International Journal for Quality Research 16(4) 973–1000
ISSN 1800-6450

Grazyna Kędzia
Iwona Staniec[1]

Article info:
Received 04.11.2020.
Accepted 17.08.2022.

UDC – 364-781.1
DOI – 10.24874/IJQR16.04-01

THE IMPACT OF SUPPLIER INVOLVEMENT IN PRODUCT DEVELOPMENT ON SUPPLY CHAIN RESILIENCE: THE MEDIATING ROLE OF COMMUNICATION

Abstract: *This article examines the role of communication during supplier involvement for building supply chain resilience. Based on the construal level theory, our model proposes the influence of supplier involvement in product development on supply chain resilience and, in turn, on company performance through the mediating effect of communication.The results of the empirical analysis, a computer-assisted telephone interviewing (CATI) method conducted on 500 manufacturing companies operating in Poland, confirm the mediating role of communication. The authors used the mediation effect, because the research aim was to recognize the mediating role of communication, and not it's another impact at different levels, which is assumed by the moderation effect. To demonstrate the mediation effect, the structural equation model was used. This research extends the literature on supplier involvement in product development by examining how communication during supplier involvement can impact supply chain resilience and company performance. It also contributes to the construal level theory by suggesting a new antecedent of communication. The research shows that the best practices performed under the supplier involvement in product development increase supply chain resilience only when the proper supplier-buyer communication occurs. We explain the specific influence of collaborative activities on supply chain resilience from the perspective of supplier involvement.*

Keywords: *Supplier involvement; Product development; Resilience; Communications; Supply chain disruptions*

1. Introduction

Supplier involvement in product development (SIPD) has been the subject of research for many years. Previous studies have looked at various aspects, though they were primarily focused on how integrating suppliers into the customer's R&D affects new product development (NPD). Researchers have explored the impact of supplier involvement on the general outcomes of NPD projects (Ragatz et al., 2002; Ye et al., 2018), on time (Danese & Filippini 2010; Langerak & Hultink 2008), costs (Feng & Wang, 2013; Yu et al. 2019), and design quality (Petersen et al., 2005). One of the most frequently studied issues is communication in the

[1] Corresponding author: Iwona Staniec
Email: iwona.staniec2p.lodz.pl

supplier–customer relationship during the product development process. It has been observed that intensive and frequent communication (e.g. a large volume of information/knowledge is exchanged) has a positive impact on SIPD results, mainly by increasing the technical quality of developed products, reducing development costs (Takeishi, 2001) and development time (Langerak & Hultink 2008; Najafi et al. 2013; Ragatz et al. 2002). However, there is a lack of research on how the communication during supplier involvement in product development influences firm's operational performance during regular production, including net profit or sales growth.

The research problem is that in the literature, not many publications have also presented studies on the relationship between supplier involvement in product development and supply chain risk or resilience, and if, they are qualitative one. The motivation of this study is to take an attempt to fill this gap by presenting the statistical relations between SIPD and supply chain resilience (SCRES). Khan et al. (2008) in the qualitative research, considered linking product design, supply chain operational performance, and risk management. They explained that joint product development is a chance for effective supply chain risk mitigation. A case study on Boeing revealed the importance of product development activities for designing supply chains that are less vulnerable to disruptions. Tang et al. (2009), based on case study, advised that supply chain risks should be managed as early as in the design stage of the product, whereas Tang and Nurmaya (2011) listed early supplier involvement as the one qualitative solution to product and process design risk, production capacity risk and operational disruption. Finally, Melnyk et al. (2014) based on Boeing's experiences, pointed out that resilience is determined by the stage of product and supply chain design.

The 2001 terrorist attacks became the key starting point for intensive research into security in global supply chains (Closs & McGarrell, 2004). Since then, risk and business continuity issues have become the topics of thousands of scientific publications (Gibb & Buchanan, 2006; Jüttner et al., 2003; C. S. Tang, 2006; Zsidisin et al., 2005; Julia Acevedo-Urquiaga et al., 2021). A few years later, the world was hit by the financial crisis, which revealed strong dependencies in supplier–customer relationships confirming the reality of the butterfly effect and the domino effect (Bação et al., 2012; Choi & Douady, 2012; Giunipero & Eltantawy, 2004; Jüttner & Maklan, 2011; Kambil & Mahidhar, 2005). Since then, the research on supply chain risk management (SCRM) has intensified and become a subject of interest of supply chain specialists and managers (Blome & Schoenherr, 2011; Y. Fan & Stevenson, 2018; Ho et al., 2015; Manuj & Mentzer, 2008; Pfohl et al., 2010; Torabi et al., 2016). In the last decade, the global economic situation has started to stabilise. However, at the turn of 2019 and 2020, the COVID-19 epidemic began, which showed that managers cannot neglect to anticipate the continuity risk even when they enjoy optimistic sales forecasts. The infectious disease caused by this coronavirus revealed an urgent need to look at contemporary global supply chains. Their feature is increased sensitivity to disruptions, what generates an increased level of risk. One of the lessons that emerge very clearly from global crises is that disruptions are less severe in resilient supply chains.

Over the past 20 years, the new concept supply chain resilience (SCRES) appeared that sets the framework for anticipating risk, responding to disruption, and recovering after crisis situations (Ali et al., 2017; Tukamuhabwa et al., 2015). According to the international standard (IS0 31000:2018, 2018), risk is the 'effect of uncertainty on objectives'. It can be defined as the combination of the probability of an event and its consequences (ISO/IEC Guide 73). Business objectives may be not achieved because of the appearance of adverse events. Risk impacts the strategic and operational performance of a company by affecting value creation or preservation (COSO, 2004). In the event of a disruption, companies should be able to perform value-adding processes at least at the minimum required level. To minimise the consequences of acute shocks, it is recommended that business continuity plans be implemented (Lam, 2002; Zsidisin et al., 2005).

SCRES consists of many different abilities. One of them is flexibility (Hohenstein et al. 2015). It is defined as 'ability to respond quickly and efficiently to changing customer and consumer demands'(CSCMP, 2013). There are four main types of flexibility in relationship with suppliers: product, volume, time, and mix flexibility (Fantazy et al., 2009). This epidemic has shown that they have become crucial in responding to the crisis successfully and their main source is close cooperation with suppliers in the area of product development and manufacturing, based on effective information exchange. Some companies had to meet demand that was several times higher (e.g. manufacturers of protective masks or logistics companies offering courier services), while others in turn suffered from a drastic decrease in demand (e.g. clothing manufacturers, restaurants, and hotels). Further, the global crisis has shown that the ability to start manufacturing different products is an opportunity to keep jobs and financial liquidity during crisis time. For example, automotive companies have started producing respirators and oil industry corporations or breweries have started producing disinfectants. Communication is one of the key enabling factors for joint product development (Lee & Wang, 2012; Sjoerdsma & van Weele, 2015). Another experience from the epidemic is that maintaining continuity of supply chain processes is possible mainly thanks to well-developed supplier-buyer communication. For example, remote work and videoconferences via Zoom or Skype, have become indispensable tools in times when people are unable to work at the company's location or use passenger transport.

The ways supply chains have been observed to react to the epidemic and the important role of communication in the effective response to global disruption have prompted researchers to consider how supplier involvement, and especially supplier–customer communication during product development, impacts supply chain resilience. This article is designed to meet this contemporary challenge.

The main objective of this article is to examine the role of communication during supplier involvement for building supply chain resilience. The manuscript makes three specific contributions to the literature. First, it develops a theoretical model on SIPD, communication, and resilience. Then, it verifies the proposed model with the use of several statistical methods. The empirical data were collected in a survey of 500 manufacturing companies and were the input to the structural equation modelling, which is the main method used in the research. Finally, based on the observations, it forms several conclusions that contribute to theory and practice.

A dynamic capability approach can be used to address the considerations on supplier involvement in product development and building supply chain resilience. It is defined as 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments' (Pereira et al., 2014; Teece et al., 1997). This study also follows the resource-based view (RBV), as it has become a complementary element in studies focusing on both SIPD and supply chain resilience. RBV is the most commonly used theory in articles presenting the issue of risk and resilience (Tukamuhabwa et al., 2015). It is also the accepted approach in research on supplier involvement in product development (Carr et al., 2008; Luo et al., 2010; Menguc et al., 2013).

The following section of the article describes the theoretical background of the study, including the theoretical model and the hypothesis. Section 3 presents the methodology which was used. The results are presented in Section 4 of the paper, whereas the discussion on the findings is conducted in Section 5. The final section of the paper provides conclusions with implications.

2. Theoretical background

2.1. Supplier involvement in product development

SIPD describes a situation in which a customer integrates a supplier within their R&D area, especially in designing new products or redesigning the customer's existing products (Carr et al., 2008). This practice entails giving the supplier some responsibility in the NPD process (Chien & Chen, 2010). The degree of involvement depends on various factors, e.g. the item's complexity or the supplier's impact on the design and specifications (Kamath & Liker, 1994; Petersen et al., 2005). One of the latest definitions for SIPD calls it 'a process of managing the involvement of suppliers in the development of (new) products/services/processes/technologies for the chosen category' (Luzzini et al., 2015). The supplier can be included at any stage of the process (Handfield et al., 1999). A particularly common situation is the inclusion of a partner at the initial stages of NPD, and even while generating ideas. Early supplier involvement (ESI) allows product design, process design, and supply chain design to be linked together (Petersen et al., 2005) through joint strategic planning and supply and demand planning or continuous improvement projects (Kähkönen et al., 2015). Thus, it is also considered to be the source of the greatest benefits for the customer. SIPD requires a mature decision regarding the stage of inclusion of the supplier and the responsibility transferred to the partner. Therefore, it is particularly important to properly select the supplier (Büyüközkan & Görener, 2015; Hoegl & Wagner, 2005; Wagner & Hoegl, 2006). As SIPD is based on close cooperation, one of the most significant aspects is the strategic fit, expressed in the alignment of goals or the similarity of the business culture, for example (Hong et al., 2011; Ragatz et al., 2002; Spina et al., 2002). Some authors also highlight the role of mutual commitment and trust (Parker et al., 2008). A supplier–customer partnership during product development entails communication and sharing information (Jayaram, 2008), knowledge sharing (Le Dain & Merminod, 2014), and sharing other intellectual, physical, and human assets (Ragatz et al., 1997) as well as external integration (Parker et al., 2008). Thus, effective SIPD involves cross-functional teams, co-location and stimulating partners (Bozdogan et al., 1998). Fan et al. (2000) highlighted the role of supplier development, among other things, for NPD performance.

2.2. Communication during supplier involvement

During cooperation on product development, processes, and supply chains, different methods and communication channels are used. Especially in the case of ESI, they are implemented very early, which provides for excellent information exchange at various levels of management (McIvor et al., 2006; Najafi et al., 2013). Cicmil and Marshall (2005) presented conditions of communication flow as factors, that increase mutual trust, allow building relations between them, as well as increase faith in the adequacy of activities and common competences. Mature communication has been an important topic of previous studies. First of all, it has been suggested to develop internal integration, which supports communication between company departments and enhances concurrent development (Dowlatshahi, 1997; Parker et al., 2008). Secondly, supplier involvement requires external integration (Johnson & Filippini, 2009), which is related to communication between the supplier and the customer. According to Littler et al. (1995), frequent communication is one of the factors of SIPD success. Ragatz et al. (2002) advised that suppliers' employees be included in the NPD team, cooperate with the supplier in the same location, and communicate with the partner frequently. Hoegl& Wagner (2005) considered the frequency and intensity of communication between members of the two organisations. In turn, Takeishi (2001) observed several benefits of frequent communication and direct contact, mutual visits, and conversations between partners' employees in the construction, sales, and production departments. Companies use various methods of communication, mainly including traditional methods such as the telephone and face-to-face meetings, but they also use Internet for emails and teleconferences/videoconferences (Birou & Fawcett, 1994; Culley et al., 1999; Hartley et al., 1997). Along with the development of ICT, companies are using more and more advanced communication methods in NPD, such as EDI (McIvor & Humphreys, 2004) or customised software (Huang & Mak, 2003; D. Tang et al., 2004). In turn, Chuang and O'Grady (2001) observed the benefits of using e-commerce technology in the NPD process. To sum up, communication is described by many features that determine its maturity, scope, and effectiveness. In this study, these characteristics were combined into a wide term, which is 'communication during supplier involvement' (CSI).

2.3. Suppy chain resilience

Supply chain resilience (SCRES) is a very broad approach that has developed over the past two decades, combining the issue of proactive risk management and the preparation for and response to disturbances. Many articles have appeared on this topic, so some authors decided to carry out a systematic review of the literature. In this way they provided a comprehensive framework for this concept. One of the newest definitions explains that supply chain resilience is

"the ability to proactively plan and design a supply chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favourable than the one prior to the event, thus gaining competitive advantage. (Ponis & Koronis, 2012)".

Generally, SCRES refers to the three phases of disruption: pre-disruption (readiness), during-disruption (responsiveness), and post-disruption (recovery and growth) (Ali et al., 2017; Tukamuhabwa et al., 2015). Each phase requires the implementation of appropriate proactive, concurrent, or reactive strategies (Ali et al., 2017). The implementation of these strategies is possible thanks to a number of elements. Hohenstein et al. (2015) identified key elements of SCRES and ordered them for each phase according to the most frequently mentioned in the literature on the subject. Among the recognised elements, 'flexibility' was the first for each phase. Other elements are as follows: redundancy, agility, collaboration, information sharing, and capacity. Lima et al. (2018) called these elements enabling factors and added information security, trust, sensing, supply chain risk culture, leadership, innovation (understood as 'reach[ing] beyond the organisation's boundaries and striv[ing] to continuously transform knowledge and ideas into new products'), and reengineering. In turn, Kochan & Nowicki (2018) considered SCRES according to context-interventions-mechanisms-outcomes (CIMO) logic. A resourced-based theory is mentioned as the most common mechanism used to explain SCRES in previous studies. It was explained that it 'provides a basis to explore relationships among specific resources, capabilities, and performance' in the SCRES literature (Kochan & Nowicki, 2018).

2.4. Development of the theoretical model and hypotheses

Based on the literature presenting both quantitative and qualitative studies, a theoretical model (Figure 1) is proposed to evaluate the importance of communication during supplier involvement for building supply chain resilience. The three individual relationships are expressed in the form of hypotheses, the justification of which is presented in figure 1.

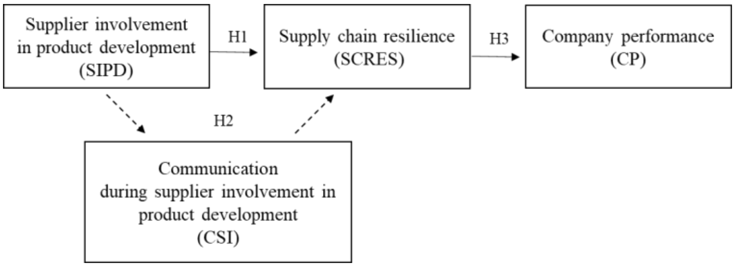

Figure 1. Theoretical model

2.4.1. The relationship between supplier involvement in product development (SIPD) and supply chain resilience (SCRES)

Supplier involvement in product development allows for more effective achievement of NPD goals in the form of shorter product development time, lower product launch costs, and better product quality and compliance (Handfield et al., 1999; Mikkola & Skjoett-Larsen, 2003; Ragatz et al., 1997). It can be assumed, that such effects are enabled by reducing the general risk that occurs when designing products, processes, and supply chains.

The main source of joint product development benefits are some specific practices. Firstly, cross-functional coordination and internal integration have a positive impact on NPD performance (Chien & Chen, 2010; Feng & Wang, 2013). Next, technology and cost information sharing during product development determine the overall satisfaction of partners with achieving the NPD objectives (Petersen et al., 2003). Finally, buyer–supplier collaboration based on trust, commitment, and mutual training is a desirable supply chain practice (Hoegl & Wagner, 2005). Above all, SIPD may improve the processes of both partners (Carr et al., 2008; Flynn et al., 2010; Najafi et al., 2013; Von Haartman & Bengtsson, 2015), such as procurement or manufacturing (Dowlatshahi, 1998; Jiao et al., 2008). Thus, according to the qualitative research, the supplier involvement in product development may be considered as a way to avoid or minimise various risks related to the supply chain (Smeltzer & Siferd, 1998; C. S. Tang et al., 2009; Zsidisin & Smith, 2005). These can be, e.g. human risks (e.g. errors) or system failures (e.g. production machines, IT), which are listed as one of the main types of operational risk ("Directive 2009/138/EC," 2009). Interestingly, one of the three pillars of SCRES is risk anticipation aimed at reducing the likelihood of adverse events.

Further, the company's decision on SIPD is based on multi-faceted assessment criteria such as the product and process knowledge, production system quality, and capabilities or financial situation of the supplier (Büyüközkan & Görener, 2015; Handfield et al., 1999). This allows the customer to increase their confidence in choosing a reliable partner and to avoid some supply risk. Simultaneously, the supplier proximity is also important for the success of cooperation (Birou & Fawcett, 1994; Wagner & Hoegl, 2006). Mainly, a local supplier increases the chances of an agile response to environmental uncertainty. This enhances flexibility, which is the main element of SCRES, especially of concurrent strategies (Hohenstein et al. 2015).

It can be noted that some items used in SIPD construct thematically overlap with the SCRES factors. For example, collaboration understood as cooperation, joint-decision making, and knowledge sharing, is regarded as a key element of both proactive and reactive resilient strategies (Hohenstein et al. 2015). Similarly, improving suppliers' effectiveness through various incentives (e.g. education) is pointed to as one strategy that mitigates supply chain disruptions (C. S. Tang, 2006).

In the light of the above considerations, the following hypothesis was built:

H1: There is a statistically significant direct effect of SIPD on SCRES.

2.4.2. The relationship between communication during supplier involvement (CSI) and supply chain resilience (SCRES)

Supply chain resilience (SCRES) is based on preventive actions as well as prepared and active responses to disruptions. In both cases communication plays a fundamental role. Supply chain risk management aimed at anticipation and risk analysis requires not only internal interactions (between employees of a single company), but also external interactions (between the company, its suppliers, and clients) (Waters, 2007, p. 86; Zeng & Yen, 2017). Thus, supply chain risk management is strengthened by effective business-to-business and business-to-government information sharing (G. Li et al., 2015). Communication with learning is the centre of risk management (Keegan, 2004, p. 13). For example, according to FERMA's guidelines, communication is important, especially for identifying and reporting risk ("FERMA," 2003). Also, reacting to disruptions is facilitated by effective communication in the supply chain. Multiple communication channels, and especially online environment support managing crisis at its every stage (Coombs, 2010). In particular, new technologies should be used to improve communication in crisis management (Sheffi, 2001). Steelman and McCaffrey (2013) point out that communication before and during a crisis allows for greater strategic flexibility in responding to disruptions. Consequently, all business continuity plans are based on well-organised and tested communication (*ISO 22301:2019*, 2019). Wieland and Wallenburg (2013) recognised that communicative and cooperative relationships have a positive effect on resilience. Seville et al. (2008) stated that resilience is often related to intangible assets such as trust and good communication, including in relationships with stakeholders (e.g. suppliers and customers) that support the company's recovery from disruption. Internal communication and information and communication tools are regarded as factors that lead to SCRES in various supply chain areas – in relationships with suppliers, for example (Pereira et al., 2014). Blackhurst et al. (2011) observed that well-defined communication networks together with prepared communication protocols are positively related to supply resiliency. It was also noted that communication and information sharing determine visibility and agility which enhance SCRES (Rwakira et al., 2015). In light of all these observations, it is recognized that there is still a lack of statistical studies on how supplier-buyer communication during NPD affects SCRES.

An extending communication with suppliers may positively influence new product development. Thus, it is advised that communication during supplier involvement should be intense and frequent and should include cross-functional teams (Hoegl & Wagner, 2005; Ragatz et al., 2002; Takeishi, 2001), traditional communication methods (Birou & Fawcett, 1994; Hartley et al., 1997), and advanced tools (Huang & Mak, 2003; McIvor & Humphreys, 2004). Therefore, these aspects were included in the CSI construct.

In this study, it was assumed that SIPD practices implemented alone are not sufficient to build supply chain resilience, since the literature shows that communication plays a key role in the successful product development as well as risk management and business continuity management. Therefore, the following hypothesis was put forward:

H2: There is a statistically significant indirect effect of SIPD on SCRES through communication (CSI) as a mediating variable.

2.4.3. The relationship between supply chain resilience (SCRES) and company performance (CP)

'Resilience is the heart of current supply chain management thinking'(Melnyk et al., 2014). Thus, whilst designing products, processes, and supply chains, managers should consider risk anticipation and reduction (e.g. transfer or avoidance) as well as the main SCRES elements such as flexibility (e.g. flexible suppliers and flexible production) and redundancy (e.g. safety stocks and back-up suppliers). All this can ensure the expected performance level of both the company and its business partners, even in the face of a sudden disruption.

Adverse events bring various losses. They can be linked to such consequences as financial, reputational, legal and regulatory, contractual, or occupational health & safety (*ISO/TS 22317:2015*, 2015; Jennison, 2007, p. 41). Losses appear due to the inability to carry out processes in accordance with legal requirements, customer requirements, or corporate regulations, for example. Thus, operational and strategic risks negatively affect company performance—especially when they are not properly managed (Hendricks & Singhal, 2003). Risk in the supplier–customer relationship may also affect objectives related to the triple bottom line (Pagell et al., 2010). The business impact of disruptions is assessed in terms of consequences and time, as the losses increase along with the duration of the disturbance ("BCI," 2018). The key to success is therefore not only to anticipate, but also to respond to crisis effectively. Sheffi and Rice (2005) considered SCRES to be 'the firm's ability to absorb disruptions [which] enables the supply chain network to return to state conditions faster and thus [it] has a positive impact on firm performance.' Resilient supply chains deal with risks by reducing the likelihood of encountering adverse events and preparing a range of response options aimed at slowing down the rate of disruption and thereby mitigating losses. The proactive strategies require additional and sometimes costly investments, which increases the operating costs of supply chains. On the other hand, an adequate response to a specific interruption allows the company to run processes at a level that ensures financial liquidity as well as a quick return to normal performance after an interruption. Certainly, SCRES determines 'the ability to maintain control over performance variability in the face of disturbance', among other things (Priya Datta et al., 2007). Hohenstein et al. (2015), based on the systematic literature review suggested to recognize the dependencies between some resilient practices (e.g. collaboration) and a firm's performance. As shown by qualitative studies, the collaborative practices realized during supplier involvement in product development may increase SCRES (). In light of these findings, the relations between SCRES and performance still require in-depth research and statistical confirmation. Therefore, Hypothesis 3 was formulated:

H3: There is statistically significant direct effect of SCRES on company performance.

3. Research methodology

Operationalisation of the presented approach (Figure 1) required that each area is expressed with an adequate construct. The measurement of SIPD and CSI were proposed following the results of a systematic literature review (Wieteska, 2019). SIPD is expressed by ten items, and CSI with six items (Appendix 1). In this research, the SCRES construct was adopted from Ponomarov(2012, p. 76), whereas the CP measurement follows from several publications; however, all four items were used by Tipu and Fantazy (2014) in their research on company strategy (innovative/customer-oriented/follower strategy), flexibility, and performance.

In the questionnaire each area was expressed through statements based on previous studies. Each statement represented one observable variable measured with a five-point Likert scale, where a value of 5 indicated ‘strongly agree’ and a value of 1 represented ‘strongly disagree’. First, a preliminary assessment of the questionnaire was conducted. The questionnaire was submitted to academicians and supply chain managers for review and was pre-tested among a sample of twelve companies. This was done to assess the questionnaire in terms of its content and structure, and the collected comments and remarks were incorporated into the revised version of the questionnaire. The key to ensuring the credibility of the answers is whether the vocabulary used is not understandable only to researchers, but primarily to the business practitioners to whom the questionnaire is addressed.

The data were collected using a computer-assisted telephone interviewing (CATI) method from small, medium-sized, or large manufacturing companies in Poland. The research included both domestic and international companies from six industries. Their capital varied, i.e. domestic, foreign, or mixed. The source of contact details of potential respondents was the Bisnode Database (www.bisnode.pl). The statistical sample included 10,051 companies, with responses being obtained from 500 companies. The number of companies representing each sector was calculated by taking into account the principle of ‘probability proportional to size’.

Purposive sampling was adopted for the sample selection. The selected companies were only those entities that develop products with suppliers. The main filter question was whether the respondent was responsible for at least one SIPD project in the past. The respondents were CEOs, board members, business owners, and managers responsible for purchasing and supply chain management. The survey was conducted between June and July 2019.

4. Research results

Before analysing the data, we pre-examined responses following the guidelines of (Byme, 2001; Hair et al., 2020) in terms of missing data, response patterns, outliers, and data distribution. Accordingly, the results indicated that there were no observations with missing values. Furthermore, no suspicious response patterns or significant outliers were observed, though the data were to some extent abnormal because several items were found with skewness or kurtosis statistics slightly higher than 1. However, since the deviations were not significant (Byme, 2001), there was no need to exclude the items.

In order to test the hypotheses and assess the conceptual model, we used structured equation modelling with AMOS 21 software. The presentation of the results is organised as follows: first, we examine the common method variance (CMV); then, we present the measurements of reliability and validity as well as the quality of the measurement model’s fit; and finally, we assess the structural model and test our hypotheses.

4.1. The common method variance

In the theory of constructing (Podsakoff et al., 2003), particular attention is paid to the fact that common variance methods may increase or decrease the observed relationships between constructs, which can lead to both type I and type II errors. Studies such as ours, in which all data were collected using the same questionnaire in the same period of time, are particularly sensitive to them because the common method variance is attributed to the measurement method, and not to individual measurement scales, i.e. no systematic measurement error is related with a deviation of estimates from the true relationship between theoretical constructs. One verification method to check for the presence of a common variance effect is Harman’s single factor test (Podsakoff et al., 2003). For this purpose, all 15 items were introduced to exploratory factor analysis.

Using principal component analysis and varimax rotation, it was determined that the number of factors necessary to account for the variance of items is 4 with an eigenvalue greater than 1.0. Identifying four factors together explained 70.752% of the total variance; the first factor did not constitute a majority of the variance, though, as it was only 20.465%; two factors constituted 40.770%, and only three factors constituted 57.414%. Thus, no single factor was identified and one general factor was not responsible for most of the covariance between items. Although the results of these analyses do not exclude the possibility of a common variance (CMV), they suggest that CMV is not a problem; therefore, it is unlikely to interfere with the interpretation of the results obtained (Podsakoff et al., 2003). Additionally, it is worth noting that in the study described, independent and dependent variables were presented separately (Akbar et al., 2016; Nguyen et al., 2020).

4.2. Reliability and validity

The reliability of the measures in this study was assessed by two commonly used measures: Cronbach's Alpha and Composite Reliability (CR) (Kline, 2015). Using both reliability criteria (Table 1), we see that all constructs meet typical requirements-values greater than 0.7 are suggested (Kline, 2015; Nguyen et al., 2020).

Table 1. Descriptive statistics and reliability of measures

Construct	Mean	SD	Cronbach's alpha	CR	AVE
SIPD	2.639	0.896	0.791	0.884	0.565
CSI	4.217	0.450	0.778	0.862	0.567
SCRES	3.954	0.403	0.855	0.907	0.712
CP	3.575	0.502	0.820	0.869	0.638

For each construct, the average variance extracted (AVE) is greater than 0.5 (Kline, 2015; Nguyen et al., 2020); consequently, we can confirm the convergent validity (see Table 2).

Concerning the discriminant validity (see Table 2), the Fornell–Larcker criterion suggests that the root square of each construct's AVE should be higher than the correlation with any other construct (Fornell & Larcker, 1981).

Table 2. Discriminant validity

	SIPD	CSI	SCRES	CP
SIPD	0.752			
CSI	0.257**	0.753		
SCRES	0.096*	0.189**	0.844	
CP	0.269**	0.080	0.256**	0.799

* Correlation is significant at the level of 0.05 (2-tailed)
** Correlation is significant at the level of 0.01 (2-tailed)

Numbers on the diagonal are square roots of AVE for constructs; numbers off-diagonal are correlations between them.

Another popular approach for establishing discriminant validity is to assess cross-loadings. In our research, each measurement item correlated weakly with all other constructs except for the one to which it is theoretically associated (Gefen & Straub, 2005).

Finally, our results show that the fit index for our measurement model is an approximate fit ($\chi2$ = 322.305 (df = 71), p <0.0001 – reject the model; $\chi2$/df = 4.54<5 – good fit; GFI=0.929>0.9 – good fit; AGFI=0.901>0.9 – good fit; TLI=0.908>0.9 – good fit; CFI=0.911>0.9 – good fit; PGFI=0.611>0.5 – good fit; RMSEA=0.076<0.08 – fair fit; SRMR=0.0666<0.08 – good fit). If the chi-squared test rejects the model but SRMR≤0.08 and all standardised residuals are small (i.e. there are no large residuals), then we can claim the model fits approximately well (Asparouhov & Muthén, 2018).

4.3. Structural model

First of all, note that the model explains 5.4% of CSI's variation, 2.8% of SCRES's variation, and 5.5% of CP's variation (see Fig. 2). Regarding the model fit, our conceptual model matches an approximate fit of the data ($\chi2$ = 336.562 (df = 73), p<0.0001 – reject; $\chi2$/df=4.61<5 – good fit; GFI=0.936>0.9 – good fit; AGFI=0.919>0.9 – good fit; TLI =0.910>0.9 – good fit; CFI=0.928>0.9 – good fit; RMSEA=0.076<0.08 – fair fit; and SRMR=0.078<0.08 – good fit).

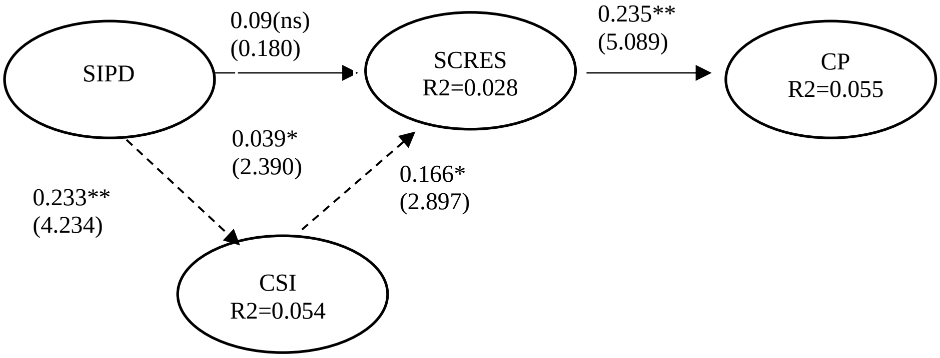

Figure 2. Empirical assessment of the structural model (n = 500)
Note: ** p < 0.001; * p < 0.01; ns = not significant; critical ratio in parentheses

Our results show that SIPD does not have a direct effect on SCRES (β = 0.09; p = 0.857). Consequently, H1 is rejected. The other results show a significant positive effect of SIPD (β = 0.233; p < 0.001) on CSI, which in turn has a significant effect (β = 0.166; p < 0.01) on SCRES. Firstly, the indirect effect for SIPD on SCRES is statistically significant (β = 0.039; p < 0.01). Secondly, the bootstrap test with a minimum of 5,000 resamples offers clear evidence of significant mediation if the 95% confidence intervals do not include the value 0 (Nguyen et al., 2020), indicating that SIPD has a significant positive indirect effect on SCRES (β = 0.039; p < 0.01; 95% CI: 0.019, 0.18; excluding 0). These results suggest that CSI totally mediates the effect of SIPD on SCRES, and we can validate H2. Our results show that SCRES has a significant positive direct effect on CP (β = 0.235; p = 0.001). Consequently, H3 is confirmed. All of the results are presented in Table 3.

Table 3. Test of hypotheses

Hypothesis	Independent variables	Dependent variables	Coefficient standardised	p-value	Results
H1	SIPD	SCRES	0.09	0.857	Not supported
H2	SIPD via CSI	SCRES	0.039	0.009	Supported
H3	SCRES	CP	0.235	<0.001	Supported

5. Discussion

According to previous research, supplier involvement at the early stages of the NPD process determines process and supply chain design in particular (Dowlatshahi, 1998; Luzzini et al., 2015; McGinnis & Vallopra, 1999; Petersen et al., 2005). Therefore, the lack of direct impact of SCRES on SIPD (unconfirmed H1) might be explained by the fact that among the companies surveyed, an integrated and mature approach for SIPD (Rauniar et al., 2017; Van Echtelt et al., 2008;

Wynstra et al., 2001) has not been fully implemented. Thus, the supplier–client cooperation was rather limited to providing the supplier with detailed requirements and technical specifications as in the case of arm's length or routine development (Staniec, 2018; Wynstra & Pierick, 2000). Simultaneously, the cooperation with partners or black box suppliers, which is based on the joint development of detailed design, early involvement, and a high degree of supplier responsibility, might have been a rare situation (Kamath & Liker, 1994; Le Dain et al., 2010). This explanation can be confirmed by the fact that some of SIPD variables aimed at strategic alliances, although identified in the literature, were removed after CFA or EFA from the construct, e.g. cooperation with the supplier was based on partner relationships or on jointly set goals (Appendix 1).

Despite the lack of an advanced partnership approach to supplier–customer relationships, our empirical research has confirmed the opinion that the cooperation between a company's employees and the supplier's employees was very close and was concentrated on product and process success. For example, product development involved cross-functional teams (I. S. Fan et al., 2000), there was mutual support in terms of improvement (Birou & Fawcett, 1994; Ragatz et al., 2002), and SIPD involved various levels of management (Fleming et al., 2014; McIvor et al., 2006). Nevertheless, such good practices of SIPD do not have an impact on supply chain resilience, unless the communication is implemented (H2 confirmation). The condition, however, is that the communication is frequent and intensive (Hartley et al., 1997; Hoegl & Wagner, 2005; Jayaram, 2008), and takes place in a friendly atmosphere (Wagner & Hoegl, 2006). In the light of previous considerations, such communication certainly allows comprehensive risk identification and mutual reporting of any problems that emerge. Mainly, communication is important at every stage of disruption management (Coombs, 2014, pp. 18–26; Pereira et al., 2014; Wieland & Wallenburg, 2013).

Our empirical research confirmed the opinion that the communication was based on traditional methods e.g. telephone, fax, or meeting in person (Birou & Fawcett, 1994; Culley et al., 1999; Hartley et al., 1997), and not using advanced ICT (Huang et al., 2003; D. Tang et al., 2004). This may be because the surveyed companies prefer traditional methods during SIPD or because ICT technologies are still rarely used in their country of operation, despite the fast pace of development today.

In the opinion of Ponomarov (2012, p. 76) supply chain resilience (SCRES) creates 6 items. However, our empirical study have not confirmed two of them: 'our firm's supply chain can move to a new, more desirable state after being disrupted' and 'our firm's supply chain is well prepared to deal with financial outcomes of supply chain disruptions'. As these two items, which are related to supply chain flexibility have been removed, it was impossible to see how the SIPD affects them (Mikkola & Skjoett-Larsen, 2003; Ragatz et al., 1997).

As an analysis of the literature shows, the issue of building resilient supply chains is very broad and involves three dimensions of time, i.e. before, during and after the disturbance. However, the SCRES construct used in this study includes variables aimed mainly at responding to disruptions. Presumably, SIPD determines individual elements of resilient supply chains differently. This may concern flexibility, for example. On the one hand, companies prefer to select responsive suppliers who provide flexible supplies and effectively adjust to the changing needs of the client (Handfield et al., 1999; Wagner & Hoegl, 2006). On the other hand, SIPD reduces purchasing flexibility, making it difficult to move to a new supply chain configuration during or after the disruption. According to the previous research, SIPD primarily enhances single sourcing (Asmus & Griffin, 1993). This is partly because the investment in the relationship increases the costs of switching (Sjoerdsma & van Weele, 2015). Furthermore, single sourcing and strategic partnerships are associated with strong dependences and risks, which is particularly indicated by the supplier–customer relationship portfolio models (Kraljic, 1983; Wieteska, 2014; Wynstra & Pierick, 2000). Therefore, in the face of supply chain disruptions, the consequences of single sourcing are very difficult to deal with (Norrman & Jansson, 2004).

Contrary to what we initially posited in our hypothesis, SIPD does not directly impact SCRES, but rather it increases the importance of CSI, which in turn positively influences SCRES. Thus, we are able to propose CSI as the underlying mechanism that explains the effect of SIPD on SCRES and CP. Finally, our empirical research confirms that communication with suppliers positively influences SCRES (Birou & Fawcett, 1994; Hartley et al., 1997). The results from our study provide empirical evidence for the significant role of SIPD within CSI and its influence on SCRES and CP (Priya Datta et al., 2007; Tukamuhabwa et al., 2015). Interestingly, the relationship between SIPD and SCRES is not partially mediated by CSI, but it appears to be fully mediated by it (Khaddama et al., 2020).

According to the results, there is a direct relationship between SCRES and a company's performance (H3 confirmed). Our empirical research has confirmed the opinion that SCRES has a positive impact on all four items: net profit, sales growth, lead time, and customer satisfaction. Thus, although a resilient supply chain requires various investments, it is robust enough to cope well with the costs of risk. This conclusion coincides with the previous observations from qualitative studies (Khan, Christopher, and Burnes 2008; Tang and Nurmaya 2011; Tang et al. 2009).

6. Theoretical and practical implications

This empirical study attempted to fill the gaps created by trajectory- and resource-based perspectives in interorganisational supply chain resilience. This study extends the research discourse on supply chain resilience and disruption management with a focus on the supplier-buyer communication during product development. The results of this study indicate that businesses should involve suppliers in product development in order to strengthen supply chain resilience, but a proper communication must become the foundation of such joint product development.

Such a conclusion certainly translates into the currently observed crisis. During the Covid-19 pandemic, an increase in communication and collaborations leading to new ventures was observed. This was evidenced by chemical companies diversifying their product portfolio and demonstrating versatility and responsiveness in developing new products to respond to local and national demand (e.g. PKN Orlen or Organika). Companies forged alliances united against the Covid-19 threat, and thanks to communication they have increased their supply chain resilience, responsiveness, and flexibility.

SIPD favours cooperation with local and flexible suppliers, and the epidemic has shown that today, the reconfiguration from global to national supply chains is becoming urgent. Product, volume, time, and mix flexibility in supply chains is critical for meeting reduced demand in the long term (e.g. the automotive sector), markedly higher demand (food or the chemical sector), or to introduce new products to seize an opportunity on the market. In the latter case, having procedures, resources, and experience in the field of supplier-buyer communication and joint product development will certainly aid rapid prototyping in the new supply chain.

It should also be emphasised that ESI in particular is based on single sourcing, which can lead to an increase in dependency risk. Therefore, even in the face of SIPD, companies need to remember not to limit themselves to this sourcing strategy. The pandemic has shown that even in national and local supply chains businesses should implement information and communication tools and test resources and competences for remote communication. Although SIPD is still based mainly on traditional methods (e.g. face-to-face meetings), developing such capabilities in supplier–customer relationships allows for efficient response in crisis situations which preclude direct contact.

7. Conclusions

This study demonstrates that, along with the severity of the disruption scenario, the effect of communication must also be considered when analysing the benefits of resilience practices implemented by a company. Appropriate communication accompanying joint product development can help to smooth out the effects of global disruptions. To mitigate negative consequences better, the company must act proactively with adequate communication practices, which also connects to the importance of better supply chain resilience and company performance.

This study suffers from the same methodological limitations typical of most empirical surveys. The data were based on a single respondent's replies, and the questionnaire is subjective in nature. The use of single respondents may generate some measurement inaccuracy. The results have to be interpreted with this limitation in mind. To address these inherent limitations, future research on various forms of supply chain resilience, communication, and supplier involvement in product development would be worth conducting in order to examine the differences. Further investigations may consider exploring some possible antecedents of supplier involvement in product development or the impact that the NPD stage of supplier involvement (e.g. early or late), supply chain resilience (e.g. including the main elements of SCRES or proactive, concurrent, and reactive strategies), and communication have on some outcome variables, such as the degree of satisfaction, loss severity, or recovery time after a supply chain disruption. The authors researched only the supplier involvement perspective. However, in the future, it is recommended to include other supply chain stakeholders too as more and more companies decide today to open innovations development.

Acknowledgment: This paper is a product of the science project 'Flexibility in relationships with suppliers in terms of supplier–purchaser models of cooperation on product development in the B2B market', no. 2016/21/B/HS4/00665, financed by the National Science Centre (NCN) in Poland.

References:

Akbar, P., Mai, R., & Hoffmann, S. (2016). When do materialistic consumers join commercial sharing systems. *Journal of Business Research*, *69*(10), 4215-4224. https://doi.org/10.1016/j.jbusres.2016.03.003

Ali, A., Mahfouz, A., & Arisha, A. (2017). Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management*, *22*(1), 16-39. https://doi.org/10.1108/SCM-06-2016-0197

Asmus, D., & Griffin, J. (1993). Harnessing the power of your suppliers. *Journal of Product Innovation Management*, *11*(5), 469-470. https://doi.org/10.1016/0737-6782(94)90039-6

Asparouhov, T., & Muthén, B. (2018). *SRMR in Mplus*.

Bação, P., Domingues, J. M., & Duarte, A. P. (2012). Financial crisis and domino effect. In J. S. Andrade, M. Simões, S. I., D. E., & H. H. (Eds.), *Managing structural changes: Trends and requirements*, (pp. 199-213). Coimbra, Portugal.

BCI. (2018). In *Exploring the Good Practice Guidelines 2018 edition: Embedding Business Continuity (PP2) | BCI*.

Birou, L. M., & Fawcett, S. E. (1994). Supplier Involvement in Integrated Product Development. *International Journal of Physical Distribution & Logistics Management*, *24*(5), 4-14. https://doi.org/10.1108/09600039410063982

Blackhurst, J., Dunn, K. S., & Craighead, C. W. (2011). An empirically derived framework of global supply resiliency. *Journal of Business Logistics*, *32*(4), 374-391. https://doi.org/10.1111/j.0000-0000.2011.01032.x

Blome, C., & Schoenherr, T. (2011). Supply chain risk management in financial crises - A multiple case-study approach. *International Journal of Production Economics*, *134*(1), 43-57. https://doi.org/10.1016/j.ijpe.2011.01.002

Bozdogan, K., Deyst, J., Hoult, D., & Lucas, M. (1998). Architectural innovation in product development through early supplier integration. *R and D Management*, *28*(3), 163-173. https://doi.org/10.1111/1467-9310.00093

Büyüközkan, G., & Görener, A. (2015). Evaluation of product development partners using an integrated AHP-VIKOR model. *Kybernetes*, *44*(2), 220-237. https://doi.org/10.1108/K-01-2014-0019

Byme, B. M. (2001). Structural equation modeling with AMOS,EQS, and LISREL: comparative approaches to testing for the factorial validity of a measuring instrument. *International Journal of Testing*, *1*, 55-86.

Carr, A. S., Kaynak, H., Hartley, J. L., & Ross, A. (2008). Supplier dependence: Impact on supplier's participation and performance. *International Journal of Operations and Production Management*, *28*(9), 899-916. https://doi.org/10.1108/01443570810895302

Chien, S. H., & Chen, J. J. (2010). Supplier involvement and customer involvement effect on new product development success in the financial service industry. *Service Industries Journal*, *30*(2), 185-201. https://doi.org/10.1080/02642060802116354

Choi, Y., & Douady, R. (2012). Financial crisis dynamics: Attempt to define a market instability indicator. *Quantitative Finance*, *12*(9), 1351-1365. https://doi.org/10.1080/14697688.2011.627880

Cicmil, S., & Marshall, D. (2005). Insights into collaboration at the project level: Complexity, social interaction and procurement mechanisms. In *Building Research and Information* (Vol. 33, Issue 6, pp. 523-535). https://doi.org/10.1080/09613210500288886

Closs, D. J., & McGarrell, E. F. (2004). Enhancing security throughout the supply chain. *Special Report to the IBM Center for the Business of Government, April*, 10-12.

Coombs, W. T. (2010). Ongoing Crisis Communication : Planning , Managing, and Responding. *IEEE Transactions on Professional Communication*, *52*(2), 174-178.

Coombs, W. T. (2014). *Ongoing crisis communication: Planning, managing, and respondin*. Sage Publications.

COSO. (2004). *Enterprise Risk Management-Integrated Framework* (Issue September). https://doi.org/10.1002/9781119201939.app4

CSCMP. (2013). *CSCMP Supply Chain Management Definitions and Glossary* (Issue August).

Culley, S., Boston, O., & MacMahon, C. (1999). Suppliers in New Product Development. *Journal of Engineering Design*, *10*(1), 58-75.

Danese, P., & Filippini, R. (2010). Modularity and the impact on new product development time performance: Investigating the moderating effects of supplier involvement and interfunctional integration. *International Journal of Operations and Production Management*, *30*(11), 1191-1209. https://doi.org/10.1108/01443571011087387

Directive 2009/138/EC. (2009). In *Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)*.

Dowlatshahi, S. (1997). The role of product design in designer-buyer-supplier interface. *Production Planning and Control*, *8*(6), 522-532. https://doi.org/10.1080/095372897234867

Dowlatshahi, S. (1998). Implementing early supplier involvement: A conceptual framework. *International Journal of Operations and Production Management*, *18*(2), 143-167. https://doi.org/10.1108/01443579810193285

Fan, I. S., Russell, S., & Lunn, R. (2000). Supplier knowledge exchange in aerospace product engineering. *Aircraft Engineering and Aerospace Technology*, *72*(1), 14-17. https://doi.org/10.1108/00022660010308624

Fan, Y., & Stevenson, M. (2018). A review of supply chain risk management: definition, theory, and research agenda. In *International Journal of Physical Distribution and Logistics Management* (Vol. 48, Issue 3, pp. 205-230). https://doi.org/10.1108/IJPDLM-01-2017-0043

Fantazy, K. A., Kumar, V., & Kumar, U. (2009). An empirical study of the relationships among strategy, flexibility, and performance in the supply chain context. *Supply Chain Management*, *14*(3), 177-188. https://doi.org/10.1108/13598540910954520

Feng, T., & Wang, D. (2013). Supply chain involvement for better product development performance. *Industrial Management and Data Systems*, *113*(2), 190-206. https://doi.org/10.1108/02635571311303532

FERMA. (2003). In *A Risk Management Standard Federation of European Risk Management Associations A Risk Management Standard 2*.

Fleming, A., Hobday, A. J., Farmery, A., van Putten, E. I., Pecl, G. T., Green, B. S., & Lim-Camacho, L. (2014). Climate change risks and adaptation options across Australian seafood supply chains - A preliminary assessment. *Climate Risk Management*, *1*, 39-50. https://doi.org/10.1016/j.crm.2013.12.003

Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management*, *28*(1), 58-71. https://doi.org/10.1016/j.jom.2009.06.001

Fornell, C., & Larcker, D. F. (1981). Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics. *Journal of Marketing Research*, *18*(3), 382. https://doi.org/10.2307/3150980

Gefen, D., & Straub, D. (2005). A Practical Guide To Factorial Validity Using PLS-Graph: Tutorial And Annotated Example. *Communications of the Association for Information Systems*, *16*(July). https://doi.org/10.17705/1cais.01605

Gibb, F., & Buchanan, S. (2006). A framework for business continuity management. *International Journal of Information Management*, *26*(2), 128-141. https://doi.org/10.1016/j.ijinfomgt.2005.11.008

Giunipero, L. C., & Eltantawy, R. A. (2004). Securing the upstream supply chain: A risk management approach. *International Journal of Physical Distribution and Logistics Management*, *34*(9), 698-713. https://doi.org/10.1108/09600030410567478

Hair, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, *109*(August 2019), 101-110. https://doi.org/10.1016/j.jbusres.2019.11.069

Handfield, R. B., Ragatz, G. L., Petersen, K. J., & Monczka, R. M. (1999). Involving Suppliers in New Product Development. *California Management Review*, *42*(1), 59-82. https://doi.org/10.2307/41166019

Hartley, J. L., Zirger, B. J., & Kamath, R. R. (1997). Managing the buyer-supplier interface for on-time performance in product development. *Journal of Operations Management*, *15*(1), 57-70. https://doi.org/10.1016/s0272-6963(96)00089-7

Hendricks, K. B., & Singhal, V. R. (2003). The effect of supply chain glitches on shareholder wealth. *Journal of Operations Management*, *21*(5), 501-522. https://doi.org/10.1016/j.jom.2003.02.003

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: A literature review. *International Journal of Production Research*, *53*(16), 5031-5069. https://doi.org/10.1080/00207543.2015.1030467

Hoegl, M., & Wagner, S. M. (2005). Buyer-supplier collaboration in product development projects. *Journal of Management*, *31*(4), 530-548. https://doi.org/10.1177/0149206304272291

Hohenstein, N. O., Feise, E., Hartmann, E., & Giunipero, L. (2015a). Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *International Journal of Physical Distribution and Logistics Management*, *45*, 90-117. https://doi.org/10.1108/IJPDLM-05-2013-0128

Hohenstein, N. O., Feise, E., Hartmann, E., & Giunipero, L. (2015b). Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *International Journal of Physical Distribution and Logistics Management*, *45*, 90-117. https://doi.org/10.1108/IJPDLM-05-2013-0128

Hong, P., Doll, W. J., Revilla, E., & Nahm, A. Y. (2011). Knowledge sharing and strategic fit in integrated product development proejcts: An empirical study. *International Journal of Production Economics*, *132*(2), 186-196. https://doi.org/10.1016/j.ijpe.2011.04.004

Huang, G. Q., & Mak, K. L. (2003). Brokering the customer-supplier partnership in product design and realization over the World Wide Web. *IIE Transactions (Institute of Industrial Engineers)*, *35*(4), 369-378. https://doi.org/10.1080/07408170304373

Huang, G. Q., Mak, K. L., & Humphreys, P. K. (2003). A new model of the customer-supplier partnership in new product development. *Journal of Materials Processing Technology*, *138*(1-3), 301-305. https://doi.org/10.1016/S0924-0136(03)00089-X

IS0 31000:2018. (2018).

ISO 22301:2019. (2019). Technical Committee : ISO/TC 292 Security and resilience.

ISO/TS 22317:2015. (2015). ISO/TC 292 Security and resilience.

Jayaram, J. (2008). Supplier involvement in new product development projects: Dimensionality and contingency effects. *International Journal of Production Research*, *46*(13), 3717-3735. https://doi.org/10.1080/00207540600787010

Jennison, B. (2007). *Zarządzanie ryzykiem w sektorze publicznym*. Mnisterstwo Finansów Rzeczpospolitej Polskliej.

Jiao, Y. Y., Jun, J., Jiao, R. J., & Butler, D. L. (2008). Operational implications of early supplier involvement in semiconductor manufacturing firms: A case study. *Journal of Manufacturing Technology Management*, *19*(8), 913-932. https://doi.org/10.1108/17410380810911709

Johnson, W. H. A., & Filippini, R. (2009). Internal vs. external collaboration: What works. *Research Technology Management*, *52*(3), 15-17. https://doi.org/10.1080/08956308.2009.11657564

Julia Acevedo-Urquiaga, A., Sablón-Cossío, N., Antonio Acevedo-Suárez, J., & Julia Urquiaga-Rodríguez, A. (2021). A model with a collaborative approach for the operational management of the supply chain. *International Journal of Industrial Engineering and Management*, *Volume 12*(Issue 1), 49–62. https://doi.org/10.24867/IJIEM-2021-1-276

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: An empirical study. *Supply Chain Management*, *16*(4), 246-259. https://doi.org/10.1108/13598541111139062

Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics Research and Applications*, *6*(4), 197-210. https://doi.org/10.1080/13675560310001627016

Kähkönen, A. K., Lintukangas, K., & Hallikas, J. (2015). Buyer's dependence in value creating supplier relationships. *Supply Chain Management*, *20*(2), 151-162. https://doi.org/10.1108/SCM-02-2014-0062

Kamath, R. R., & Liker, J. K. (1994). A second look at Japanese product development. *Long Range Planning*, *28*(2), 155. https://doi.org/10.1016/0024-6301(95)91069-7

Kambil, A., & Mahidhar, V. (2005). *Disarming the value killers: A risk management study | Deloitte Insights*. Https://Www2.Deloitte.Com/Uk/En/Insights/Topics/Risk-Management/Disarming-the-Value-Killers-a-Risk-Management-Study.Html. https://www2.deloitte.com/uk/en/insights/topics/risk-management/disarming-the-value-killers-a-risk-management-study.html

Keegan, M. (2004). *The Orange Book Management of Risk: Principles and Concepts*. London: HM Treasury.

Khaddama, A. A., Irtaimeh, H. J., & Bader, B. S. (2020). The effect of supply chain management on competitive advantage: The mediating role of information technology. *Uncertain Supply Chain Management*, *8*. https://doi.org/10.5267/j.uscm.2020.3.001

Khan, O., Christopher, M., & Burnes, B. (2008). The impact of product design on supply chain risk: A case study. *International Journal of Physical Distribution and Logistics Management*, *38*(5), 412-432. https://doi.org/10.1108/09600030810882834

Kline, R. B. (2015). *Principles and Practice of Structural Equation Modeling*. The Guilford Press.

Kochan, C. G., & Nowicki, D. R. (2018). Supply chain resilience: a systematic literature review and typological framework. *International Journal of Physical Distribution and Logistics Management*, *48*(8), 842-865. https://doi.org/10.1108/IJPDLM-02-2017-0099

Kraljic, P. (1983). Purchasing Must Become Supply Management. *Harvard Business Review*, *September-October*, 109-117. https://doi.org/10.1225/83509

Lakemond, N., Berggren, C., & Van Weele, A. (2006). Coordinating supplier involvement in product development projects: A differentiated coordination typology. *R and D Management*, *36*(1), 55-66. https://doi.org/10.1111/j.1467-9310.2005.00415.x

Lam, W. (2002). Planning Cycle Continuity. *IT Professional*, *4*(3), 19-25.

Langerak, F., & Hultink, E. J. (2008). The effect of new product development acceleration approaches on development speed: A case study. *Journal of Engineering and Technology Management - JET-M*, *25*(3), 157-167. https://doi.org/10.1016/j.jengtecman.2008.06.004

Le Dain, M. A., Calvi, R., & Cheriti, S. (2010). Developing an approach for design-or-buy-design decision-making. *Journal of Purchasing and Supply Management*, *16*(2), 77-87. https://doi.org/10.1016/j.pursup.2010.03.010

Le Dain, M. A., & Merminod, V. (2014). A knowledge sharing framework for black, grey and white box supplier configurations in new product development. *Technovation*, *34*(11), 688-701. https://doi.org/10.1016/j.technovation.2014.09.005

Lee, Y. H., & Wang, K. J. (2012). Performance impact of new product development processes for distinct scenarios under different supplier-manufacturer relationships. *Mathematics and Computers in Simulation*, *82*(11), 2096-2108. https://doi.org/10.1016/j.matcom.2012.04.008

Li, G., Fan, H., Lee, P. K. C., & Cheng, T. C. E. (2015). Joint supply chain risk management : An agency and collaboration perspective. *Intern. Journal of Production Economics*, *164*, 83-94. https://doi.org/10.1016/j.ijpe.2015.02.021

Li, S., Gu, S., & Wang, Q. (2010). An empirical study on the influencing factors of supplier involvement in new product development. *Frontiers of Business Research in China*, *4*(3), 451-484. https://doi.org/10.1007/s11782-010-0106-z

Lima, F. R. P. de, Da Silva, A. L., Godinho Filho, M., & Dias, E. M. (2018). Systematic review: resilience enablers to combat counterfeit medicines. *Supply Chain Management*, *23*(2), 117-135. https://doi.org/10.1108/SCM-04-2017-0155

Littler, D., Leverick, F., & Bruce, M. (1995). Factors affecting the process of collaborative product development: A study of UK manufacturers of information and communications technology products. *The Journal of Product Innovation Management*, *12*(1), 16-32. https://doi.org/10.1016/0737-6782(94)00025-B

Luo, C., Mallick, D. N., & Schroeder, R. G. (2010). Collaborative product development: Exploring the role of internal coordination capability in supplier involvement. *European Journal of Innovation Management*, *13*(2), 244-266. https://doi.org/10.1108/14601061011040276

Luzzini, D., Amann, M., Caniato, F., Essig, M., & Ronchi, S. (2015). The path of innovation: Purchasing and supplier involvement into new product development. *Industrial Marketing Management*, *47*, 109-120. https://doi.org/10.1016/j.indmarman.2015.02.034

Maffin, D., & Braiden, P. (2001). Manufacturing and supplier roles in product development. *International Journal of Production Economics*, *69*(2), 205-213. https://doi.org/10.1016/S0925-5273(00)00023-2

Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. *International Journal of Physical Distribution and Logistics Management*, *38*(3), 192-223. https://doi.org/10.1108/09600030810866986

McGinnis, M. A., & Vallopra, R. M. (1999). Purchasing and supplier involvement: Issues and insights regarding new product success. *Journal of Supply Chain Management*, *35*(2), 4-15. https://doi.org/10.1111/j.1745-493X.1999.tb00057.x

McIvor, R., & Humphreys, P. (2004). Early supplier involvement in the design process: Lessons from the electronics industry. *Omega*, *32*(3), 179-199. https://doi.org/10.1016/j.omega.2003.09.005

McIvor, R., Humphreys, P., & Cadden, T. (2006). Supplier involvement in product development in the electronics industry: A case study. *Journal of Engineering and Technology Management - JET-M*, *23*(4), 374-397. https://doi.org/10.1016/j.jengtecman.2006.08.006

Melnyk, B. S. A., Closs, D. J., Griffis, S. E., Zobel, C. W., & Macdonald, J. R. (2014). Understanding Supply Chain Resilience. *Supply Chain Management Review, 18*(1), 34-41.

Menguc, B., Auh, S., & Yannopoulos, P. (2013). Customer and supplier involvement in design: The moderating role of incremental and radical innovation capability. *Journal of Product Innovation Management*, *31*(2), 313-328. https://doi.org/10.1111/jpim.12097

Mikkola, J. H., & Skjoett-Larsen, T. (2003). Early supplier involvement: Implications for new product development outsourcing and supplier-buyer interdependence. *Global Journal of Flexible Systems Management*, *4*(4), 31-41.

Najafi, T. S., Sharifi, H., Soleimanof, S., & Najmi, M. (2013). An empirical study of firms absorptive capacity dimensions, supplier involvement and new product development performance. *International Journal of Production Research*, *51*(11), 3385-3403. https://doi.org/10.1080/00207543.2013.774480

Nguyen, S., Didi Alaoui, M., & Llosa, S. (2020). When interchangeability between providers and users makes a difference: The mediating role of social proximity in collaborative services. *Journal of Business Research*, *April 2019*, 1-10. https://doi.org/10.1016/j.jbusres.2020.03.021

Norrman, A., & Jansson, U. (2004). Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident. *International Journal of Physical Distribution and Logistics Management*, *34*(5), 434-456. https://doi.org/10.1108/09600030410545463

Pagell, M., Wu, Z., & Wasserman, M. E. (2010). Thinking differently about purchasing portfolios: An assessment of sustainable sourcing. *Journal of Supply Chain Management*, *46*(1), 57-73. https://doi.org/10.1111/j.1745-493X.2009.03186.x

Parker, D. B., Zsidisin, G. A., & Ragatz, G. L. (2008). Timing and extent of supplier integration in new product development: A contingency approach. *Journal of Supply Chain Management*, *44*(1), 71-83. https://doi.org/10.1111/j.1745-493X.2008.00046.x

Pereira, C. R., Christopher, M., & Lago Da Silva, A. (2014). Achieving supply chain resilience: the role of procurement. *Supply Chain Management*, *19*, 626-642. https://doi.org/10.1108/SCM-09-2013-0346

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. (2003). A model of supplier integration into new product development. *Journal of Product Innovation Management*, *20*(4), 284-299. https://doi.org/10.1111/1540-5885.00028

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. (2005). Supplier integration into new product development: Coordinating product, process and supply chain design. *Journal of Operations Management*, *23*(3-4), 371-388. https://doi.org/10.1016/j.jom.2004.07.009

Pfohl, H. C., Köhler, H., & Thomas, D. (2010). State of the art in supply chain risk management research: Empirical and conceptual findings and a roadmap for the implementation in practice. *Logistics Research*, *2*(1), 33-44. https://doi.org/10.1007/s12159-010-0023-8

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. *Journal of Applied Psychology*, *88*(5), 879-903. https://doi.org/10.1037/0021-9010.88.5.879

Ponis, S. T., & Koronis, E. (2012). Supply Chain Resilience? Definition of concept and its formative element. *The Journal of Applied Business Researc*, *28*(5), 921-935. https://doi.org/10.4018/978-1-7998-0945-6.ch093

Ponomarov, S. Y. (2012). Antecedents and consequences of supply chain resilience: a dynamic capabilities perspective. *Doctoral Dissertations University*, 1-151.

Primo, M. A. M., & Amundson, S. D. (2002). An exploratory study of the effects of supplier relationships on new product development outcomes. *Journal of Operations Management*, *20*(1), 33-52. https://doi.org/10.1016/S0272-6963(01)00080-8

Priya Datta, P., Christopher, M., & Allen, P. (2007). Agent-based modelling of complex production/distribution systems to improve resilience. *International Journal of Logistics Research and Applications*, *10*(3), 187-203. https://doi.org/10.1080/13675560701467144

Ragatz, G. L., Handfield, R. B., & Petersen, K. J. (2002). Benefits associated with supplier integration into new product development under conditions of technology uncertainty. *Journal of Business Research*, *55*(5), 389-400. https://doi.org/10.1016/S0148-2963(00)00158-2

Ragatz, G. L., Handfield, R. B., & Scannell, T. V. (1997). Sucess Factor for Integrating Suppliers into New product Development. *Journal Product Innovation Management*, *14*, 190-202. https://doi.org/10.1111/1540-5885.1430190

Rauniar, R., Rawski, G., & Hudson, D. (2017). Antecedents and consequences of IPPD effectiveness. *International Journal of Innovation Management*, *21*(7), 1-38. https://doi.org/10.1142/S1363919617500591

Rwakira, B. T., Stevenson, M., & Busby, J. (2015). Supply chain resilience in a developing country : A case study analysis of a supply network in Uganda. In *Paper presented at Euroma Conference, Gothenburg, Sweden*.

Seville, E., Brunsdon, D., Dantas, A., Le Masurier, J., Wilkinson, S., & Vargo, J. (2008). Organisational resilience: Researching the reality of New Zealand organisations. *Journal of Business Continuity & Emergency Planning*, *2*(3), 258-266.

Sheffi, Y. (2001). Supply Chain Management under the Threat of International Terrorism. *The International Journal of Logistics Management*, *12*(2), 1-11. https://doi.org/10.1108/09574090110806262

Sheffi, Y., & Rice, J. B. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review*, *47*(1), 41-48.

Sjoerdsma, M., & van Weele, A. J. (2015). Managing supplier relationships in a new product development context. *Journal of Purchasing and Supply Management*, *21*(3), 192-203. https://doi.org/10.1016/j.pursup.2015.05.002

Smeltzer, L. R., & Siferd, S. P. (1998). Proactive Supply Management: The Management of Risk. *International Journal of Purchasing and Materials Management*, *34*(4), 38-45. https://doi.org/10.1111/j.1745-493x.1998.tb00040.x

Song, L. Z., Song, M., & Di Benedetto, C. A. (2011). Resources, supplier investment, product launch advantages, and first product performance. *Journal of Operations Management*, *29*(1-2), 86-104. https://doi.org/10.1016/j.jom.2010.07.003

Spina, G., Verganti, R., & Zotteri, G. (2002). Factors influencing co-design adoption: Drivers and internal consistency. *International Journal of Operations and Production Management*, *22*(12), 1354-1366. https://doi.org/10.1108/01443570210452048

Staniec, I. (2018). Technological Entrepreneurship: How does Environmental Turbulence Impact upon Collaboration Risk? *Sustainability*, *10*(8), 2762. https://doi.org/10.3390/su10082762

Steelman, T. A., & McCaffrey, S. (2013). Best practices in risk and crisis communication: Implications for natural hazards management. *Natural Hazards*, *65*(1), 683-705. https://doi.org/10.1007/s11069-012-0386-z

Swink, M. (1999). Threats to new product manufacturability and the effects of development team integration processes. *Journal of Operations Management*, *17*(6), 691-709. https://doi.org/10.1016/s0272-6963(99)00027-3

Takeishi, A. (2001). Bridging inter- and intra-firm boundaries: Management of supplier involvement in automobile product development. *Strategic Management Journal*, *22*(5), 403-433. https://doi.org/10.1002/smj.164

Tang, C. S. (2006). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics Research and Applications*, *9*(1), 33-45. https://doi.org/10.1080/13675560500405584

Tang, C. S., Zimmerman, J. D., & Nelson, J. I. (2009). Managing New Product Development and Supply Chain Risks: The Boeing 787 Case. *Supply Chain Forum: An International Journal*, *10*(2), 74-86. https://doi.org/10.1080/16258312.2009.11517219

Tang, D., Eversheim, W., & Schuh, G. (2004). A new generation of cooperative development paradigm in the tool and die making branch: Strategy and technology. *Robotics and Computer-Integrated Manufacturing*, *20*(4), 301-311. https://doi.org/10.1016/j.rcim.2003.11.001

Tang, O., & Nurmaya, M. S. (2011). Identifying risk issues and research advancements in supply chain risk management. *International Journal of Production Economics*, *133*(1), 25-34. https://doi.org/10.1016/j.ijpe.2010.06.013

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509-533. https://doi.org/10.1142/9789812796929_0004

Tipu, S. A. A., & Fantazy, K. A. (2014). Supply chain strategy, flexibility, and performance: A comparative study of SMEs in Pakistan and Canada. *International Journal of Logistics Management*, *25*(2), 399-416. https://doi.org/10.1108/IJLM-01-2013-0001

Torabi, S. A., Giahi, R., & Sahebjamnia, N. (2016). An enhanced risk assessment framework for business continuity management systems. *Safety Science*, *89*, 201-218. https://doi.org/10.1016/j.ssci.2016.06.015

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research*, *53*(18), 5592-5623. https://doi.org/10.1080/00207543.2015.1037934

Van Echtelt, F. E. A., Wynstra, F., & Van Weele, A. J. (2007). Strategic and Operational Management of Supplier Involvement in New Product Development: A Contingency Perspective. *IEEE Transactions on Engineering Management*, *54*(4), 644-661.

Van Echtelt, F. E. A., Wynstra, F., Van Weele, A. J., & Duysters, G. (2008). Managing supplier involvement in new product development: A multiple-case study. *Journal of Product Innovation Management*, *25*(2), 180-201. https://doi.org/10.1111/j.1540-5885.2008.00293.x

Von Haartman, R., & Bengtsson, L. (2015). The impact of global purchasing and supplier integration on product innovation. *International Journal of Operations and Production Management*, *35*(9), 1295-1311. https://doi.org/10.1108/IJOPM-03-2015-0128

Wagner, S. M. (2010). Supplier traits for better customer firm innovation performance. *Industrial Marketing Management*, *39*(7), 1139-1149. https://doi.org/10.1016/j.indmarman.2009.12.001

Wagner, S. M. (2012). Tapping Supplier Innovation. *Journal of Supply Chain Management*, *48*(2), 37-52. https://doi.org/10.1111/j.1745-493X.2011.03258.x

Wagner, S. M., & Hoegl, M. (2006). Involving suppliers in product development: Insights from R&D directors and project managers. *Industrial Marketing Management*, *35*(8), 936-943. https://doi.org/10.1016/j.indmarman.2005.10.009

Waters, D. (2007). Supply Chain Risk Management - Vulnerability and Resilience in Logistics - Knovel. In *Supply Chain Risk Management - Vulnerability and Resilience in Logistics*. Kogan Page.

Wieland, A., & Wallenburg, C. M. (2013). The influence of relational competencies on supply chain resilience: A relational view. *International Journal of Physical Distribution and Logistics Management*, *43*(4), 300-320. https://doi.org/10.1108/IJPDLM-08-2012-0243

Wieteska, G. (2014). Supplier risk in building B2B relationships - portfolio models approach. *International Journal of Supply Chain and Operations Resilience*, *1*(1), 104. https://doi.org/10.1504/ijscor.2014.065455

Wieteska, G. (2019). How to Measure the Supplier Involvement? *Gospodarka Materiałowa i Logistyka*, *8*, 29-39. https://doi.org/10.33226/1231-2037.2019.8.4

Wynstra, F., & Pierick, E. T. (2000). Managing supplier involvement in new product development: A portfolio approach. *European Journal of Purchasing and Supply Management*, *6*(1), 49-57. https://doi.org/10.1016/S0969-7012(99)00035-0

Wynstra, F., Van Weele, A., & Weggemann, M. (2001). Managing supplier involvement in product development: Three critical issues. *European Management Journal*, *19*(2), 157-167. https://doi.org/10.1016/S0263-2373(00)00090-6

Ye, Y., Huo, B., Zhang, M., Wang, B., & Zhao, X. (2018). The impact of modular designs on new product development outcomes: the moderating effect of supply chain involvement. *Supply Chain Management*, *23*(5), 444-458. https://doi.org/10.1108/SCM-01-2018-0021

Yu, W., Hou, G., Xia, P., & Li. J. (2019). Supply chain joint inventory management and cost optimization based on ant colony algorithm and fuzzy model. *Tehnicki Vjesnik - Technical Gazette*, *26*(6), 1729-1737. doi: https://doi.org/10.17559/TV-20190805123158

Zeng, B., & Yen, B. P. C. (2017). Rethinking the role of partnerships in global supply chains: A risk-based perspective. *International Journal of Production Economics*, *185*(June 2016), 52-62. https://doi.org/10.1016/j.ijpe.2016.12.004

Zsidisin, G. A., Melnyk, S. A., & Ragatz, G. L. (2005). An institutional theory perspective of business continuity planning for purchasing and supply management. *International Journal of Production Research*, *43*(16), 3401-3420. https://doi.org/10.1080/00207540500095613

Zsidisin, G. A., & Smith, M. E. (2005). Managing supply risk with early supplier involvement: A case study and research propositions. *Journal of Supply Chain Management*, *41*(4), 44-57. https://doi.org/10.1111/j.1745-493X.2005.04104005.x

Grazyna Kędzia
University of Lodz,
Faculty of Magament
Lodz,
Poland
grazyna.wieteska@uni.lodz.pl
ORCID 0000-0002-5616-3234

IwonaStaniec
Lodz University of Technology,
Institut of Management,
Lodz,
Poland
iwona.staniec@p.lodz.pl
ORCID 0000-0002-5580-5450

Appendix 1

Table 4. Research instrument: survey questions and references

Construct	Item		References	Loading
Supplier involvement in product development (SIPD)	Question: To what extent do you agree with the statement below?Scale: 1–5. Answers: 1 – strongly disagree; 5 – strongly agree			
	SIPD 1*	Cooperation with the supplier was based on partner relationships	(Hoegl & Wagner, 2005; S. Li et al., 2010; Wagner, 2012)	Reject EFA
	SIPD 2*	Cooperation with the supplier was based on jointly set goals	(Hoegl & Wagner, 2005; Kähkönen et al., 2015; Parker et al., 2008; Wagner, 2010)	Reject EFA
	SIPD 3	Cooperation with the supplier was based on mutual willingness to develop a long-term relationship	(Primo & Amundson, 2002; Song et al., 2011)	0.695
	SIPD 4*	Cooperation with the supplier was based on equitable risk and reward sharing	(McGinnis & Vallopra, 1999)	Reject EFA
	SIPD 5	Cooperation with the supplier was based on sharing technical/technological knowledge	(Chien & Chen, 2010; Hoegl & Wagner, 2005; Jayaram, 2008; McGinnis & Vallopra, 1999)	0.668
	SIPD 6	Cooperation with the supplier was based on sharing cost information	(Chien & Chen, 2010; Hoegl & Wagner, 2005; Jayaram, 2008; McGinnis & Vallopra, 1999)	0.692
	SIPD 7*	Cooperation with the supplier was based on sharing physical assets, for example, a plant or only equipment	(Birou & Fawcett, 1994; Bozdogan et al., 1998; McGinnis & Vallopra, 1999; Parker et al., 2008)	Reject EFA
	SIPD 8	Cooperation between the company's employees and the supplier's employees was very close. For example, the cross-functional product development team consisted of employees of both the company and the supplier.	(I. S. Fan et al., 2000; Primo & Amundson, 2002)	0.797

	SIPD 9	Cooperation with the supplier was based on mutual support in improving, e.g. quality or production capacity, through specific activities: educational and training programmes, evaluations, or audits	(Birou & Fawcett, 1994; Ragatz et al., 2002)	0.66
	SIPD 10	Cooperation with the supplier involved various levels of management, e.g. strategic and operational	(McGinnis & Vallopra, 1999; McIvor et al., 2006; Van Echtelt et al., 2007, 2008)	0.955
Communication during supplier involvement (CSI)	Question: To what extent do you agree with the statement below?Scale: 1–5. Answers: 1 – strongly disagree; 5 – strongly agree			
	CSI1	Communication was frequent	(Culley et al., 1999; Hartley et al., 1997; Hoegl & Wagner, 2005; Jayaram, 2008)	0.791
	CSI2	Communication was intensive (e.g. a large volume of information/knowledge was exchanged)	(Flynn et al., 2010; Hoegl & Wagner, 2005; Najafi et al., 2013)	0.777
	CSI3	Communication took place in a friendly atmosphere	(Wagner & Hoegl, 2006)	0.687
	CSI4*	Communication involved employees from various departments of the company and employees from various departments of the supplier	(Birou & Fawcett, 1994; Dowlatshahi, 1998; Lakemond et al., 2006; Maffin & Braiden, 2001; Parker et al., 2008; Swink, 1999)	Reject EFA
	CSI5	Cooperation with the supplier was based on communication using traditional methods, e.g. telephone, fax, or face-to-face meetings	(Birou & Fawcett, 1994; Culley et al., 1999; Hartley et al., 1997)	0.595
	CSI6*	Cooperation with the supplier was based on communication with the use of advanced information and communication tools	(Huang et al., 2003; D. Tang et al., 2004)	Reject EFA

Supply chain resilience (SCRES)	Question: To what extent do you agree with the statement below? Scale: 1–5 Answers: 1 – strongly disagree; 5 – strongly agree			
	SCRES1	Our firm's supply chain is able to adequately respond to unexpected disruptions by quickly restoring its product	Construct adopted from (Ponomarov, 2012, p. 76)	0.895
	SCRES2	Our firm's supply chain can quickly return to its original state after being disrupted		0.916
	SCRES3*	Our firm's supply chain can move to a new, more desirable state after being disrupted		Reject EFA
	SCRES4*	Our firm's supply chain is well-prepared to deal with the financial outcomes of supply chain disruptions		Reject EFA
	SCRES5	Our firm's supply chain has the ability to maintain a desired level of control over structure and function at the time of disruption		0.854
	SCRES6	Our firm's supply chain has the ability to extract meaning and useful knowledge from disruptions and unexpected events		0.692
Company performance (CP)	Question: How well does your organisation perform relative to major competitors in terms of…? Scale: 1–5. Answers: 1 – very badly; 5 – very well			
	CP1	Net profit	(Flynn et al., 2010; Tipu & Fantazy, 2014)	0.972
	CP2	Sales growth	(Petersen et al., 2005; Tipu & Fantazy, 2014)	0.887
	CP3	Lead time for fulfilling customers' orders	(Flynn et al., 2010; Tipu & Fantazy, 2014)	0.789
	CP4	Customer satisfaction	(Flynn et al., 2010; Najafi et al., 2013; Tipu & Fantazy, 2014)	0.445

* Item dropped after analysis