The impact of procurement digitalization on supply chain resilience: empirical evidence from Finland

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Abstract

Purpose – The purpose of this study is to investigate the role of procurement digitalization in reducing uncertainty in the supply chain (SC) and how it relates to mitigating SC risks and improving SC resilience (SCRES).

Design/methodology/approach – Based on survey data collected from the procurement functions of 147 Finnish firms, this study conceptualizes data analytics, information sharing and procurement process digitalization as drivers of procurement digitalization and investigates their impact on SC risk management and SCRES by using partial least squares path modeling.

Findings – Procurement digitalization through data analytics and digital process maturity requires effective information sharing among SC partners and SC risk management to be able to improve SCRES. Procurement digitalization increases information-processing capacities and reduces uncertainty in the SC.

Originality/value – This study contributes to the understanding on the relationships between procurement digitalization and SCRES.

Keywords Procurement digitalization, Supply chain resilience, Data analytics, Information sharing, Information processing theory

Paper type Research paper

Introduction

Procurement digitalization is an emerging topic related to the digital transformation of supply chains (SCs) (Handfield *et al.*, 2019; Srai and Lorentz, 2019; Seyedghorban *et al.*, 2020). Essentially, the use of digital technologies – that is, digitalization (Srai and Lorentz, 2019) – means that SCs and procurement are becoming smarter through the integration of increasing amounts of data, complex, interconnected technological systems and new data-related capabilities (Wu *et al.*, 2016).

In the era of digitalization, procurement executives are increasingly reporting SC disruptions and a lack of sufficient SC resilience (SCRES), for example, because of the COVID-19 pandemic (van Hoek, 2020). The lack of resilience within SCs increases vulnerability in firms and decreases their resistance to disruptions. From a managerial perspective, the increased utilization of data and advanced technologies within SCs means that decision-making can be more data-driven and technology-assisted, and as a result, potential risks and disruptions become more visible and collectively manageable at the SC level. Recently, the role of digitalization in risk mitigation and the improvement of resilience in SCs has been intensively studied (Ivanov *et al.*, 2019; Fischer-Preßler *et al.*, 2020; Spieske and Birkel, 2021; Zouari *et al.*, 2021). These investigations illustrate that the adoption of novel digital technologies could result in substantial benefits for managing SC disruptions, and this is the main reason why the impact of digitalization on SCs should be researched further.

However, research on the digitalization of SCs has not specifically considered the role of procurement digitalization and its derived impact on SCRES and operational SC risk management (SCRM). Furthermore, while information processing in the procurement function is acknowledged as crucial in, for example, the integration of global sourcing between business units (Trautmann *et al.*, 2009), studies taking an information processing view on procurement digitalization are rare (Fan *et al.*, 2017).

While many studies have discussed the general influence of digitalization on SCs and procurement (Bienhaus and Haddud, 2018; Büyüközkan and Göçer, 2018; Colicchia *et al.*, 2019; Srai and Lorentz, 2019; Fischer-Preßler *et al.*, 2020; Zekhnini *et al.*, 2021), it is particularly notable that empirically-obtained considerations of the procurement function are limited. Furthermore, the significance of research on the potential interplay of procurement digitalization and SCRES is also

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illustrated by the numerous negative effects that SC disruptions may cause for firms (Christopher and Lee, 2004; Hendricks and Singhal, 2005; Wagner and Bode, 2008) and how controlling disruptions in the SC may improve firm performance and competitiveness (Thun and Hoenig, 2011; Wieland and Wallenburg, 2012). Based on reports from procurement executives studying the impact of various aspects of digitalization on operational SCRM and SCRES is highlighted as a promising research context in post-COVID-19 SCs (van Hoek, 2020).

By analyzing cross-sectional survey data collected from the procurement functions of 147 Finnish firms, this study conceptualizes the digital maturity of procurement processes, the use of data analytics and information sharing as underlying elements of procurement digitalization and provides evidence about their influence on SCRES. The results contribute to an understanding of how the mitigation of risks and resilience in the SC may be improved through procurement digitalization. By taking an information-processing view, the results of this study clarify the importance of procurement digitalization in improving the resilience of upstream SCs. Overall, the results obtained from a procurement perspective also highlight opportunities for further research on digitalization, operational SCRM and SCRES. For managers, this study offers encouraging evidence on how to engage in increased procurement digitalization to manage risks and increase resilience in the SC.

Conceptual background

Information processing theory

Information processing theory (IPT) posits that increasing task uncertainty in organizations must be complemented by an increased amount of real-time information processing to achieve given performance objectives (Galbraith, 1973). Information processing needs may be generated by various sources of uncertainty related to external and internal environment of the procurement organization, such as various organizational tasks or transactions between stakeholders (Premkumar *et al.*, 2005; Tushman and Nadler, 1978). As such, information processing needs can be facilitated by either reducing the amount of information to be processed or increasing information processing capacity. According to Galbraith (1974), the organization must adopt at least one of four design strategies to maintain performance when faced with uncertainty:

1 creation of slack resources;
2 creation of self-contained tasks;
3 investment in vertical information systems; or
4 creation of lateral relations.

A fit perspective suggests that optimal performance can be achieved by finding the fit between information-processing needs and capacity (Tushman and Nadler, 1978; Premkumar *et al.*, 2005).

Organizations can be understood as information processing systems (Tushman and Nadler, 1978). According to Fan *et al.* (2017), information processing systems are divided into three subprocesses in the SCRM context:

1 risk information sharing;
2 risk analysis and assessment; and
3 risk sharing mechanism.

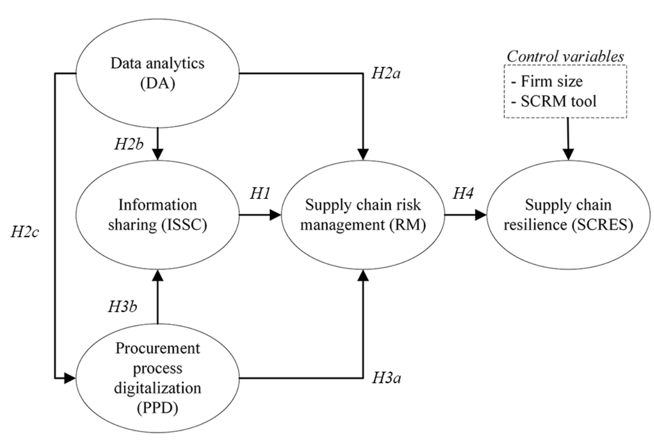
The purpose of the risk information sharing process is to collect SC risk information for analysis and assessment. Moreover, the risk-sharing mechanism expedites the processing of risk knowledge into operative SCRM decision-making processes by aligning incentives and coordinating the behavior of SC partners. Therefore, information collection, its conversion into knowledge and its subsequent sharing and application in the SC are fundamental attributes of SCs that contribute to information-processing capabilities and managing uncertainty in the SC (Tushman and Nadler, 1978; Fan *et al.*, 2017).

Based on IPT, we argue that procurement digitalization contributes to holistic information processing performance through the collection, assessment and application of procurement-related information to reduce uncertainty in the SC. As proposed by Fan *et al.* (2017), information can be collected by possessing information-processing capabilities and by engaging in interorganizational risk information sharing in the SC. While we distinguish between information processing needs and capabilities, we refrain from assessing the optimal fit between them in our model. Previous research supports the notion that information processing needs are demonstrated by risks and disruptions that are primarily caused by uncertainty in the SC (Bode *et al.*, 2011; Kauppi *et al.*, 2016). It is, thus, theorized that uncertainty can be alleviated by implementing procurement digitalization as an information-processing capability, as illustrated by the model in Figure 1. Ultimately, this reduction in uncertainty is expected to increase risk prevention and resilience in the SC (Fan *et al.*, 2017; Dubey *et al.*, 2021).

Procurement digitalization: procurement process digitalization, data analytics and information sharing

Procurement is primarily concerned with strategic supply management decisions and purchasing arrangements between buyers and potential suppliers that influence material, information and financial flows in the internal and external SC (Chen and Paulraj, 2004). The organizational transactions that initiate and advance the external resource flows relevant to the operations of the purchasing firm can be considered procedural by nature (van Weele, 2014). More specifically, we regard these procurement processes from a purchasing point of view: as transactions in buyer–supplier relationships that encapsulate

Figure 1 The conceptual model



the stages in the purchasing of asset flows (i.e. from price quotation to invoicing and payment).

It should be recognized that procurement processes can be greatly leveraged by the firm's implementation of information technology resources (Hallikas *et al.*, 2021). Much of the groundwork for technology use in procurement originates in the implementation of internet and e-procurement systems (Davila and Gupta, 2003). Therefore, the utilization of functional e-procurement requires technologies that promote the online acquisition of goods or services for private or public organizations. As stated by Trkman and McCormack (2010), e-procurement impacts the entirety of procure-to-pay processes from sourcing to payment.

Building on e-procurement, the development toward an increased level of digitalization within the procurement function is believed to withhold numerous opportunities to be taken advantage of by firms (Seyedghorban *et al.*, 2020). However, empirical research about the topic is still nascent. In one of the few recent publications regarding procurement digitalization, Srai and Lorentz (2019) categorized the impacts of digitalization based on basic and advanced forms of digitalization, which cover a wide variety of technologies. Evidently, the implementation of particularly advanced technologies (such as cloud technologies, big data analytics and artificial intelligence) in procurement processes is likely to notably impact procurement value drivers, such as the management of upstream SC transactions and the generation of supply-market knowledge. Digitalization is also understood to augment traditional procurement processes by supporting various technology-driven capacities for the monitoring of procurement activities (Bienhaus and Haddud, 2018). Similarly, Viale and Zouari (2020) provided early evidence of the impact of digitalization on procurement via robotic process automation.

The amount of available data is expanding in the form of big data, which is predicted to lead to a transformation in SC-related analytics (Kache and Seuring, 2017). According to Souza (2014), the purpose of SC analytics (SCA) is to use information and analytical tools to improve decision-making in the context of matching supply and demand. Moreover, the nature of the data analytical approach in SCs is understood to consist of descriptive, predictive and prescriptive analytics (Wang *et al.*, 2016). Also, developments in the literature have led to the nascent conception of procurement analytics, which calls for a more intricate data analytics-based approach to sourcing and procurement-related decisions, for example, by using real-time data to analyze spend, contracts and supply risks (Handfield *et al.*, 2019). Although analytics in SC management (SCM) is not necessarily a brand-new phenomenon, the future of data-driven SCA is estimated to have enormous benefits for business process improvements, particularly when firms start integrating big data (Wang *et al.*, 2016). Past empirical research has supported this notion by evidencing that big data analytics influences SC performance and value creation, which can be considered indicative of the importance of data analytics in the procurement context (Trkman *et al.*, 2010; Chen *et al.*, 2015; Hallikas *et al.*, 2021).

Due to SC processes being relational and interdependent by definition, specific importance must be placed on the nature of the information exchange mechanisms that are achieved through the adoption of new and complementary technologies in SCs. While it has long been established that the bidirectional flow of information is one of the core activities related to efficient SCM processes (Mentzer *et al.*, 2001), information sharing in the SC remains as an increasingly important area of theoretical and practical research (Colicchia *et al.*, 2019). When integrating information flows, it is crucial to consider the degree of operational, tactical and strategic information sharing between SC partners (Rai *et al.*, 2006). Furthermore, information sharing can be used to coordinate decisions or manage uncertainty in the SC (Fan *et al.*, 2017). It can also be suggested that an important part of moving toward digitalization in SCs is becoming connected to integrated technological mechanisms for information sharing among SC partners. This is due to the potential for information sharing to be enhanced by various information technologies used in SCs (Fawcett *et al.*, 2007). On the whole, information sharing can be summarized as the process of distributing sufficient amounts of relevant and timely knowledge between SC partners through the use of integrated IT infrastructure or other communications technology (Li *et al.*, 2006).

Supply chain risk management and supply chain resilience

SC risks are often regarded as a combination of the probability and impact of specific risk consequences (Ritchie and Brindley, 2007). Prior research has established that the origins of SC risks can be traced to numerous sources and categories of exposure to vulnerabilities and adverse contingencies in the SC (Manuj and Mentzer, 2008). As such, the vertical interdependency of SC processes implies that the disruptions caused by risk realization are not always contained within organizational boundaries. Hence, one of the important dimensions of managing SC risk is the devastating ripple effects that might be extended to other internal processes or even further upstream or downstream in the SC (Norrman and Jansson, 2004). This notion is critical from the point of view of the procurement function because it revolves around managing contractual supply transactions that bidirectionally affect material, information and financial flows throughout the SC. Because procurement-related risks are often included in the more holistic approach to SCRM, they are principally indicated by the effects that upstream supply and operational risks may have on the entirety of SC processes, which may lead to scenarios in which customer demands are insufficiently satisfied (Zsidisin *et al.*, 2004). For example, specific SC risks that can be linked to procurement may include various supply-side perturbations, such as faulty suppliers and problems in supplier relationships (Wagner and Bode, 2006) or late deliveries and sudden changes in prices and costs (Hallikas and Lintukangas, 2016).

While managing supply-related risks is an important consideration in SCRM, it should be noted that SCRM also reflects the management of risks that are outside the scope of procurement, such as demand and manufacturing risks (Tummala and Schoenherr, 2011). However, as this study specifically investigates procurement digitalization, it is critical to consider risk prevention in the SC, which can be directly related to procurement (Hallikas and Lintukangas, 2016). Overall, SCRM can be defined as collaborative risk management processes linked to increased continuity and profitability (Fan and Stevenson, 2018) and decreased vulnerability (Jüttner, 2005). Consequently, the purpose of SCRM is to improve methods and strategies in the areas of SC risk identification, assessment, treatment and monitoring (Manuj and Mentzer, 2008).

SCRES is defined as the adaptive capacity of the SC to prepare, respond and recover when faced with SC disruptions (Ponomarov and Holcomb, 2009). Prior research has suggested that SCRES is linked to multiple relational SC capabilities and practices that can support SCs during disruptions (Ali *et al.*, 2017; Chowdhury *et al.*, 2019). For example, early literature found that SCRES consists of aspects such as SC re-engineering, collaboration, agility and SCRM culture (Christopher and Peck, 2004). Scholars have further inspected often interdependent SCRES antecedents, such as flexibility, redundancy, visibility, velocity and information sharing in the SC (Jüttner and Maklan, 2011; Brandon-Jones *et al.*, 2014; Tukamuhabwa *et al.*, 2015). As such, it is evident that SCRES is partly driven by the improvement of relational SC processes, which also contribute to the prevention of SC risks (Ambulkar *et al.*, 2015; El Baz and Ruel, 2021). However, it is important to note that SCRES additionally reflects the reactive capacity for performance recovery (Sheffi and Rice, 2005) and adaptation after unanticipated SC disruptions, which distinguishes it from SCRM as a concept (Pettit *et al.*, 2010).

The role of digitalization in improving supply chain risk management and supply chain resilience

Digitalization and technology-assisted management of information in SCs can be argued to have considerable potential for SCRM and SCRES (Spieske and Birkel, 2021). As such, the extant literature has displayed evidence that more efficient managing of risks and disruptions in the SC can be enabled by supporting operational decision-making with the usage of information and communications technology in the SC; however, the current knowledge can still be considered insufficient due to how little research has been conducted (Fischer-Preßler *et al.*, 2020).

Efforts to mitigate SC disruptions may benefit from the implementation of decentralized and interorganizational IT systems among SC partners, for example, by reducing information asymmetries and improving disruption identification in the SC (Giannakis and Louis, 2011). This notion is also supported by the perceived importance of real-time visibility in dealing with SC disruptions (Blackhurst *et al.*, 2005), which can be increased with the use of collaborative technology and information sharing (Barratt and Oke, 2007). Furthermore, Ivanov *et al.* (2019) examined the relationship between digitalization and the ripple effects of SC risks. They showed that the use of novel technological approaches, such as using big data analytics, may benefit firms by controlling SC risks and enhancing resilience in the SC, both proactively and reactively. Similar conclusions were put forward by Baryannis *et al.* (2019), who exposed the inherent potential of researching SCRM within the big data analytics dimension by reviewing and analyzing state-of-the-art research. Moreover, it has been evidenced that increasing digital maturity and adopting digital tools in SCs positively influence SCRES (Zouari *et al.*, 2021). Another benefit of digital technology is that it can be extended to joint SCRM practices related to information sharing, which may assist in functional SCRM processes (Li *et al.*, 2015; Fan *et al.*, 2017). However, studies have also predicted that the implementation of advanced technologies by businesses will result in new and additional uncertainties, such as information security risks and increased susceptibility to cyberattacks, as dependency on digital infrastructure grows (Smith *et al.*, 2007; Smith, 2009). Therefore, it is implied that integrating digital technologies and new technology-related practices in SCM processes may be double-edged, even though benefits can be presently expected to outweigh increased risk exposure (Ivanov *et al.*, 2019).

Hypothesis development

Impact of information sharing on supply chain risk management

When linking the concept of SCRM to information sharing in SCs, it is important to consider the role of information processing and its effect on performance. IPT links information processing capability to better performance; thus, information sharing plays a significant role in risk prevention and SC disruption management (Fan *et al.*, 2017). In practice, the identification mechanisms of risk based on data analytics enable early warnings and monitoring of SC disruptions. However, there is also a need for effective information sharing between actors in the SC to respond to disruptions and enable organizations to take a proactive approach to threat and risk mitigation (Burnard and Bhamra, 2011). Information that affects risks and other parties must be shared between the parties in the SC to enable them to respond to the risks (Fan *et al.*, 2017). In terms of SC information sharing, we posit the following:

H1. The sharing of information in the SC has an effect on SCRM.

Impact of data analytics on supply chain risk management, information sharing and procurement process digitalization

The purpose of data analytics is to refine complex and often dispersed data into information that can support decision-making processes within the SC. By using data analytics, firms are able to increase their information-processing capacity, which may ultimately reduce uncertainty in the SC (Srinivasan and Swink, 2018). Past research has shown that data analytics on social media platforms may refine useful information about potential disruptions that can be used to improve SCRM, for example, by detecting and broadcasting real-time information that could be related to emerging SC disruptions before they are publicly acknowledged (Chae, 2015). Furthermore, various sources of data can be used in the SC risk analytics context to improve the proactivity and resilience of the SC (Ivanov *et al.*, 2019). Procurement data analytics can improve management of spend, contracts and supply markets that reduce uncertainty and SC risks (Handfield *et al.*, 2019).

Sharing information in the SC requires not only technology-based mechanisms but also data sources that are readily available, sufficient in quality and accurate that can be provided to SC partners when required (Zhou and Benton, 2007). Thus, it can be argued that the acquisition of data and analytically refining it into collectively usable information are at the center of transferring useful knowledge between trustworthy buyers and suppliers. As such, shared information between SC partners is often based on forecasted demand and sales data (Kembro *et al.*, 2017). Different types of predictive forecasting have been regarded as practical ways of using data analytics in SCs and can, therefore, be considered to contribute to information-sharing capabilities in SCs (Choi *et al.*, 2018). Furthermore, the potential range of different types of contextual data that are used in decision-making can be predicted to expand as the use of big data in SC processes increases (Kache and Seuring, 2017). This may allow different and previously unknown information to be shared between trusted SC partners.

Data analytics affects process development of companies that seek to find approaches to leverage management capabilities in companies' interfaces to SCs (Wang *et al.*, 2016). The shift is tied to wider digital transformation of the business that renew technical platforms and e-business processes for fluent operation in seller–customer interfaces (Zhu *et al.*, 2015). In this, increased demand for standardized data plans especially drives thorough changes, which assures utilization and extracting value of stored data (Acito and Khatri, 2014). Moreover, earlier studies have shown that digital procurement processes are driven by effects that emerge from both internal process monitoring and external market analytics, the latter of which play a larger role in change (Schriber and Löwstedt, 2020; Hallikas *et al.*, 2021). Thus, we can posit that:

H2a. Data analytics has an effect on SCRM.

H2b. Data analytics has an effect on information sharing in SCs.

H2c. Data analytics has an effect on procurement process digitalization.

Impact of procurement process digitalization on supply chain risk management and information sharing

The technological maturity of procurement processes may vary between traditional information technologies and more advanced digital procurement technologies (Srai and Lorentz, 2019). Principally, this means that improving the digital maturity of procurement processes enables potential SC partners to be more integrated in their strategic decision-making, which has several implications for enhanced SCRM. Therefore, technological maturity in procurement processes should imply more visibility and shared information between suppliers, which ultimately reduces uncertainty and the need for, for example, safety stocks (Christopher and Lee, 2004). The digitalization of SC processes also transforms how data is processed and makes it more efficient; hence, beneficial connections between procurement technology adoption and SCRM are further implied (Ivanov *et al.*, 2019). According to Fawcett *et al.* (2007), using information systems leads to better connectivity, which reduces uncertainty in the SC, leads to smaller inventories and increases responsiveness to customer requests. Consequently, digital procurement processes are also believed to offer several advantages related to, for example, organizational efficiency and complex decision-making processes (Bienhaus and Haddud, 2018), which can be theoretically projected to further assist the procurement function's contribution to risk management in the SC.

As established previously, information sharing is a core part of information integration among SC partners and is generally enabled through the collaborative usage of information technology and access to the internet (Swaminathan and Tayur, 2003; Rai *et al.*, 2006). Moreover, increased transparency and traceability due to digital technology use are thought to improve buyer–supplier relationships and increase the level of trust in procurement relationships (Bienhaus and Haddud, 2018). It has also been proposed that crucial barriers to collaboration in the SC are derived from a lack of technology, information and measurement systems (Fawcett *et al.*, 2008). Moreover, the influence of digital technology on collaborative processes can be argued to be primarily due to the increase in relationship performance that integration of advanced technologies in the SC may provide (Nasiri *et al.*, 2020). Therefore, we hypothesize the following:

H3a. The digitalization of procurement processes has an effect on SCRM.

H3b. The digitalization of procurement processes has an effect on information sharing in SCs.

Impact of supply chain risk management on supply chain resilience

Numerous studies have highlighted the role of SCRM in firms becoming aware of SC disruptions and mitigating them (Manuj and Mentzer, 2008; Ho *et al.*, 2015; Fan and Stevenson, 2018). Likewise, it can be suggested that the purpose of SCRM is to reduce risk effects and increase risk-specific knowledge, which ultimately enhances SCRES (Jüttner and Maklan, 2011). SCRM process practices have also previously been found to positively influence SCRES (El Baz and Ruel, 2021). Another key aspect that theoretically links SCRM and SCRES is their perceived interdependency, which is illustrated by the notion that creating an SCRM culture is one of the requisites of a resilient SC (Christopher and Peck, 2004; Chowdhury and Quaddus, 2016). Therefore, it can be proposed that:

H4. SCRM has an effect on SCRES.

Empirical study

Sample description

The sample was drawn from the financial information AMADEUS database, which includes companies registered in

Europe. The final sample was framed to cover Finnish manufacturing and retail sector companies of at least 100 employees and a turnover of at least €50m. The aim of election of respondents was to focus on personnel with the best knowledge of the companies' procurement operations, to whom the survey was then sent as an e-mail link. The questionnaire was sent to 383 different companies' procurement experts. A total of 147 companies provided responses to the survey, yielding a response rate of 38.4%. Based on their organizational status, the respondents were distributed as follows: top management = 21.8%, middle management = 46.3%, operational tasks = 11.6%, experts = 19.7% and other tasks = 0.7%. Table 1 illustrates the industries that included the final sample and their frequencies.

Before analyzing the conceptual model built on the basis of theory, we briefly explore how the companies in the sample currently use various procurement tools in terms of the mean value and % distribution of evaluations (Likert scale; 1 = strongly disagree 5 = strongly agree). As can be seen from the summary table (Table 2) regarding the selected tools and platforms, companies seem to make strong use of systems related to reporting and management of operational purchasing and procurement spend in particular. The utilization of systems in the processes of tactical/strategic procurement, supplier management and integration are, on the other hand, at a rather low maturity level in companies. Also, the use of SCRM tools is on average quite low maturity among the companies in the sample.

The survey instrument and model specification

The survey constructs were derived from the literature. From a digitalization perspective, the survey includes three constructs:

1. data analytics ("DA") (Brinch *et al.*, 2018);
2. information sharing ("ISSC") (Fan *et al.*, 2017); and
3. digitalization of the purchasing process ("PPD") (van Weele, 2014).

The survey instrument also contains constructs for risk management ("RM") (Hallikas and Lintukangas, 2016) and resilience ("SCRES") in SCs (Ambulkar *et al.*, 2015). DA probes the level of utilization of automated data storage, extraction, transformation and reporting procedures in a firm. ISSC measures information sharing between SC partners, where the type of information, frequency of information sharing and expected level of integration have been probed by multiple items. PPD measures the utilization of digital tools in procurement processes that cover activities from tendering to invoicing. RM focuses on measuring upstream side risk prevention of the firms that are related to product quality, availability and prices. SCRES measures firms' capabilities to recognize and adapt their SC operations in response to disruptions in the SC. Finally, firm size and the adoption of

Table 1 Sample description

Industry	Sample size *(N = 147)*	No. of employees *(avg.)*
Manufacture of chemical products	12	1,603
Manufacture of paper and wood products	12	2,959
Resale	34	1,187
Manufacture of machinery and equipment	26	2,311
Plastics and metal industry	15	1,116
Manufacture of food products	8	949
Construction industry	27	839
Other	13	3,251

Table 2 Utilization of procurement tools and platforms in companies (% share of respondent companies at different levels based on a 1–5 scale)

Purchasing and supply managements tools	1	2	3	4	5	Mean	SD
The organization has ERP or purchase order system for purchase orders and reporting	6.1	4.8	5.4	16.3	67.3	4.34	1.16
IT systems are integrated with suppliers systems for business document transfers (EDI)	28.6	21.8	22.4	21.8	5.4	2.54	1.26
Purchase contracts are available and terms easily verifiable in contract management system	10.9	25.9	32.7	21.8	8.9	2.92	1.12
The organization's spend (value of purchases) can be reported and analyzed with a reporting tool	1.4	8.2	16.3	31.3	43.0	4.06	1.02
Procurement uses an electronic tendering systems for RFx:s	36.7	20.4	19.1	17.0	6.8	2.36	1.31
The organization uses Supplier relationship management (SRM) information systems	34.0	22.4	19.1	19.0	4.8	2.40	1.28
The organization uses product data management systems	8.9	20.4	17.7	32.0	21.0	3.36	1.28
The organization uses real-time supply chain risk management tool for risk identification and anticipation	32.0	39.5	21.7	4.8	2.0	2.04	0.95

real-time SCRM tools to anticipate disruptions were applied to model as control variables. The measurement items, scales and sources of the survey instrument are presented in detail in Appendix.

The constructs were specified in the model as both first-order reflective and formative measurements. The reflective measurements – DA, ISSC, RM and SCRES – form the empirical construct by measuring respondents' perceptions of the effects of the constructs (Diamantopoulos *et al.*, 2008; Kline, 2011). The formative measurement of PPD describes the actual digitalization level of firm's purchasing function, which includes independent processes (Cenfetelli and Basselier, 2009; Diamantopoulos, 2011). To test the hypotheses, the PLS estimator provides a robust approach for extracting results from path models when the data has some level of non-normality or collinearity, a relatively low sample size, and when the model includes formative measures (Henseler *et al.*, 2014; Hair *et al.*, 2017; Hair *et al.*, 2019b). The empirical study was conducted using SmartPLS 3.0 software.

Assessment of the survey instrument

The research instrument was assessed in terms of construct reliability ("CR"), factor structure, measurement validity by the average variance extracted ("AVE") and discriminant validity (Fornell and Larcker, 1981; Gefen and Straub, 2005; Henseler *et al.*, 2009) (Table 3). The CRs of the applied latent constructs (Table 3) achieve good reliability ranging from 0.845 to 0.936 (very high), which are clearly above critical values of 0.50 for acceptable and 0.70 for good reliability (Little *et al.*, 2002; Kline, 2011). The factor structure of the PLS-model was assessed by significance and weight of loadings and cross-loadings. The loadings of reflective constructs were significant ($p < 0.001$), ranging from 0.600 to 0.842, indicating acceptable structure. The measurement validity of all the latent constructs reaches also acceptable level ranging from 0.529 to 0.627 in comparison to critical value 0.50 of AVE (Fornell and Larcker, 1981). The discriminant validity of the measurement model was assessed by the cross-loadings of the measurement items, the square root of AVE and the Heterotrait–Monotrait (HTMT) criterion (i.e. the Fornell–Larcker criterion) (Gefen and Straub, 2005; Henseler *et al.*, 2009; Hair *et al.*, 2019b). By the tests, the measurement items were highly loaded to the certain latent factors and the cross-loadings varied from 0.038 to 0.511. Also, the square roots of AVE demonstrate acceptable discriminant validity of the measurement model being higher than the correlations between the latent constructs. Finally, the HTMT between latent factors did not exceed the critical value for HTMT (<0.90), varying from 0.068 to 0.647.

PLS-path modeling

The PLS-path model tests the causal effects empirically (Table 4), and its structure follows the conceptual model. In this study, the PLS-model was extracted using a bootstrap sample of n = 147 (equal to the original sample) and a resampling rate of 5,000 repetitions, which are adequate for estimating the effects for hypothesis testing (Henseler *et al.*,

Table 3 Measurement reliabilities

	Loading	*t*-value	*p*-value	Mean	SD	CR	AVE
Data analytics (DA)						*0.936*	*0.618*
DA 1	0.798	26.833	***	2.823	1.123		
DA 2	0.797	22.689	***	3.293	1.150		
DA 3	0.831	31.232	***	2.755	1.146		
DA 4	0.814	28.91	***	2.324	1.021		
DA 5	0.747	19.119	***	2.592	1.061		
DA 6	0.842	29.489	***	2.796	0.990		
DA 7	0.754	14.608	***	2.510	0.999		
DA 8	0.730	15.218	***	2.667	0.971		
DA 9	0.754	13.96	***	2.170	0.950		
Information sharing in supply chain (ISSC)						*0.886*	*0.529*
ISSC 1	0.649	9.836	***	3.442	1.011		
ISSC 2	0.832	25.786	***	3.442	0.874		
ISSC 3	0.773	21.747	***	3.388	1.006		
ISSC 4	0.748	18.097	***	3.082	0.877		
ISSC 5	0.768	17.818	***	3.483	0.844		
ISSC 6	0.699	11.114	***	3.367	0.834		
Procurement process digitalization[f] (PPD)						–	–
PPD 1	0.407	2.719	**	2.845	1.342		
PPD 2	0.434	3.018	**	2.878	1.272		
PPD 3	0.720	5.914	***	3.090	1.208		
PPD 4	0.407	2.612	**	2.785	1.322		
PPD 5	0.772	7.463	***	3.905	1.164		
PPD 6	0.845	7.206	***	3.430	1.292		
PPD 7	0.625	4.787	***	3.180	1.263		
PPD 8	0.456	3.27	***	4.227	0.864		
Resiliency (SCRES)						*0.871*	*0.627*
SCRES 1	0.824	23.431	***	3.823	0.687		
SCRES 2	0.774	17.908	***	3.279	0.789		
SCRES 3	0.797	16.975	***	3.520	0.767		
SCRES 4	0.772	16.881	***	3.449	0.834		
Supply chain risk management (RM)						*0.845*	*0.578*
RM 1	0.802	22.912	***	3.891	0.775		
RM 2	0.805	22.761	***	3.750	0.756		
RM 3	0.698	14.791	***	3.741	0.800		
RM 4	0.729	17.766	***	3.796	0.746		

Notes: n = not significant; *statistically significant at $p < 0.05$; **statistically significant at $p < 0.01$; ***statistically significant at $p < 0.001$
[f]Formative construct

2009). The quality of the structural model was validated by the following aspects:

- collinearity and overall fit;
- explanatory power and predictive relevance;
- significance of paths; and
- endogeneity.

Collinearity of the latent constructs was not found by the variance inflation factor (VIF), as the highest value of the inner VIF =1.632 remained below the critical value of VIF = 5 (Hair *et al.*, 2019a). The goodness and explanatory power of the PLS-path model can be assessed by observing endogenous variables regarding the proportion of the variance explained *R*-squared ("*R*2"), the predictive relevance Q-squared ("Q2") and the

Table 4 Direct effects in the default model to test the hypotheses

Hypothesis	Path	β	*T Statistics*	*p-Values*
H1	ISSC → RM	0.302	2.302	*
H2a	DA → RM	0.053	0.481	n
H2b	DA → ISSC	0.48	7.14	***
H2c	DA → PPD	0.404	5.381	***
H3a	PPD → RM	0.04	0.301	n
H3b	PPD → ISSC	0.247	3.224	**
H4	RM SCRES	0.435	5.396	***
Post hoc tests: total effects				
Total effect	DA →→ SCRES	0.338	4.311	***
	ISSC →→ SCRES	0.132	1.934	n
	PPD →→ SCRES	0.234	2.100	*

Notes: n = not significant; *statistically significant at $p < 0.05$; **statistically significant at $p < 0.01$; ***statistically significant at $p < 0.001$

sizes and significances of the path coefficients in the structural model (Astrachan *et al.*, 2014). In practice, *R*2 measures the proportion of the variance captured in the endogenous latent constructs, whereas the Q2 is an indicator for accuracy prediction of the endogenous constructs and out-of-sample generalizability potential of the model (Hair *et al.*, 2019a; Sarstedt *et al.*, 2014). The Q2 must be positive for endogenous latent variables before any predictive relevance of the structural model can be manifested where the critical values are at 0.25 and 0.50, demonstrating the medium and large accuracy, respectively (Hair *et al.*, 2019a). The R2s for the latent variables in the path model were ISSC = 0.387, PPD = 0.164, SCRES = 0.318 and RM = 0.127, whereas the Q2 for the endogenous variables were ISSC = 0.191, PPD = 0.051, SCRES = 0.180 and RM = 0.066. The explanatory power and predictive accuracy of the model are acceptable, but they vary from good to rather low because of the relatively small sample size and complexity of the phenomenon, which includes multiple influences outside the tested model (Abelson, 1985; Prentice and Miller, 1992). Furthermore, the test statistics also support the assumption that the model has out-of-sample predictive relevancy and some generalizability potential of the results. Finally, contamination of the model by endogeneity and insufficient sample creates risk for faulty conclusions by the statistics if those features of modeling are neglected. Sample sizes in relation to model complexity and effect size influence also on the quality of the PLS-modeling. The "10-times rule" provides a basic rule of thumb by which the minimum count of observations equals 10 times the maximum number of paths pointing to the latent in the inner or outer model (Hair *et al.*, 2011) by which the requirement for sample size is 90 at a minimum. The statistical power of the sample by effect sizes (f-squared, "f2") of *significant paths* in the inner model has critical values of 0.02, 0.15 and 0.35 indicating small, medium and large effect (Sullivan and Feinn, 2012; Hair *et al.*, 2017; Haverila *et al.*, 2020). By the f2 statistics, effect sizes vary from small to medium effect (f2min = 0.03, f2max = 0.31), which indicates meaningful relations and potential of the sample to provide enough statistical power. At the final stage, common method bias was tested by the construct-to-construct full collinearity test for assessing overall reliability of results where the critical value for not serious common method bias is VIF < 3.3 (Kock, 2017; Baumgartner *et al.*, 2021). The full collinearity test shows that VIF of the model varies between $VIF_{min} > 1.070$ and $VIF_{max} < 1.603$, indicating no common method bias issues in the model.

The default model (Table 4) shows that ISSC has a statistically significant positive influence on risk management, which confirms *H1*. Based on the empirical model, DA does not have an influence on RM, but it still has a strong, statistically significant positive effect on ISSC and PPD, by which we reject *H2a* and confirm *H2b* and *H2c*. Based on our findings, PPD has no effect on RM, but it has a relatively strong, positive effect on ISSC. Thus, we reject *H3a*, whereas *H3b* is confirmed. Finally, the model shows that RM has a strong, statistically significant positive effect on SCRES, which confirms *H4*. Overall, the model seems to explain how procurement digitalization drives the resiliency of SCs, in which information sharing and risk management have significant mediator roles. The model also shows that the DA activities have a major role as an enabler for the risk and resiliency management procedures where the ISSC increases transparency between actors. The post hoc tests regarding the mediation effects show that the total effects of digitalization elements by DA and PPD on SCRES exist in this data, indicating significant role of RM as source of SC resiliency. By the findings, the ISSC seems to have leveraging role for RM but not specific effects on SCRES.

The dependent variable SCRES was controlled for company size and utilization of risk management systems, which did not indicate statistically significant influences at a *p*-value of <0.05.

Discussion

Theoretical contributions

The contributions of the results are twofold:

1 We present an empirically validated model that displays the impact of procurement digitalization on SCRES.
2 We use IPT to predict how procurement digitalization decreases uncertainty and improves information processing capacities of the SC to mitigate SC risks and increase its resilience.

The findings of this study build on SC theory and practice by demonstrating how SC upstream digitalization benefits disruption mitigation and recovery among SC partners and points out the role of information sharing in achieving SCRES in line with Colicchia *et al.* (2019).

First, the results suggest that the use of data analytics and procurement process digitalization positively influences information sharing and that information sharing positively affects SCRM. Furthermore, the results posit that SCRM has a positive influence on SCRES. As such, this study advances extant theory by providing empirical evidence that procurement digitalization through data analytics and digital process maturity requires effective information sharing among SC partners to improve risk mitigation and enhance SCRES.

The results of this study support the notion that increasing technological maturity of procurement to share proprietary information between SC partners improves anticipation of SC disruptions and the capacity to respond quickly to potential issues in the SC. Similarly, previous literature has found that risk information sharing in the SC has positive implications for SCRM and SCRES; as such, this study is also aligned with previous results. For example, prior research has found that a joint information-sharing approach to the management of SC risk between SC members has positive implications for financial performance (Li *et al.*, 2015) and that it supports risk analysis and assessment (Fan *et al.*, 2017). It has also been argued that certain social media platforms can be used as sources of risk mitigation in shared information contexts by SC partners through real-time monitoring, sensing and collaboration during disruptive SC events (Chae, 2015). Also, risk information sharing has been encapsulated within concepts such as collaboration and SC visibility, which have been proposed to mitigate SC risks and improve SCRES (Christopher and Peck, 2004; Pettit *et al.*, 2010; Jüttner and Maklan, 2011; Brandon-Jones *et al.*, 2014; Tukamuhabwa *et al.*, 2015). Moreover, IPT suggests that information sharing acts as a crucial mechanism for sharing risk-related information in the SC that enables SC partners to obtain risk-specific knowledge for SCRM purposes (Fan *et al.*, 2017). Therefore, this study contributes to literature by empirically investigating the mechanisms for exploiting the benefits of information sharing in upstream of SCs to enhance SCRES, which has been specifically called for more research (Colicchia *et al.*, 2019).

This study also identified data analytics as a contributor to procurement digitalization, and we argue that it is becoming an increasingly important aspect of digital SCs. Past research has also provided evidence of this (Trkman *et al.*, 2010; Hallikas *et al.*, 2021). Moreover, while it has been previously proposed that SCs can be adapted to benefit from digitally-enhanced SC risk analytics (Ivanov *et al.*, 2019), few studies have empirically assessed the relationship between data analytics capability and information sharing in SCs or procurement. Previously it has been suggested that different data analytics capabilities can enhance the coordination and visibility of humanitarian SCs (Dubey *et al.*, 2018). SCA could, in theory, contribute to the content and quality of information, which can be considered important in the context of information sharing (Li and Lin, 2006; Zhou and Benton, 2007). As such, it has also been argued that adequate data quality is a requirement for the effective usage of SC-related data analytics (Hazen *et al.*, 2014). The findings also support the previously established notion that data analytics capabilities enhance digital procurement processes (Hallikas *et al.*, 2021).

Regarding the results on data analytics in the default model, the discovered mediator role of information sharing is partly expected due to network-level dependencies in resilience improvement and SC reconfiguration. SCRES is influenced by multiple parallel decisions to re-align SCs to adapt to their environment, which requires visibility increasing mechanisms in the SC network (Jüttner and Maklan, 2011; Chowdhury *et al.*, 2019). As such, data analytics and SCRES represent different levels of hierarchy. Data analytics is linked to processes and infrastructure to acquire supply-related information, whereas information sharing and SCRM outline core processes to manage SC reconfiguration in SC networks with the use of such information. The finding receives support, especially from the information processing perspective, because the capacity of procurement to assist in SC risk prevention and support response strategies to SC disruptions are largely dependent on collaborative practices between networked SC partners, such as the capacity to share proprietary risk information about anticipated SC risks or disruptions with suppliers (Chowdhury and Quaddus, 2016; Colicchia *et al.*, 2019). Hence, our results add to the SCRES research by showing the connections of upstream information processing to SCRES dimensions (Chowdhury and Quaddus, 2016).

Furthermore, this study attributed the digital maturity of procurement processes to the overall procurement digitalization in the conceptual approach. The results provide empirical evidence regarding how the adoption of digital procurement processes positively influences SCRES when being mediated by information sharing in the SC and SCRM. As such, the results differentiate themselves from those of the extant literature by empirically focusing on the digital maturity of the procurement function rather than observing impending digitalization at the holistic SC level. Previous studies adopting procurement digitalization as a research perspective have been considerably fewer, which limits theoretical reflection of the results; however, the findings are also indirectly supported in the related SCM literature. For example, the ability to share information in the SC is considered to be dependent on the internal connectivity that IT can provide to the SC (Swaminathan and Tayur, 2003). Recently, similar conceptual affirmations have been provided regarding the positive impact of digitalization on SCM processes such as procurement (Tjahjono *et al.*, 2017; Zekhnini *et al.*, 2021). Extant research has also considered the impact of digital technology on SCRM and SCRES. For example, the use of IT in supporting decision-making has been identified as assisting with SC disruption management (Giannakis and Louis, 2011). More recent empirical research has also shown how digital tools adoption and maturity degree in SCs positively contribute to SCRES (Zouari *et al.*, 2021).

Ultimately, one of the pivotal objectives of this study was to comprehensively analyze procurement digitalization's influence on SCRES. Building on the previously examined theoretical contributions, the results show that SCRM is a mediator that enables the benefits of digitalization to extend toward increasing SCRES. The early literature also established a positive connection between SCRM and SCRES (Jüttner and Maklan, 2011), and a recent study by El Baz and Ruel (2021) provided additional empirically-validated evidence that SCRM process practices improve SCRES. Thus, the results of this study further clarify the theoretical understanding of SCRM and SCRES and how procurement digitalization is beneficially linked to them.

Second, we contribute to the theory by integrating IPT as a theoretical background to examine how procurement digitalization reduces uncertainty in the SC and how reduced uncertainty leads to improved SCRM and SCRES. The results show that procurement digitalization can reduce uncertainty, but it is largely dependent on information-sharing capabilities in the SC. This is in line with prior research using IPT; for instance, Fan *et al.* (2017) identified the sharing of risk information as a basis for forming risk-sharing mechanisms in the SC.

In summary, the results advance knowledge in nascent empirical SCRM literature regarding how to use digitalization to improve SCRM and SCRES. For some time now, the digitalization of SCs has been considered an emerging stream of research that primarily focuses on novel technology implementation and digital-technology-driven benefits in the SCM context. In particular, the research concentrating on the effects of digitalization on risk mitigation and resilience in the SC can be considered to be in its infancy (Ivanov *et al.*, 2019; Fischer-Preßler *et al.*, 2020; Spieske and Birkel, 2021). This research gap can be also found in the literature on the procurement perspective, in which, to the best of our knowledge, empirical implications regarding SCRM and SCRES are limited in number.

Managerial implications

It should be highlighted that firm's investment in procurement digitalization may positively affect the SC's ability to manage risks and increase its resiliency. Moreover, the results suggest that practices for the more effective sharing of information between SC partners are requisite to extend the benefits of procurement digitalization toward improved SCRES. Therefore, firms seeking to further their procurement digitalization are urged to simultaneously ensure that the information-sharing capacities of the SC are sufficiently implemented in procurement technology integration decisions. Ultimately, firms are encouraged to invest in the collaborative integration of procurement technology in their respective SCs. In line with the IPT, we show that this will lead to increased information-processing capacities and reduced uncertainty in the SC. It is also interesting to note that the relationship between the utilization of the real-time SCRM systems did not indicate significant influences on SCRES. This may be due to the still relatively low level of maturity of risk management systems in companies. However, it is expected that as part of the development of digitalization, the actual systems dedicated to risk management in the supply chain will also develop in the future. Also, based on the survey data of this paper, many capabilities of digitization, data analytics and information sharing are still at a relatively low maturity level in companies. In managing digital transformation, understanding a company's current technological maturity is important so that management can outline development paths for the implementation of practices and ways of using various tools to increase digitalization maturity. In this way, the benefits of the digital transformation, such as risk management and flexibility, can be increased in the company.

The findings also suggest that management should focus on hierarchy of activities to increase SCRES via digitalization of procurement processes. In practice, the performance gains are related to data management processes, which include data gathering, modeling, reporting and knowledge-sharing activities. The data management processes should aim to converge internal and external data into valuable information, which increases overall visibility of the SC and supports firm-specific risk management strategies. Finally, SCRES is achieved if the network of firms is capable in creating common procedures to access meaningful information, which enables coherent operationalization of risk management strategies.

Limitations and future research

Several limitations and avenues for future research are acknowledged. First, even though we have provided evidence for the impact of procurement digitalization on SCRES, the design of our quantitative study, which used geographically focused, cross-sectional survey data, poses limitations. To attain increased theoretical and practical knowledge about the subject, future research should include other research methodologies and data collection in diverse settings. For example, qualitative studies can be conducted to increase theoretical understanding of variables relevant to advancing the digital maturity of the procurement function. Longitudinal case studies should be used to better understand the process and transformation of implementing procurement technologies in practice and understand how they are integrated to coordinate risk management activities between SC partners. We also propose that further quantitative studies should be conducted to test theory and examine the influence of digitalization in the SC on other known SCRES capabilities.

Second, it might be difficult for firms to assess their levels of procurement digitalization through the used survey constructs due to the technological uncertainty and dynamic circumstances surrounding technology integration in SCs. This issue has recently been raised in the context of data analytics and calls for more research (Handfield *et al.*, 2019; Hallikas *et al.*, 2021). We assert that more research on best practices regarding the adoption of advanced technologies is required, which would consolidate the holistic understanding of firms' technological maturity to their competitors and SC partners. Here, it is also important to investigate in more detail what kind of paths technology and digitalization maturity should be developed in firms. To enable the mutual exploitation of advanced technologies, reduce uncertainty and improve resilience, future research should also more precisely investigate the capabilities required to efficiently use technology in procurement and how to encourage digital collaboration within the SC.

Third, the empirical research on procurement digitalization is nascent. The gap in research is even more evident in SCRM and SCRES settings. While this study contributes to the SCRM literature, it should be noted that our construct of SCRM reflects operational risk management. Also, the construct of SCRES only captures a portion of the complex and multifaceted aspects related to disruption mitigation in SCs. Future research should examine how risk management of other more strategic and industry-level risks, such as technological change and reputational risk, may influence SCRES. Therefore, we appeal to scholars in the field of procurement and SCRM to undertake relevant research and provide more insights into the effects of procurement digitalization on disruption mitigation in SCs.

Conclusions

Procurement digitalization has a considerable impact on the SC's ability to mitigate disruptions and increase its resiliency. First, we have found that the procurement function's capacity to use data analytics and attain digital process maturity positively affects the level of information sharing in the SC. Second, information sharing and SCRM mediate the positive relationship between procurement digitalization and resilience in the SC. Third, we used IPT to illustrate how procurement digitalization increases SC information processing capacities to reduce uncertainty in the SC. The contributions of this study are significant due to the novelty of digitalization as a research stream in procurement and the lack of empirical research related to its impact on disruption mitigation capabilities of SCs.

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Appendix. Items used in the survey instrument

Data analytics (DA)

Brinch, M., Stentoft, J., Jensen, J.K. and Rajkumar, C. (2018), Practitioners understanding of big data and its applications in supply chain management. *International Journal of Logistics Management*, Vol. 29, No. 2, pp. 555-574.

We use data analysis in our operations to (1 = fully disagree, 5 = fully agree):

DA 1 Automated data collection methods.
DA 2 Store large amounts of data.
DA 3 Cross-data and cross-system analysis.
DA 4 Apply advanced data analysis methods.
DA 5 Apply visualization techniques making complex data simple to the decision-maker.
DA 6 IT-enabled processes for fact-driven decision-making.
DA 7 Determine optimal decision.
DA 8 Identify problems and opportunities within existing processes.
DA 9 Discover explanatory and predictive patterns.

Information sharing (ISSC)

Fan, H., Li, G., Sun, H. and Cheng, T.C.E. (2017), An information processing perspective on supply chain risk management: Antecedents, mechanism and consequences. *International Journal of Production Economics*, 185, 63–75.

Consider the following statements concerning information sharing (1 = fully disagree, 5 = fully agree):

ISSC 1 Our partners share proprietary information with us.
ISSC 2 We share accurate risk-related information with our supply chain members.
ISSC 3 We are willing to share real-time information on demand with our suppliers.
ISSC 4 Information is actively shared between functional teams in our firm.
ISSC 5 It is expected that members in the supply chain keep each other informed about events or changes that may affect the other party.
ISSC 6 Our partners keep us fully informed about issues that affect our business.
ISSC 7 We have closely integrated information systems with key suppliers and logistic providers.

Procurement process digitalization (PPD)

Based on van Weele, A.J. (2014), Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice. 6th ed. Andover: Cengage Learning.

How far have you digitalized the following procurement processes? (1 = not used, 5= used routinely):

PPD 1 Request for quotation (buyer requests quotation from seller).
PPD 2 Offer (seller delivers offer to buyer).
PPD 3 Product catalog (transmission of product information).
PPD 4 Tender (buyer organizes tender for several sellers).
PPD 5 Order (the buyer delivers the order to the seller of the product or service).
PPD 6 Order tracking.
PPD 7 Order change (seller or buyer can propose a change to the order).
PPD 8 Invoicing (seller delivers invoice to buyer; product, service).

Resiliency in supply chain (SCRES)

Ambulkar, S., Blackhurst, J. and Grawe, S. (2015), Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management*, 33, 111–122.

How well do you think the company is able to respond to and adapt to supply chain disruptions (1 = fully disagree, 5 = fully agree):

SCRES 1 We are able to cope with changes brought by the supply chain disruption.
SCRES 2 We are able to adapt to the supply chain disruption easily.
SCRES 3 We are able to provide a quick response to the supply chain disruption.
SCRES 4 We are able to maintain high situational awareness at all times.

Supply chain risk management (RM)

Hallikas, J. and Lintukangas, K. (2016), Purchasing and supply: An investigation of risk management performance. *International Journal of Production Economics*, pp. 487-494.

Evaluate how well your procurement can prevent the supply chain risks in (1 = fully disagree, 5 = fully agree):

RM 1 The availability of products.
RM 2 Risks of late deliveries.
RM 3 Quality risk.
RM 4 Cost/price risks.

Supply chain risk management tool

The organization uses real-time supply chain risk management tool for risk identification and anticipation (1 = fully disagree, 5 = fully agree).

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