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SUPPLY CHAIN REDESIGN FOR RESILIENCE – THE PERSPECTIVE OF THE CONSEQUENCES OF DISRUPTION

PRZEPROJEKTOWANIE ŁAŃCUCHA DOSTAW W CELU ZAPEWNIENIA ODPORNOŚCI – PERSPEKTYWA SKUTKÓW ZAKŁÓCENIA

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Summary: The purpose of this paper is to draw attention to the issue of "redesign" in the supply chain resilience concept as a way of dealing with the consequences of disruption. The article presents this issue in light of SCRES literature and survey results. The literature analysis allowed to identify key terminology (design, reconfiguration and redesign terms) and assign them to the specific phase of the disturbance. Additionally, the SCRES closed loop including five SCRES abilities is proposed. The newly added "ability to improve" is related to supply chain redesign in the post-disruption phase. As the survey results show, manufacturing companies take improvement actions to avoid similar disruptions in the future. For example, the researched enterprises "redesign a disrupted process's structure" the most often. The several hypotheses were confirmed. Additionally, the TBLR construct for the measuring the impact of the disruptions was confirmed.

Keywords: supply chain resilience, redesign, reconfiguration, disruption.

Streszczenie: Celem artykułu jest zwrócenie uwagi na zagadnienie przeprojektowywania i rekonfiguracji łańcucha dostaw w koncepcji SCRES (Supply Chain Resilience). Artykuł prezentuje wyniki analizy literatury przedmiotu oraz badania ankietowego. Zidentyfikowano terminologię kluczową w badanym obszarze oraz przypisano ją do specyficznych faz zakłócenia. Zaproponowano też zamknięty cykl SCRES z pięcioma zdolnościami (*abilities*) zapewniającymi odporność łańcucha dostaw. Dodano w nim nową „zdolność do doskonalenia", związaną z przeprojektowywaniem struktury i zasobów łańcucha dostaw w fazie po wystąpieniu zakłócenia. Wyniki badania ankietowego pokazują, że przedsiębiorstwa produkcyjne podejmują działania doskonalące w celu uniknięcia podobnych zakłóceń w przyszłości. Działanie polegające na przeprojektowywaniu struktury zakłóconego procesu realizowane jest najczęściej. W badaniu postawiono kilka hipotez. Opracowano też nowy konstrukt mierzący wpływ zakłócenia na łańcuch dostaw.

Słowa kluczowe: odporność łańcucha dostaw, projektowanie, rekonfiguracja, zakłócenie.

1. Introduction

In recent years, the supply chain resilience (SCRES) concept has developed intensively. It is a combination of the supply chain risk management concept (SCRM) and the business continuity management concept (BCM). Due to supply chain crisis situations caused by global uncertainty as well as internal operational risk, scientists and practitioners are paying more and more attention not only to prevention, but also to the appropriate actions taken during the occurrence of an adverse situation as well as after its expiry. The risk management concept is focused on threat anticipation and risk assessment. It also pays special attention to risk mitigation with the use of various methods, e.g. a reduction of probability and consequences. Among these methods, there is that of reacting to the emergency situations. This method is reflected in the business continuity management concept. BCM is also based on risk analysis. However, it mainly focuses on managing crisis situations where critical resources are lost. BCM provides tools such as business continuity plans launched in an emergency situation, as well as recovery plans launched when the crisis situation and the domino effect of disturbances stopped. After a disruption, especially for the risk management concept, it is crucial to draw conclusions, identify root causes, estimate losses and take measures to avoid similar problems in the future. One of the improvement actions is supply chain redesign. Unfortunately, there are still very few considerations on this subject. Most often the issue of dealing with crises ends when the recovery is completed, and yet it is crucial to improve the processes and structure of the supply chain. The aim of this article is to draw attention to the issue of supply chain redesign in SCRES literature and its presentation in light of the performed survey, and especially the different types of consequences of disruption.

This paper contributes to the literature in the following way:

- explores supply chain redesign issue in the literature on SCRES;
- identifies the terminology used in the literature (design, redesign, reconfiguration) in relation to individual phases of disturbance;
- draws attention to the issue of supply chain improvement after the occurrence of a disruption. It proposes to include "ability to improve" into the SCRES concept;
- presents the consequences of the most serious disturbances in supply chains and the construct that can be used to measure these consequences;
- presents how companies improve supply chains to avoid similar disruptions in the future;
- draws attention to the issue of redesign with regard to the emerging consequences of disturbances.

The article is structured as follows. Section 2 explains the methodology utilized to perform the systematic literature review as well as a survey. The findings on the redesign issue in the SCRES literature are presented and discussed in Section 3. Section 4 presents the results from the quantitative study. The final section refers to the theoretical and practical implications as well as its limitations and conclusions.

2. Research method

2.1. Systematic literature review

The research covered two research methods. The first part, based on desk research, used a literature review methodology applied following Tranfield, Denyer and Smart [2003]. The review process consisted of the following phases: question formulation, keyword search in databases, screening (removing duplicates, closer inspection, checking cited articles) and analysis of articles. First, the main research question, i.e. what is the role of redesign in building supply chain resilience, was constructed. In the second phase the author used five research databases, which are the EBSCOhost Online Research Databases, Emerald Insight, Scopus, Web of Science and the Wiley Online Library. They were chosen as they are the leading global providers of the top articles evaluated using the double-blind peer review policy. This ensured the highest quality of the literature research.

Three search terms and the following restrictions were used in the phase of the databases search:

- Search term: SYSTEMATIC LITERATURE REVIEW, restriction: occurrence in title AND
- Search term: SUPPLY CHAIN, restriction: occurrence in abstract AND
- Search term: RESILIENCE, a restriction: occurrence in abstract.

There was no restriction on the date of publication in order to identify as many articles presenting the results of a systematic literature review on SCRES as possible. However, only the results from academic journals were taken into account to ensure the highest level of quality of publications.

Table 1. The screening phase results

Phase description	Database	Output (number of papers)
First database search with the use of three search terms	EBSCOhost	9
	Emerald	9
	Scopus	13
	Web of Science	15
	Wiley Online Library	0
Screening 1: removing duplicates	EBSCOhost, Emerald, Scopus, Web of Science, Wiley Online Library	23
Screening 2: closer inspection (selecting articles that are strictly related to the supply chain resilience and refer to the design issue)	EBSCOhost, Emerald, Scopus, Web of Science, Wiley Online Library	14
Screening 3: checking cited articles on SLR	EBSCOhost, Emerald, Scopus, Web of Science, Wiley Online Library	14

Source: own study.

The research was conducted at the beginning of April 2019. For the final analysis, fourteen full papers were taken into account (Table 1), published between 2011 and March 2019. The detailed results of the desk research are presented in the third section of this article.

2.2. Survey

The key research was a survey conducted with the use of Computer Assisted Telephone Interview (CATI) method, which was chosen to ensure data availability. The selection of the sample in the study was deliberate. The researched enterprises were large manufacturing companies (employing 250 or more employees) from various industries carrying out production activity in Poland. The sampling used the database "500 List" of the "Rzeczpospolita" newspaper and was also supported by the Bisnode database. The large manufacturing companies from the "500 List" were chosen to ensure the assessment of the most mature companies' approaches to supply chain management and access to best practices. Data collection was supported by the CBM Indicator.

The study was preceded by a pilot on the n = 3 sample, aimed at checking the adequacy of the research tool and the quality level of the collected data. The questions were designed with the aim of needing to be simple and easy to answer. After the pilot test the final instrument was developed, with the number of researched companies reaching 202.

To ensure the reliability of answers, the respondents chosen were senior management with key competences in the field of supply chain management and knowledge of risk management. Additionally, the following restrictions were used:

- a minimum three years of job experience in the management of the supply chain in the current place of employment,
- in the last three years the occurrence of some disruptions of the business process in the company of the respondent.

In general, the survey referred to the most serious disruptions that occurred in the supply chain processes of the researched companies. The questionnaire was divided into three parts. The first part referred to the types of disrupted supply chain processes, sources of disruptions as well as the domino effect of supply chain disruptions [Wieteska 2018b]. The next part covered the issue of business impact analysis of supply chain disruptions [Wieteska 2018a]. The third part was related to the type of implemented supply chain adaptive response to similar disruptions that might occur in the future, and to the maturity of the companies' approach to the supply chain risk and business continuity management.

This paper presents selected results from the third part of the questionnaire and combines them with other results to answer the following questions:

1. How do companies redesign supply chains to avoid similar disruptions in the future?

2. How do companies redesign supply chains in light of the type of consequences?

3. (Re)design and re(configuration) in supply chain resilience concept

This section shows the issue of supply chain design in the SCRES literature. Each of the papers taken into account referred to this issue in a specific way. The articles are presented chronologically.

The first paper [Bhamra, Dani, Burnard 2011] draws attention to the fact that the resilience concept appeared in various fields of science, e.g. ecology and psychology. It provides several definitions of resilience referring also to their organizational context. The authors referred to the paper written by Ponomarov and Holcomb [2009], in which the following elements of supply chain resilience are identified:

- readiness and preparedness,
- response and adaption,
- recovery or adjustment.

The first listed elements refer to the situation from before the disruption. Such elements as adaption or adjustment concern the phase after the occurrence of the disturbance. They concern supply chain network and processes.

Roberta Pereira, Christopher and Lago Da Silva [2014] considered the role of procurement in building supply chain resilience. They recognized intra and inter-organizational issues related to this topic. Interestingly, there was an issue of supply chain design [configuration] and reengineering in the second group of issues. The authors underlined that strategic sourcing can determine reducing supply chain complexity, which is the most common barrier to the supply chain resilience.

Hohenstein et al. [2015] distinguished four supply chain resilience phases. Three of them are similar to these mentioned by Ponomarov and Holcomb [2009] and the last phase is new:

- readiness,
- response,
- recovery,
- growth.

Only readiness is related to the proactive strategy. The other phases, according to the authors, represent the reactive strategy which enables companies to cope and adapt to disruptions reactively. Among the elements of the post-disruption phase there are [Hohenstein et al. 2015]: agility, collaboration, flexibility, human resource management, redundancy. Agility is understood among others as quick supply chain redesign to minimize the negative consequences of disturbance [Blackhurst et al. 2011]. It determines "rapid system reconfiguration in the face of unforeseeable changes" [Bakshi, Kleindorfer 2009]. Conversely, based on the studied literature, Tukamuhabwa et al. [2015] indicate supply chain network structure/design as an important proactive strategy for building resilience. This approach shows that appropriate supply chain design can minimize the risk of unexpected disturbances in terms of both probability and/or consequences.

Chowdhury and Quaddus [2016] studied readiness, response and recovery for resilience. They argue that a resilient organization should be able to reconfigure its resources, which facilitates responding to disruptions and recovering from crisis situations.

Kamalahmadi and Parast [2016] pay attention to the need for supply chain reengineering following Christopher and Peck [2004]. They argue that "traditional supply chains need to be redesigned to integrate resiliency into their design". Papers on SLR usually provide key definitions. Kamalahmadi and Parast [2016] also list several definitions of SCRES. One of them mentions that SCRES is "the ability to proactively plan and design a supply chain network for anticipating unexpected disruptive [negative] events…" [Ponis, Koronis 2012]. Considerations in this publication present the previous research results on density and complexity of a system's structure. These two characteristics determine supply chain resiliency significantly [Craighead et al. 2007]. Furthermore, in the article [Kamalahmadi, Parast 2016] various SCRES strategies are identified following previous publications. For example, Melnyk et al. [2014] distinguished among others supply chain design strategy.

The literature analysis conducted by Ali et al. [2017] revealed 27 different elements of SCRES. Most often the researched studies referred to supply chain network design through configuration. This issue occurred in 38 publications. This was also confirmed by Shin and Park [2019]. Furthermore, SLR allowed to distinguished three strategies, adequate abilities and elements:

- Proactive strategy: ability to anticipate (elements: situation awareness, robustness, visibility, security, knowledge management in pre-disruption phase).
- Concurrent strategy: ability to adapt (elements: flexibility, redundancy), ability to respond (elements: collaboration, agility).
- Reactive strategy: ability to recover (elements: contingency planning, market position); ability to learn (knowledge management in post-disruption phase, building social capital).

In this approach, supply chain network design occurs as an anticipative practice carried out to achieve robustness. In turn, contingency planning includes such practices as supply chain reconfiguration (e.g. [Blackhurst et al. 2005]) and resource reconfiguration (e.g. [Ambulkar et al. 2015]).

Datta [2017] combines sources of risks (context of disruption) together with the appropriate interventions that are necessary to obtain the expected outcomes (e.g. competitiveness or growth). Among the interventions there is "understanding the supply chain" (e.g. geographical structure, supplier-buyer dependences), which involves preventive practices and reconfiguring the supply chain choosing the less vulnerable options. Here, the key decision regards the compromise between flexibility and redundancy.

The paper written by Karl [2018] reveals that supply chain design is one of the elements of "during disruption phase" and can be measured using such non-financial

KPIs as quality of delivered goods, order lead time and consumer satisfaction. The author underlines the role of real time re-designing in minimizing risk consequences (reducing or even avoiding).

Kochan and Nowicki [2018] show that there are various supply chain vulnerabilities. They divide them into three groups: external, internal and structural. Among the last group they point out such issues as supply chain structure, supplier chain design characteristics and supply chain complexity. Therefore, it can be assumed that an improper supply chain design may be a threat and strengthen the negative consequences of disruptions.

Bak [2018] recognized the "design continuum" appearing in the literature on supply chain resilience. The author lists the following aspects:

- designing supply chain risk loops;
- development of key risk management stages;
- new product development and co-design with suppliers;
- physical operations and systems design;
- supply chain density and complexity.

Stone [2018] paid attention to the issue of adaptive resilience. The author points out that "resilience is something that is cyclical and cumulatively developed by a continual process of adaptation and learning from ongoing disturbances", and that Stone, following other publications, presented an "adaptive cycle of system dynamics" that consists of four stages: exploitation, conservation, release and reorganisation. This approach is very important for improving the supply chain network and resources after a crisis situation.

Shin and Park [2019] asked the following research questions: "how can practitioners systematically identify and design SCRES improvement planning for a higher level of sustainability and a competitive advantage?". They indicated 24 capabilities that should be developed for achieving higher levels of supply chain resilience. Supply chain network design is one of the key SCRES elements.

Summing up, an in-depth analysis of SLR papers allows to form several conclusions:

- when considering supply chain network and resources the following terms appear: design, redesign, configuration and reconfiguration;
- design and configuration as well as redesign and reconfiguration are used as synonyms;
- in the pre-disruption phase, design or configuration is used. Configuration is used much less often. This phase refers to the risk anticipation;
- in the during-disruption phase, the reconfiguration term is usually used. It is related to structural flexibility and real time changes. The supply chain modifications are usually temporary;
- in the case of the post-disruption phase, the supply chain improvement issue is not sufficiently explored.

Based on the literature analysis, it is recommended to use the mentioned terms in a certain way (Figure 1).

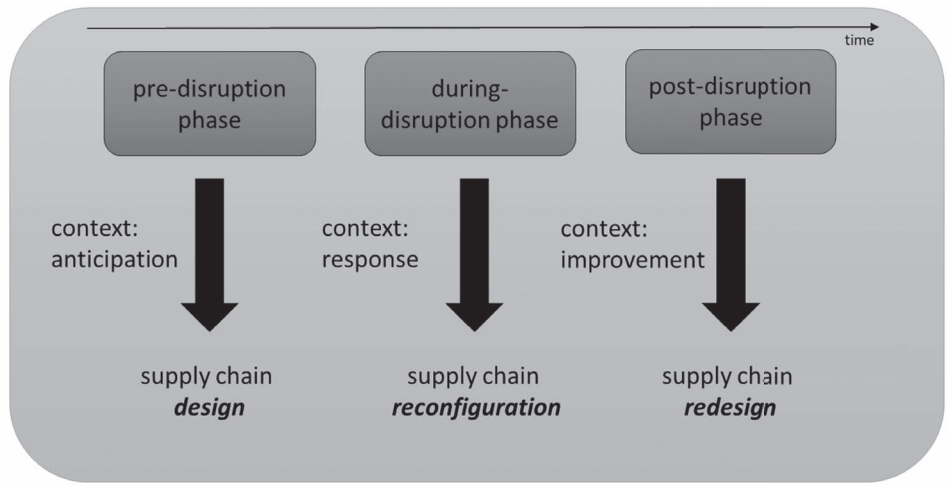

Fig. 1. Supply chain design, reconfiguration and redesign in three disruption phases

Source: own study.

For future research, it is important to apply the terms "design", "reconfiguration" and "redesign" appropriately to the three main phases of disruption: pre-disruption, during-disruption, post-disruption.

The following conclusions refer to the these recommendations:

- Ali et al. [2017] pay attention to ability to learn (knowledge management in post--disruption phase, building social capital), yet little attention is devoted to this in the SCRES concept. During the risk management process it is important to identify the root causes and evaluate losses of disruptions. It is advised to include these practices in ability to learn more clearly.
- After a disruption it is crucial to take proper actions to avoid similar problems in the future. The issue of supply chain reengineering appears in the literature [Christopher, Peck 2004, Kamalahmadi, Parast 2016]. Nevertheless, the need for taking improvement actions in the post-disruption phase is still neglected in the SCRES concept. Therefore it is recommended to apply the ability to improve for the post-disruption phase (Figure 2) with the following practices: redesign the disrupted process's structure, redesign the disrupted process's resources, redesign other processes' structure or resources, redesign the supply chain structure, redesign the resources of other supply chain links. As the results of the conducted survey show, companies take such improvement actions towards supply chain processes and network.

Figure 2 presents a circle of five different SCRES abilities in three different disruption phases. Ability to anticipate is required in the pre-disruption phase (proactive strategy). Ability to respond refers to the during-disruption phase

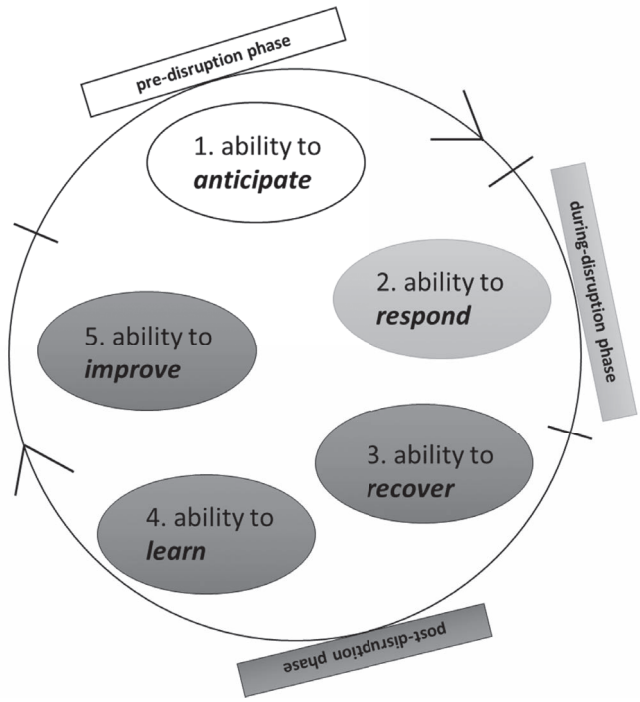

Fig. 2. Supply chain design, reconfiguration and redesign in three disruption phases

Source: own study.

(concurrent strategy). The last three abilities should be developed in the post-disruption phase (reactive strategy).

4. Survey findings

4.1. Consequences of supply chain disruptions

In the questionnaire, several types of disruption consequences were listed. First of all, the triple bottom line (TBL) consequences were distinguished: financial consequences, environmental consequences and social consequences. Next, following ISO/DTS 22317:2015, the reputational consequences and negative impact on achievement of the process's objective were included. Finally, the duration of interruption was taken into account according to the guide of The Business Continuity Institute [2008b, pp. 4-7]. To measure the consequences of disruptions, the six-point Likert scale was used. The descriptive statistics of the consequences for the most serious disruptions recognized by researched companies are presented in Table 2.

Table 2. Consequences of supply chain disruptions - descriptive statistics

Consequence type	Symbol	Average level
Financial consequences (1-6; 1 – none, 2 – very low, 6 – very high)	M	**3.33**
	Me	3.00
	Σ	1.20
	Max	6.00
	Min	1.00
Environmental consequences (1-6; 1 – none, 2 – very low, 6 – very high)	M	**1.36**
	Me	1.00
	Σ	0.88
	Max	6.00
	Min	1.00
Social consequences (1-6; 1 – none, 2 – very low, 6 – very high)	M	**1.37**
	Me	1.00
	Σ	0.90
	Max	5.00
	Min	1.00
Reputational consequences (1-6; 1 – none, 2 – very low, 6 – very high)	M	**1.99**
	Me	1.50
	Σ	1.33
	Max	6.00
	Min	1.00
Duration of interruption (0-5; 0 – no break in process, 1 – very short, 5 – very long)	M	**1.00**
	Me	1.00
	Σ	1.11
	Max	5.00
	Min	0.00
Negative impact on the achievement of the process's objective (1-6; 1 – none, 2 – very low, 6 – very high)	M	**2.68**
	Me	2.36
	Σ	1.20
	Max	6.00
	Min	1.00

Source: own study.

The financial consequences of the disruptions reached the highest level (3.33). The environmental and social consequences are definitely lower. Additionally, in the case of the social impact, 'very high' (level six) consequences did not appear for any

supply chain disruption. Interestingly, the reputational consequences are higher than the environmental and the social one.

When considering the general size of the consequences, it can be noted that usually they were not catastrophic. The highest size (level six) of TBL consequences always referred to the financial consequences, except for one case concerning the reputational consequences. Interestingly, two disruptions with a very long duration of interruption (level 5) were not connected with the highest TBL consequences. On the contrary, they were associated with the negative effect on the 1 to 3 level. The negative impact on the achievement of the process's objective occurred with the highest level three times and once with the catastrophic (level six) financial and reputational consequences.

Based on the above considerations, several hypotheses were put (Table 4). Table 3 displays the Spearman's rank correlation between all the presented variables measured using the Likert scale, and shows, as expected, correlations between the most dependent variables. All the variables are significantly and positively correlated. This allowed to fully confirm most of the hypotheses.

Table 3. Spearman's rank correlation

	Financial consequences	Environmental consequences	Social consequences	Reputational consequences	Duration of interruption	Negative impact on achievement of the process's objective
Financial consequences	1.00	0.20	0.19	**0.37**	**0.31**	0.19
Environmental consequences	0.20	1.00	**0.44**	**0.33**	0.21	**0.02**
Social consequences	0.19	**0.44**	1.00	0.22	0.27	0.18
Reputational consequences	**0.37**	**0.33**	0.22	1.00	**0.40**	0.17
Duration of interruption	0.31	0.21	0.27	**0.40**	1.00	0.30
Negative impact on achievement of the process's objective	0.19	**0.02**	0.18	0.17	0.30	1.00

Source: own study.

Considering the strength of correlations using Guilford's classification [Guilford 1982], the highest one appears between:

- environmental consequences and social consequences (0.44);
- reputational consequences and duration of interruption (0.40);
- financial consequences and reputational consequences (0.37);
- environmental consequences and reputational consequences (0.33);
- duration of interruption and financial consequences (0.31);

where: $|r| = 0$ – no correlation,
$0.0 < |r| \leq 0.1$ – very weak correlation,
$0.1 < |r| \leq 0.3$ – weak correlation,
$0.3 < |r| \leq 0.5$ – average correlation,
$0.5 < |r| \leq 0.7$ – high correlation,
$0.7 < |r| \leq 0.9$ – very high correlation,
$0.9 < |r| < 1.0$ – almost full correlation,
$|r| = 1$ – full correlation.

Table 4. Hypotheses

	Hypothesis	Comment
H1	Greater financial, environmental and social consequences are associated with greater reputational consequences	confirmed
H2	Greater financial and environmental consequences are associated with greater social consequences	confirmed
H3	Greater financial consequences are associated with greater environmental consequences	confirmed
H4	Greater consequences (financial, reputational, environmental and social consequences) of supply chain disruptions are associated with a longer duration of interruption	confirmed
H5	Greater consequences of supply chain disruptions are associated with a greater negative impact on the achievement of the processes' objectives	partially confirmed (not in the case of environmental consequences)
H6	Greater negative impact on the achievement of the processes' objectives is associated with greater duration of interruption	confirmed

Source: own study.

From the four questions on the type of consequences (Table 2), one multivariable has been constructed. Its reliability coefficient is 0.6411 (Table 5). The reliability analysis allowed to confirm the reliability of the new construct. Confirmatory factor analysis allowed to verify the homogeneity of the built construct TBLR (triple bottom line and reputation).

It is required that the studied scales have Cronbach's alpha coefficient higher than 0,7. This condition is called the Nunnally criterion [Nunnally, Bernstein 1994 pp. 145-164, Bowling, 2002 p. 49]. It is also required that removing variables from the scale would cause a decrease in the value of the Cronbach's alpha coefficient

(Table 6). In this case, the value is lower than 0.7 but higher than 0.6. It is assumed that for new constructs, 0.6 is a minimal value [Cronbach 1951 in: Brzeziński 2005, pp. 177-212].

Table 5. Factor loading

Variable	Factor loading	Cronbach's alpha when variable is removed	Item reliability
Financial consequences	0.6931	0.56	**0.6411**
Environmental consequences	0.6184	0.62	
Social consequences	0.7129	0.57	
Reputational consequences	0.7595	0.52	

Source: own study.

In view of the above it was decided to classify companies into homogeneous groups due to the designated measure. The total construct variability interval was divided into three class intervals to which individual test units were assigned according to the formula [Łogwiniuk 2011, pp. 7-23]:

- high level: $z_i \in \left\langle \max_i z_i ; \max_i z_i - h \right)$
- average level: $z_i \in \left\langle \max_i z_i - h; \max_i z_i - 2h \right)$
- low level: $z_i \in \left\langle \max_i z_i - 2h; \min_i z_i \right\rangle$

The span of class intervals is based on the constant h determined by the formula:

$$h = \frac{\max_i z_i - \min_i z_i}{3} \text{ for i = 1 ... } n.$$

Table 6. The classification of the consequences in the construct

	Min	max	Number of companies	% of companies
I high level	3.17	4.25	19	9.41%
II average level	2.08	3.17	48	23.76%
III low level	1	2.08	135	66.83%

Source: own study.

According to the results (Table 6), 66.83% companies assess the level of all consequences as low, 23.76% as average and 9.41% as high.

4.2. Supply chain redesign in light of the consequences of disruptions

After a disruption, a company should implement adequate changes to avoid similar problems in the future. In the study, 14.36% enterprises implemented no improvement, both in resources or the structure of the supply chain processes. However, the rest of the companies decided to learn from the disruption and to adapt the company through (Table 7):

- redesigning disrupted process's structure and/or
- redesigning disrupted process's resources and/or
- redesigning other processes' structure or resources and/or
- redesigning the supply chain structure and/or
- redesigning resources of other supply chain links.

In the questionnaire the respondents could mark any number of changes made after the disturbance to avoid similar problems in the future.

Table 7. Redesign changes after disruptions

Type of adaptive change	Percentage of answers
Redesign the disrupted process's structure	**68.79%**
Redesign the disrupted process's resources	55.49%
Redesign other processes' structure or resources	48.55%
Redesign the supply chain structure	47.98%
Redesign resources of other supply chain links	28.90%

Source: own study.

To avoid similar disruptions in the future, most often the researched companies redesigned the structure (68.79%) or resources (55.49%) of the disrupted process. Almost half of the studied manufacturers decided to change the structure or resources of other processes. Similarly, 47.98% of them improved the supply chain structure (47.98%). Almost 30% of the adaptive changes were related to redesigning the resources of other supply chain links.

Table 8 presents what redesign changes were made regarding the size of the disruptions' consequences.

In general, the collected data show the lack of very distinctive situations. However, some detailed observations can be made. Mainly, it can be seen that the "redesign other processes' structure or resources" is usually used for the strongest financial, environmental, social and reputational consequences as well for the longest duration of interruptions. In turn, the "redesign supply chain structure" is applied to the strongest negative impact on the achievement of the process's objective.

In the survey the respondents were also asked about:

- the size of the change (1 – very small; 5 – very big, radical) and
- the effectiveness of the change (1 – none, 2 – very small; 6 – very big).

Table 8. The level of the effects of the disturbances and the type of applied redesign change

	Financial consequences	Environmental consequences	Social consequences	Reputational consequences	Duration of interruption	Negative impact on achievement of the process's objective
Redesigning disrupted process's structure	3.24	1.26	1.32	1.92	2.46	2.67
Redesigning disrupted process's resources	3.26	1.25	1.29	1.92	2.47	2.64
Redesigning other processes' structure or resources	**3.44**	**1.29**	**1.37**	**2.06**	**2.48**	2.77
Redesigning supply chain structure	3.24	1.29	1.35	2.00	2.36	**2.99**
Redesigning resources of other supply chain links	3.12	1.24	1.32	1.74	2.34	2.70

Source: own study.

The results show that the respondents assessed the size of the introduced changes at an average level of 2.64. At the same time, they recognized that these changes were rather effective (4.34).

5. Conclusions

The design issue appears in practically every article about SLR on SCRES. However, it is still not well researched. This article presented the first attempt to describe this practice and also to determine the terminology in this unexplored area (Figure 1).

The presented calculations allowed to confirm a number of hypotheses indicating the relations between various types of consequences of disruptions. The TBLR construct (Table 5) built for the impact of the most serious disturbances is also confirmed. Apart from the social, environmental and financial dimensions of effects, it is also worthwhile to assess the reputational consequences which sometimes outweigh the others. This is especially so in the case of a long-term interruption in operation. The surveyed companies had to indicate the most serious disturbances, but

according to the results they usually were not disastrous. This means that the supply chains of large manufacturing companies operating in Poland are characterized by rather good resilience or that the business environment in Poland is relatively stable. For most situations the duration of interruption was very short. However, one of the disruptions lasted for 365 days. These data were removed while clearing the data for the reasons of distortion.

As the results of the survey show, companies try not only to rebuild, but also to improve both resources and the structure of the disrupted processes and supply chains. Therefore, it is suggested to add "ability to improve" to the key SCRES abilities (Figure 2).

It should be noted that the trend of introducing adaptive changes concerns not only supply chains, but also the public sector. Cities and regions are increasingly paying attention to the problem of adaptation to climate change [Wieteska-Rosiak 2017]. Choosing a safe location is of particular importance when designing and redesigning the supply chain structure and resources.

The article provides both implications for both theory and practice. In the case of theoretical implications, it explores the terminology related to the supply chain (re)design and (re)configuration, provides SCRES closed loop and presents a new TBLR construct. Practitioners may first of all use the research results to increase the knowledge of building resilient supply chains and the necessary SCRES abilities. Future research should take a closer look at the consequence-reconfiguration-redesign relation. None of the analysed SCRES articles mention this. The article draws attention to this issue, however the topic still requires in-depth studies.

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