681015.2021.1883134.
70. Zahiri, B., Zhuang J., Mohammadi, M. (2017). Toward an integrated sustainable-resilient supply chain: A pharmaceutical case study. *Transportation Research, Part E, 103*, 109-142, doi.org/10.1016/j.tre.2017.04.009.