



## DISRUPTION OF CHEMICAL INDUSTRY SUPPLY CHAINS AND THEIR RESILIENCE: DATA ANALYSIS

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### Abstract

The issue of supply chain resilience is currently being raised in part because of the pandemic and the war between Ukraine and Russia, which have disrupted flows in the chemical supply chain. In the latest research available, one of the main options for strengthening supply chains is to shorten them. This could be reflected in the degree to which chains are used in the export and import of chemical industry products in Poland. There are scenarios that turn more towards the relocation of raw materials and recommend nearshoring and trading over shorter distances. This is important for the operation and management of the supply chain, as it would mean simpler and faster logistics operations. The purpose of the study is to analyze to what extent the crisis situations of recent years have affected the exchange of exports and imports of chemical industry products in Poland with selected countries. We used statistical methods based on time series analysis over the period 2017-2021. One of the conclusions of the study is that despite the crises, chemical supply chains have not shortened in terms of both value. It can be observed that in the post-pandemic period, there has been a change in the structure of chemical product supply chains. It remains an open question whether the changes in chemical supply chains are due to their changes in geographic location due to the disruption.

**Keywords:** SCM, chemical industry, resilience, pandemic COVID-19

### 1. INTRODUCTION

The area of supply chain (SC) resilience has gained prominence in recent years as a number of new threats, from climate change to cybersecurity and infectious diseases, have emerged as serious threats to operational efficiency in SC. In particular, the COVID-19 pandemic has exposed the fragility of global supply chains in many sectors [1], including chemical industry products. COVID-19 and the armed conflict between Ukraine and Russia is considered a significant risk event that severely affected chemical supply chains in Poland. Changes in supply by producers can be conceptualized as a recovery from the disruptions caused by the crisis. The purpose of the publication is to analyze the disruption of the chemical industry supply chain and analyze the construction of its resilience. On the other hand, the specialization of chemical industry products, the availability of resources and their price may make it impossible to shorten the chain in Poland. The purpose of the study is to analyze to what extent the crisis situations of recent years have affected the exchange of exports and imports of chemical industry products in Poland with selected countries. We used statistical methods based on time series analysis over the period 2017-2021.

Disruption occurs when the supply chain is broken or supplies are delayed. Decision-making for the recovery process is reactive to disruption (caused by events) and aims to resume company operations and cash flow as quickly as possible [2-6]. Supply Chain Resilience (SCR) is a concept with a practical focus on finding the best, most expedient solutions to problems that arise in supply chains. The term "resilience" refers to the ability to recover from a period of stress (destabilizing changes) [7]. SCR focuses on recovery, or how quickly and



effectively a system can return to normal. In supply chains, risk events have been categorized as macro including natural and man-made risks, and micro including risks related to demand, production, supply and infrastructure [8,9]. Resilience at each stage of supply chain execution is enhanced by one or more SCR factors. Resilience analysis in supply chain management (SCM) uniquely contributes to preparedness by creating resilience during the system design phase and preparing supply chains to respond to disruptions. These factors lose their effectiveness once a disruption occurs and they move into the response phase. At this point, information sharing, collaboration and agility are often the reinforcing factors that enhance resilience in the response phase, and must be initiated through the development of protocols and relationships in the preparedness phase [10,11]. The supply chain management information system requires that members of the supply chain or network work together. Typically, this collaboration starts at the level of two neighboring links, and other businesses are gradually involved. The maximum effect is achieved when all links are involved and the material flow can be optimized at the supply chain level. Determinants affecting the transformation of supply chains apply to each area of the business entity's operations. Starting from the closest surrounding of links in the supply chain, through social conditions, ending with the geopolitical situation of the world and globalization processes. The flow of information in supply chains plays a huge role in their efficiency, as well as the changes in it. Supply chain evaluation based [12] on joint planning and management offers the opportunity to dynamically adapt orders in individual organizations to the individual requirements [13], and thus can optimize lead times, including during the period of SC interruption.

Supply chain resilience is worth analyzing not only from the perspective of loss of capacity in general, but from the perspective of the value delivered to the end customer. This perspective makes it possible to assess the degree of supply chain [14] resilience in the context of supply chain performance. It allows you to assess the extent to which the occurrence of various types of situations and events affects the ability to create and delivery of value [15]. Achieving a high level of resilience by logistics systems, such as supply chains [16], requires taking certain measures to facilitate the strengthening of resilience. For the creation of transport models and the design of logistics concepts in sources from distribution and in relation to Covid-19, it is necessary to apply in detail not only the current situation in logistics, but also the essence and basic principles of logistics, logistics technologies, data structure and the current pandemic application of the state [17].

## 2. METHODOLOGY

This paper uses a qualitative research approach to identify chemical supply chain interruptions and supply chain attributes that affect supply chain resilience, and to develop an appropriate resilience framework in the context of the COVID-19 pandemic and future data analysis affected by military action between Ukraine and Russia. The analysis of statistical data allows the application of systems engineering attribute determination and summarizes key approaches to their chemical supply chain resilience drawn from the literature. The aim is to analyze the disruption of the chemical industry's supply chain and analyze the construction of its resilience.

A review of the literature reveals that analytical research on resilient supply chain is scattered. To date, a small segment of resilience issues have been addressed, with single models that address the requirements when a disruptive event hits a stable network. Therefore, the lack of adequate quantitative research on resilient supply chain leads to the construction of the following research questions, which further help in SCR design:

H1: How to absorb the phenomenon of chemical supply chain interruption?

H2: How is SCM interruption of chemical industry products identified?

H3: How can the value framework be controlled in the process of disrupting SCM of chemical industry products?

For the analysis, data for the period 2017-2021 of chemical imports and exports from selected countries were taken: Germany (due to the volume of imports and exports), China (due to distance and disruption of supply



chains during the pandemic period), and Belarus, Russia and Ukraine due to future in-depth data analysis. Time-Series analysis was used - data changing over time; data containing series (series) of values / quantities varying over time.

### 3. RESULTS

One-dimensional inference about the dynamics of the time variable is made solely on the basis of past and current observations. Table 1 shows the value of imports and exports in thousands euro in 2017 as a basis for analyzing changes in the chemical industry supply chain.

**Table 1** Imports and exports of chemical industry products for selected countries in 2017 (in thousand Euro) [18]

Area of analysis - country	Imports (in thousand Euro)	Exports (in thousand Euro)
Belarus	150,139	141,744
China	728,580	99,492
German	5,084,830	3,376,412
Russia	767,916	1,190,058
Ukraine	107,584	461,022

Germany is the largest import partner for Poland's chemical industry products. China and Russia are comparable in terms of the amount of imports. For exports, Germany remains the largest partner, followed in order by Russia and Ukraine. Poland exports the least amount of chemical industry products to China.

**Table 2** shows imports of chemical industry products in the period 2017-2021. The period 2017-2019 was assumed as the pre-pandemic period, the period 2020-2021 as the time of the SARs-CoV-2 pandemic. In addition, in the case of China, the pandemic and economic closure of the area already occurred in 2019. Data from 2017 was taken as 100 percent.

**Table 2** Import value index of chemical industry products by selected countries (Belarus, China, Germany, Russia, Ukraine) in 2017-2021 [18]

Area of analysis - country	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)
Belarus	100.00	123.75	127.08	90.11	128.53
China	100.00	125.73	149.51	177.64	272.11
German	100.00	100.09	101.71	103.69	125.99
Russia	100.00	106.23	114.94	86.06	131.09
Ukraine	100.00	162.98	139.86	116.45	165.14

In the case of Belarus, Russia and Ukraine, there was a disruption of supply chains, but in the later period (2021) and reconstruction. In the case of China and Germany, there was high supply chain resilience (SCR). Imports of chemical industry products from Poland to Belarus and Russia, if we compare to 2019, there is a decrease of nearly 30 percent.

**Table 3** shows exports of chemical industry products in the period 2017-2021. The period 2017-2019 was assumed as the pre-pandemic period, the period 2020-2021 as the time of the SARs-CoV-2 pandemic. In



addition, in the case of China, the pandemic and economic closure of the area already occurred in 2019. Data from 2017 was taken as 100 percent.

**Table 3** Value index of exports of chemical industry products by selected countries (Belarus, China, Germany, Russia, Ukraine) in 2017-2021 [18]

Area of analysis - country	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)
Belarus	100.00	107.64	130.57	127.04	128.73
China	100.00	77.77	105.56	122.12	159.53
German	100.00	107.09	119.92	131.31	165.08
Russia	100.00	96.33	110.62	95.57	97.73
Ukraine	100.00	121.86	137.17	138.73	170.80

In 2018, there was a disruption in the supply chains of chemical industry products from the Chinese and Ukrainian markets to achieve resilience in 2019. For stable markets such as Germany, the supply chain showed high resilience during the Covid-19 pandemic. Supply disruption in SCM was most pronounced with Russia, but without the projected increase with Belarus and Ukraine. High SCM reconstruction after the interruption occurs between Poland and China, Germany and Ukraine in 2021.

#### 4. CONCLUSION

The flagship enterprise of chemical industry products in the supply and distribution network should be characterized by differentiated processes implemented in the value-added stream (processes related to the management of inventory, organization of transportation processes, differentiation of processes in the area of deferred production, logistics and marketing information management, etc.). Resilient supply chains require the resilience of its individual components and subsystems, and the resilience of the entire supply chain is determined by the resilience of the weakest link. This is evident in the case of chemical supply chains with Belarus, Russia and Ukraine in procurement and distribution.

Supply chain resilience does not mean the ability to once to overcome difficulties resulting from the occurrence of unforeseen phenomena and events. Resilience should be understood in the context of a continuous process of anticipating threats to business continuity, or maintaining the supply of chemical industry products at its current operating capacity throughout the period. This means continuous improvement of processes, procedures and structures at all chemical industry companies and intermediate links in the supply chain. These activities should be subordinated to the results of the resilience audit, for its evaluation a value analysis was developed to improve their resilience.

The presence of threats to companies producing and importing and exporting chemical industry products in SCMs was analyzed in the period before and during the COVID-19 pandemic. Identification of SCMs in selected areas revealed disruption of supply chains and building of SCR resilience. Only with stable markets and short distances, as is the case between Poland and Germany, there has been no disruption, and it can be said that there has been strengthening in supply chains. It should be noted that in this case there was a shortening of supply chains. It can be concluded the larger the stream of products in the SCM the greater the resilience of the SCR to events.

The Synthesis of Resilience Analysis 2017-2021 is a concept designed to clarify the range of concepts from the literature in a more concise format using the example of SCM of chemical industry products. The nature of this combination is recommended as a value analysis of supply chains and SCR. The amplitudes of fluctuations for chemical exports and imports (resulting from the comparison of the actual values of the variable with the



theoretical values obtained from the model) are divided into absolute constants (in analogous phases of the cycle) and relative constants (the magnitudes of the amplitudes vary in approximately the same ratio).

By analyzing data thanks to IT systems equipped with an additional module for Supply Chain Analytics information management, you can obtain a comprehensive picture of interrupting the supply chain. Automatically generated alerts about potential threats (excessive dependence on one supplier, low safety stocks, delayed deliveries). Analyzing data regarding the performance of individual processes allows you to identify trends and possible problems based on the collected data.

The recommended steps for developing an effective chemical industry product disruption action plan are:

- analysis of the causes of interruption of the supply chain of chemical industry products and its possible consequences for the production, storage or transport of goods to the end customer,
- ordering the effects according to importance, and then the stored materials, raw materials and products of the chemical industry should be secured,
- consultations with other participants in the supply chain of chemical industry products - an effective plan cannot be limited only to the activities of one chemical industry enterprise, because in such a case it would not be possible to ensure full control of the product.
- cooperation with external entities – including: 3PL-10PL logistics operators who have an appropriate data management system and experience, with other participants in the supply chain of chemical industry products or relevant authorities and services.

Resistance to disruptions of the chemical industry sector may have an impact on economic security, which should be considered systemically, in an integrated manner, because only then can the synergistic effect with the expected reliability potential be analyzed.

The research should be continued on the basis of obtaining future data from the CSO in the period 2022-2023, that is, the occurrence of armed conflict between Ukraine and Russia. Deliberately, the publication chose countries like Belarus, Russia and Ukraine for analysis in order to assess SCR resilience in these areas.

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