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The role of supply chain risk mitigation strategies to manage supply chain disruptions

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Background: Supply chain disruptions have always existed, but have become more intense during the last decade or so. Factors in the macro environment have also contributed and none more so than during the coronavirus disease 2019 (COVID-19) pandemic. In general, firms were not ready for disruptions caused by the COVID-19 pandemic. Yet, numerous firms were resilient and recovered quicker to their pre-COVID positions than other firms.

Objectives: This research addressed how firms with effective supply chain risk mitigation strategies managed supply chain disruptions caused by the COVID-19 pandemic and which lessons were learned to prepare for future disruptions.

Method: An online survey instrument with scalable responses was used to conduct quantitative research. A total of 221 workable questionnaires were used to analyse the data using SPSS software. Several hypotheses were formulated and were tested using *t*-tests.

Results: The findings show clear differences in how firms used agility and flexibility, collaboration and redundancy as supply chain risk mitigation strategies to manage upstream, internal and downstream disruptions.

Conclusion: The level of effective supply chain risk management strategies implemented by firms seems to significantly contribute to the effective management of upstream, internal and downstream disruptions. It appears as if agile and flexible firms that collaborate more with their supply chain partners and who implement redundancy strategies, are better prepared to respond to disruptions.

Contribution: Managers can improve the effectiveness of their supply chain risk management strategies by seeking more agile and flexible solutions, collaborating more with supply chain partners and utilising redundancy strategies.

Keywords: supply chain risk mitigation; supply chain disruption; supply chain resilience; COVID-19 pandemic; supply chain strategy; supply chain agility; supply chain flexibility; supply chain collaboration.

Introduction

A supply chain, in essence, consists of all firms involved with the buying and selling of goods and services to each other to fulfil customers' requests and can include suppliers, manufacturers, transporters, warehouses and retailers, to mention a few (Chopra 2019:15). Supply chains have become extremely complex to manage (Christopher 2016:174). These complexities expose supply chain vulnerabilities because of numerous direct and indirect risk factors (Magableh 2021:3), which in turn expose supply chains to significant disruptions resulting from risks that may be internal or external to the firm and its supply chain (Chowdhury & Quaddus 2017:185; Christopher 2016:222). Disruptions are the manifestation of supply chain risks and there need to be responses to these disruptive situations (Habermann, Blackhurst & Metcalf 2015:494). It is thus no secret that supply chains across all industries were already exposed to various risks and disruptions before the coronavirus disease 2019 (COVID-19) pandemic (Scheibe & Blackhurst 2018:43).

Supply chain risk management (SCRM) is thus necessary and had already become a key ingredient for supply chain management (SCM) in managing and mitigating risks to ensure firms' survival and the continuity of their operations (Nel & Simon 2020:150; Revilla & Saenz 2017:559; Trkman, De Oliveira & McCormack 2016:1061). When existing literature is condensed, SCRM essentially comprises four phases, namely risk identification, risk assessment, risk mitigation and risk control (El Baz & Ruel 2021:3; Nel & Simon 2020:154). An essential part of SCRM is implementing supply chain risk mitigation strategies. The SCRM is not only valuable for unanticipated events and a

response to disruptions but also to ensure that supply chains continue to operate at the desired level (Trkman et al. 2016:1064). Ultimately, the supply chain risk mitigation strategies are used to keep the effects of disruptions from stopping the continuity of various flows and operations in the supply chain and aim to minimise the effects of these disruptions (Scheibe & Blackhurst 2018:43). Supply chain risk mitigation strategies thus require an effective preparation, and response to disruptions and for supply chains to be more resilient (Trkman et al. 2016:1063). Supply chain resilience (SCRES) is a supply chain's ability to recover its performance during and after a disruption (Sarkar, Ismael & Tkachev 2022:611). The SCRES has become an important ingredient of SCRM (Scala & Lindsay 2021:672). The article focuses on the response phase.

The COVID-19 pandemic

The COVID-19 pandemic caused major disruptions for the majority of companies in the world (Singh, Kumar & Kumar 2023:2). The article endeavours to determine which lessons were learned during the pandemic and how firms can use these lessons to be better prepared for future disruptions. Firms and their supply chains faced significant disruptions during the pandemic (Magableh 2021:1; Weber 2021:1) as they tried to manage their supply chains through this period of immense uncertainty. Firms experienced increased uncertainties and had to adapt their supply chains to respond to changing competitive environments because their entire supply chains were affected (Magableh 2021:1; Modgil, Singh & Hannibal 2021:1). The COVID-19 pandemic caused a ripple effect in many firms' supply chains. Disruptions in one part of the firm's supply chain impacted and caused disruptions in other parts of the supply chain too.

Coronavirus disease 2019 was declared a pandemic in March 2020 and many countries implemented lockdowns, which placed severe restrictions on the movement of individuals and firms alike (Ali, Rahman & Frederico 2021:128). During that time, the South African government declared the COVID-19 pandemic a national state of disaster (Government of South Africa 2022). The South African government also implemented lockdowns and managed the COVID-19 pandemic according to different alert levels. The alert levels ranged from levels one to five, with level five imposing the most restrictions in terms of the movement of individuals. The first lockdown in South Africa was implemented in March 2020 and lasted for 5 weeks. During this period, there were severe restrictions. Individuals could not leave their homes (except under exceptional circumstances). There were also strict working restrictions. These restrictions were the most severe during alert level five where people had to stay home, and travel was restricted severely. In slightly more than 2 years, firms lost 295 days to restrictions posed by the government at levels three, four and five (of which 94 days were at alert levels four and five) (Government of South Africa 2022). This had a significant impact on firms and their supply chains. This article focuses on alert levels three, four and five of the pandemic, but more specifically levels four and five. The COVID-19 pandemic has forced several firms

to rethink their supply chain network designs (Modgil et al. 2021:2; Wieland 2021:64). Omni-channels in the retail industry (Weber 2021:3) and the shipping industry are two such examples. In the retail industry, omni-channels and the accompanying last mile logistics changed dramatically (Weber 2021:2–4) In the shipping industry, container lines adjusted their strategy to adapt to decreasing volumes resulting in increased shipping costs. Online buying increased significantly during the COVID-19 pandemic, which in turn increased the demand for manufactured products and shipments via maritime trade. However, numerous containers were left at locations where they were not required resulting in container shortages at other locations (Grater & Chasomeris 2022:2, 3).

Mishra, Singh and Subramanian (2021:5, 6) identify some important research gaps, which this article aims to address. Firstly, there is a need to conduct research as to how resilient firms responded in real time to supply chain disruptions. Previously, a lot of research was conducted by means of modelling. The research in this article addresses the risk mitigation strategies implemented by firms to manage the disruptions they faced in real time, that is, what the firms actually implemented during the COVID-19 pandemic. Secondly, little attention has been given in supply chain risk research, on how resilience can help to mitigate disruptions caused by pandemics, and it is argued that supply chains in developing countries may be affected more by the COVID-19 pandemic (Butt 2022:371; Scala & Lindsay 2021:672). Research is thus necessary to identify how resilient firms in developing countries such as South Africa responded to supply chain disruptions during the COVID-19 pandemic and how these risk mitigation strategies can help firms to be more resilient in the future. In addition, some firms were managing their risks effectively prior to the COVID-19 pandemic (as opposed to other firms who acknowledge that they were not doing so). This article will thus focus on the role of effective supply chain risk mitigation strategies to manage supply chain disruptions. With this as background, the following research questions were addressed:

- How did firms in South Africa with an effective supply chain risk mitigation strategy manage their supply chain disruptions during the COVID-19 pandemic?
- Was there a significant difference in risk mitigation strategies between firms who managed their supply chain risks effectively prior to the COVID-19 pandemic and those that did not?
- Which lessons can be learned from firms with an effective supply chain risk mitigation strategy to enable firms to be better prepared for future disruptions?

The following primary hypothesis was formulated, namely:

H_1: There is a difference between firms with effective supply chain risk mitigation strategies (and those without them) with regard to managing the disruptions in their supply chains during the COVID-19 pandemic.

The contributions of this research are, firstly, to contribute towards theory building and building on existing theories in SCM. The findings of this research expand academic

literature in SCRM and specifically supply chain risk mitigation from a COVID-19 pandemic perspective in South Africa. Secondly, this article provides an exploration of how South African firms were: (1) disrupted by the COVID-19 pandemic, (2) how they responded to the disruptions, and (3) if there were significant differences in how firms with effective risk management managed their supply chains as opposed to those who don't. The conclusions of this article also provide managers with valuable lessons on how to respond to risk events that may disrupt their supply chains in the future.

Literature review
Theoretical foundation

Supply chain disruptions have been categorised differently by researchers and it is thus necessary to distinguish between a few approaches. For a start, Revilla and Saenz (2017:558) distinguish between supply chain risks that originate from a firm's internal operations as well as risks that emerge from external supply chain partners. Christopher and Peck (2004:5) distinguished between supply risks, process risks, demand risks, control risks and environmental risks. Building on these categories that were used by Chistopher and Peck (2004), Parast and Subramanian (2021:551) argue that process disruptions originate from disruptions in a firm's internal operations.

Mishra et al. (2021:3) categorised supply chain disruptions resulting from the COVID-19 pandemic into supply-side disruptions, logistics-side disruptions and demand-side disruptions and then looked at firms' capabilities to determine how resilient they were. Habermann et al. (2015:495) distinguish between three disruption categories, namely supply-side disruptions, internal disruptions (which can be linked to Parast and Subramanian's [2021] process disruptions), and customer-side disruptions. A common theme is derived when scrutinising the above-mentioned research, namely that disruptions happen in any firm's upstream, internal and downstream supply chains. This distinction of supply chain disruptions is adequate because it encompasses the entire supply chain (Habermann et al. 2015:495). In addition, these disruptions can all occur within the wider macro environment and can severely impact each other as is evident from the bullwhip effect, where upstream fluctuations increase because of uncertainties in the supply chain (Chopra 2019:259). Each of these disruption categories requires specific mitigation strategies for firms to be resilient. Figure 1 illustrates these three disruption categories, which will be used as part of the theoretical foundation that is used in this article.

The dynamic capabilities theory

Firms utilise their resources to develop capabilities that provide them with a competitive advantage (Modgil et al. 2021:6). Dynamic capabilities (DCs) are the firm's ability to adapt quickly to rapidly changing business situations by integrating and aligning internal as well as external
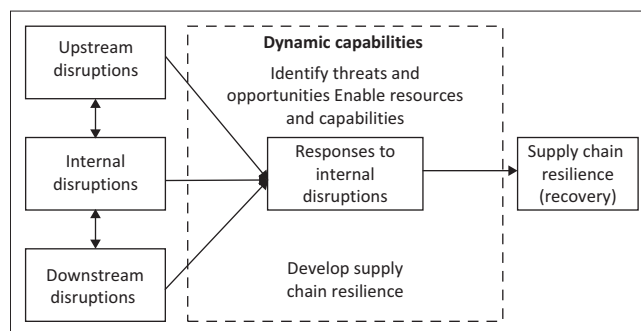
Source: Adapted from Habermann, Blackhurst and Metcalf (2015); Mishra, Singh and Subramaniam (2021); Modgil, Singh and Hannibal (2021); and Parast and Subramanian (2021).

Note: Please see the full reference list of the article, Nel, J.D., 2024, 'The role of supply chain risk mitigation strategies to manage supply chain disruptions', *Journal of Transport and Supply Chain Management* 18(0), a1035. https://doi.org/10.4102/jtscm.v18i0.1035, for more information.

FIGURE 1: Theoretical foundation for the research.

competencies (Do, Ramudhin & Milligan 2021:739; Teece, Pisano & Shuen 1997:515). The DC theory is built on this premise and is closely related to supply chain resilience capabilities (Modgil et al. 2021:6). Dynamic capabilities are known for identifying and assessing threats and opportunities and then responding by enabling resources and capabilities to ensure continuity of the business in a dynamic environment to capture value (Do et al. 2021:739; Modgil et al. 2021:6). Dynamic capabilities are very applicable in complex supply chains and firms utilise DCs to develop SCRES (Modgil et al. 2021:6).

The following hypotheses are derived from the primary hypothesis:

H_2: There is a difference between firms with effective supply chain risk mitigation strategies (and those without them) with regard to managing the:

H_{2a}: upstream disruptions in their supply chains during the COVID-19 pandemic.

H_{2b}: internal disruptions in their supply chains during the COVID-19 pandemic.

H_{2c}: downstream disruptions in their supply chains during the COVID-19 pandemic.

Supply chain disruptions

All risk events have minor (or even negligible) to severe impacts on supply chains (Rahman et al. 2021:2). Risk events that disrupt the normal flow of goods and materials within a supply chain are defined as supply chain disruptions (Craighead et al. 2007:132; Nel, De Goede & Niemann 2018:2; Parast & Subramanian 2021:548). This article focuses on the disruption risk events experienced during the COVID-19 pandemic.

In any supply chain, it is essential to properly match supply with demand (Parast & Subramanian 2021:551). Disruptions may result in mismatching supply and demand. Therefore, the interrelatedness between upstream, internal and downstream disruptions needs to be reiterated

(Chopra & Sodhi 2004:54). Supply chain disruptions may spread through (or impact) the entire supply chain. One supply chain disruption may impact other parts of the supply chain, either upstream, internal and/or downstream (Habermann et al. 2015:494; Scheibe & Blackhurst 2018:44). For example, upstream disruptions may result in internal delays, which in turn have an impact on meeting customer demands on time (Parast & Subramanian 2021:551). Alternatively, rapid changes in downstream demand patterns (i.e. either a sudden increase or decrease) may cause problems for upstream suppliers to plan and meet demand (Singh et al. 2023:3). Internal capacity-related disruptions also occur when firms experience fluctuating demand patterns. For example, if there are spikes in demand, firms struggle to meet increased demand or alternatively have excess underutilised capacity or overstock in inventories of finished goods when demand drops (Paul et al. 2021a:11). The COVID-19 pandemic simultaneously disrupted the upstream, internal and downstream parts of the supply chain (Magableh 2021:13; Weber 2021:2).

Upstream disruptions

Supply-side disruptions take place in the upstream part of a firm's supply chain (Habermann et al. 2015:495; Parast & Subramanian 2021:550). A lack of collaboration or coordination between firms and their suppliers can all result in upstream disruptions (Parast & Subramanian 2021:551, 553; Paul et al. 2021a:11). Upstream disruptions caused by the COVID-19 pandemic were widespread (Rahman et al. 2021:2). Table 1 summarises some upstream disruptions that have been identified in literature.

Internal disruptions

Internal disruptions are disruptions experienced inside a firm's internal operations (Habermann et al. 2015:495; Parast & Subramanian 2021:551). Internal disruptions can be caused

because of difficulties in planning production (Chopra & Sodhi 2004:57; Paul et al. 2021a:11, 12) or an inefficient IT infrastructure (Ambulkar et al. 2015:111; Chopra & Sodhi 2004; Parast & Subramanian 2021:551; Paul et al. 2021a:12). Internal disruptions can also result in increased waste in the firm (Paul et al. 2021a:12) and working capital challenges (Chopra & Sodhi 2004:57; Paul et al. 2021a:11, 12). Examples of internal disruptions include:

- Inventory-related disruptions such as shortages on the one hand, and high inventory obsolescence and carrying costs on the other (Paul et al. 2021a:11).
- Capacity-related disruptions, that is capacity limitations, machine breakdowns (and maintenance disruptions), facility closures (Aljuneidi et al. 2023:10; Ambulkar et al. 2015:116; Chopra & Sodhi 2004:57; Min 2023:1766; Parast & Subramanian 2021:551, 553; Paul et al. 2021a:11; Singh et al. 2023:6).
- Increased operating and inventory holding costs (Paul et al. 2021a:11, 12).
- Quality-related challenges (Ambulkar et al. 2015:111; Min 2023:1766; Parast & Subramanian 2021:551; Singh et al. 2023:12).
- Labour-related disruptions. Labour shortages can disrupt a firm (e.g. absenteeism or labour strikes). Human errors and a high staff turnover may also cause internal disruptions (Aljuneidi et al. 2023:10; Min 2023:1766; Nel et al. 2018:3; Paul et al. 2021a:12; Singh et al. 2023:3).

Downstream disruptions

Downstream disruptions occur in the downstream supply chain. Disruptions in the customer facing side of the supply chain, can expose the upstream supply chain (Habermann et al. 2015:495; Parast & Subramanian 2021:551). The COVID-19 pandemic caused several downstream disruptions. Examples of downstream disruptions are included in Table 2.

Macro-environmental disruptions

All firms operate within the broader macro-environment and are thus subject to disruptions in the macro environment. Environmental disruptions occur in a firm's macro-environment (Christopher & Peck 2004:5) and firms do not

TABLE 1: Upstream supply chain disruptions.

Upstream disruption	Sources
Increased upstream uncertainties and complexities (e.g. supplier bankruptcy or closures, difficulties in finding alternative suppliers, upstream price increases)	• Aljuneidi, Bhat and Boulaksil (2023:10) • Butt (2022:374, 378) • Chopra and Sodhi (2004:54, 57) • Mohezar, Mohamad and Nor (2022:119) • Paul et al. (2021a:11)
Upstream inventory shortages (e.g. insufficient stock availability)	• Butt (2022:374, 378) • Chopra and Sodhi (2004:57) • Mohezar et al. (2023:121) • Paul et al. (2021a:11)
Decrease in performance levels from upstream supply chain partners (in terms of, say, quality, reliability, delivery times).	• Butt (2022:374, 378) • Mohezar et al. (2023:121) • Paul et al. (2021a:11) • Parast and Subramanian (2021:551, 553)
Purchasing, logistics and transportation delays (e.g. purchase order delays, shipment delays, customs clearance delays, transport breakdowns, longer lead times, etc.)	• Aljuneidi et al. (2023:10) • Ambulkar, Blackhurst and Grawe (2015:111) • Butt (2022:374, 378) • Chopra and Sodhi (2004:54, 57) • Min (2023:1766) • Mohezar et al. (2023:121) • Parast and Subramanian (2021:551, 553) • Paul et al. (2021a:11, 12) • Singh et al. (2023:6)
Upstream capacity and flexibility restrictions	• Butt (2022:374, 378) • Chopra and Sodhi (2004:57) • Min (2023:1766) • Paul et al. (2021a:11)

Note: Please see the full reference list of the article, Nel, J.D., 2024, 'The role of supply chain risk mitigation strategies to manage supply chain disruptions', *Journal of Transport and Supply Chain Management* 18(0), a1035. https://doi.org/10.4102/jtscm.v18i0.1035, for more information.

TABLE 2: Downstream supply chain disruptions.

Downstream disruption	Sources
Customer demand fluctuations and challenges (including forecasting challenges) resulting from, for example, spikes in demand, changing buying patterns, order cancellations (or delays) from downstream customers, customer payment challenges, etc.	• Aljuneidi et al. (2023:10) • Chopra and Sodhi 2004:54, 57 • Mohezar et al. (2023:121) • Parast and Subramanian (2021:551, 553) • Paul et al. (2021a:12) • Rahman et al. (2021:3) • Sharma et al. (2021:1845)
Disruptions in downstream distribution and logistics activities, such as transportation delays, logistical inefficiencies in meeting downstream delivery times; limited options for distribution, etc.	• Aljuneidi et al. (2023:10) • Mohezar et al. (2023:121) • Parât and Subramanian (2021:551, 553) • Paul et al. (2021a:12)

Note: Please see the full reference list of the article, Nel, J.D., 2024, 'The role of supply chain risk mitigation strategies to manage supply chain disruptions', *Journal of Transport and Supply Chain Management* 18(0), a1035. https://doi.org/10.4102/jtscm.v18i0.1035, for more information.

have control over these disruptions. Macro-environmental disruptions include disruptions in the political, economic, social, technological, and natural environments (Rahman et al. 2021:3). Pandemics, epidemics and natural disasters (e.g., floods, droughts) are examples of disruptions in the natural environment (Parast & Subramanian 2021:551). Firms were impacted in the macro-environment because of the COVID-19 pandemic. So, governments imposed rules and regulations across different alert levels during lockdowns (political and legal environments) in an attempt to curtail the spread of the COVID-19 virus (the natural environment) that impacted firms' upstream, internal and downstream supply chains, which in turn is the focus of this research.

Supply chain risk mitigation strategies

The COVID-19 pandemic has tested the resilience of supply chains in various industries and the recovery of the supply chain is essential to SCRES (Paul et al. 2021b:316). As already mentioned, SCRES is a supply chain's ability to recover its performance during and after a disruption (Sarkar et al. 2022:611). The recovery process from a disaster is thus essential and it is important to identify challenges for the recovery process to ensure that the appropriate risk mitigation strategies are formulated (Paul et al. 2021b:316). Supply chain resilience requires from firms to develop capabilities to proactively improve the firm's ability to be prepared (before the disruption), respond (during the disruption) and recover (after the disruption).

Numerous research has been performed to propose resilience strategies to address disruptions (Aljuneidi et al. 2023:1; Chopra & Sodhi 2004), and current literature highlights several risk mitigation strategies across the supply chain (Sharma et al. 2021:1845). In addition, several researchers have categorised supply chain risk mitigation strategies for (or responses to) supply chain disruptions (Paul, Moktadir & Ahsan 2021c:3). These strategies are typically referred to as the overarching supply chain resilience strategies.

Scala and Lindsay (2021:674–675) distinguish between several SCRES characteristics such as agility, flexibility, collaboration and redundancy. Agrawal and Jain (2021: 2510–2514) did a comprehensive literature review of SCRES strategies and eventually came up with 14 strategies. Similarly, Pimenta et al. (2022:651) also categorised SCRES strategies and distinguished between six different categories. Paul et al. (2021c:12–15) briefly allude to nine such categories. Weber (2021:6) distinguished between five broad categories. Lee (2004) suggests agility, adaptability and alignment as supply chain strategies to improve performance, and Khan, Piprani and Yu (2022:1334) build on these three concepts, namely agility, adaptability and alignment as supply chain strategies to enhance supply chain performance amid increasing complexities and uncertainties.

It is sometimes difficult to distinguish between some of these concepts, and current literature shows a clear overlap between some of the resilience strategies. For example, Agrawal and Jain (2021:2510–2514) distinguish between flexibility, velocity and agility. Pimenta et al. (2022:651) and Weber (2021:6) also distinguish between flexibility and agility. Yet, other researchers, such as Khan et al. (2022:1334), Gligor (2014:583) and Christopher (2016) consider flexibility and velocity as critical aspects of agility. Other researchers such as Do et al. (2021:739) and Shekarian, Nooraie and Parast (2020:2) agree with the latter statement and state that speed (or velocity) and flexibility form part of supply chain agility and that flexibility is a driver of agility. In addition, Shekarian et al. (2020:2, 3) also state that flexibility is a firm's capability of adapting to changes across its supply chain adaptability. Moreover, Christopher and Peck (2004:10) argue that visibility can be viewed as part of agility, while other researchers argue that collaboration through long-term relationships with suppliers increases visibility and velocity, thus contributing to SCRES (Scala & Lindsay 2021:675). It can also be argued that SCRES strategies such as integration, trust, and information sharing, as distinguished by Khan et al. (2022:1334), are essential elements of collaboration. For this article, the following supply chain risk mitigation strategies have been identified, namely (1) agility and flexibility, (2) collaboration and (3) redundancy:

- **Agility and flexibility:** Agility is the ability of a firm to quickly respond to potential and actual upstream, internal, downstream or external disruptions (Agrawal & Jain 2021:2513; Pimenta et al. 2022:651; Singh et al. 2023:16, 17; Weber 2021:6). Paul et al. (2021c:12) state that firms need to be agile in each node of the supply chain to enhance resilience. This may entail reconfiguring the supply chain network design (Modgil et al. 2021:2; Paul et al. 2021c:12;). Flexibility refers to the ability to create capabilities to perceive and respond to potential and actual disruptions (Agrawal & Jain 2021:2510; Butt 2022:374, 378; Pimenta et al. 2022:651; Scala & Lindsay 2021:674–675). Flexibility can be enhanced by means of investments into the firm's infrastructure, production systems that can accommodate multiple products, and employees' skills (Pimenta et al. 2022:651) and can thus be achieved by having multiple interchangeable resources (Weber 2021:6). Flexibility can thus be achieved across the upstream, internal and downstream supply chain.
- **Collaboration:** Collaboration in the supply chain refers to two or more independent firms in the supply chain working closely together to implement supply chain strategies that are appropriate (Agrawal & Jain 2021:2513; Butt 2022:374, 378; Paul et al. 2021c:14, 15; Scala & Lindsay 2021:674–675; Singh et al. 2023:17). Information sharing and trust are essential components of collaboration (Pimenta et al. 2022:651; Weber 2021:6). In fact, information sharing is seen as one of the most important elements of collaboration in SCRES (Agrawal & Jain 2021:2514; Sharma et al. 2021:1845). Visibility enhances collaboration. Visibility refers to the ability of a firm to view the entire supply chain (Agigi, Niemann & Kotzé 2016:4) and thus, the extent to which the supply chain is

transparent for a firm (Weber 2021:6) in terms of having knowledge about all aspects of the supply chain (Agrawal & Jain 2021:2513; Paul et al. 2021c:3; Pimenta et al. 2022:651; Scala & Lindsay 2021:674–675; Singh et al. 2023:16) and also thus having better control (Butt 2022:374, 378). Modgil et al. (2021:3) argue that supply chain visibility was more important than ever during the COVID-19 pandemic.

- **Redundancy:** Redundancy involves having extra capacity as well as inventory (Agrawal & Jain 2021:2513) and using safety stock as response to disruptions to maintain capacity requirements (Agigi et al. 2016:4; Pimenta et al. 2022:651; Sharma et al. 2021:1845; Singh et al. 2023:17). Other examples of redundancy as a SCRES strategy include multi-sourcing (Agigi et al. 2016:4; Weber 2021:6). In summary, these strategies include stockpiling inventories, diversifying options, using backup suppliers, implementing emergency sourcing, buffer inventories, and having reserve capacities available (Butt 2022:374, 379; Sharma et al. 2021:1845).

Research methods
Research design

A cross-sectional, quantitative study was conducted in 2023 using an online survey. The questionnaire comprised five sections that were structured as follows: (1) background information, (2) supply chain strategy and supply chain resilience, (3) upstream supply chain, (4) internal operations and (5) downstream supply chain. The questions from section 2 onwards collected data about firm's strategies implemented prior to the COVID-19 pandemic, disruptions experienced during the COVID-19 pandemic, risk mitigation strategies to overcome the disruptions and also about which lessons were learned during the COVID-19 pandemic.

Sampling and data collection

The target population for this study was senior managers (including, for example, owners and presidents of firms), managers, and supervisors of firms across South Africa and from different industries. A database comprising 17 000 such respondents was used as sample frame and the questionnaires were sent out to 8500 of the respondents in the database via email. One reminder email was sent a week later. The questionnaires were sent to respondents from September to November 2023. The respondents were knowledgeable about their firms and their supply chains and were employed in supply chain-related departments within the firm such as management, SCM, purchasing, logistics, operations and distribution management. In addition, they were in their current position at their firms during the COVID-19 pandemic from at least 2020 onwards. A total number of 514 questionnaires were received, yielding a response rate of 6.05%. After cleaning the data, 221 questionnaires were usable for the research in this article.

Data analysis

Independent *t*-tests were used for hypothesis testing using SPSS v29. The independent *t*-test is used to determine if statistically significant differences exist between the two risk effectiveness groups with regard to upstream, internal and downstream supply chain disruptions and the supply chain risk mitigation strategies implemented to respond to the disruptions. Although the item data are ordinal, which are generally analysed utilising a Mann–Whitney non-parametric test, De Winter and Dodou (2010:5) showed that the t-test is applicable, and will show similar results and have equal power if the data are normally distributed, which is the case in this study. Furthermore, the assumption of equal variances was tested using Levene's test of equality of variances and was supported for the majority of the test. In the cases where it was not supported, the adjusted t-test statistic for these cases was used.

Potential non-response bias was investigated. A comparison of the results of the early responses (first 10%) and the late responses (last 10%) yielded no statistically significant difference in the means on any of the items (all $p > 0.05$). Common method bias can occur if there are resemblances in measurement methods, for example using the same measurement scale. Different Likert type response scales were therefore used in this study. Respondents were assured that their responses were anonymous. A pilot survey was conducted and the opinions of experts were used to refine the survey instrument.

Findings

The majority of respondents who completed the questionnaire were from Gauteng (62.8%) and the Western Cape (19%) and were employed in logistics, transportation and storage (37%), manufacturing and operations (15.8%) and retail, wholesale (and/or sales) (14.5%). Table 3 provides a summary of the respondents who partook in the research.

Firms were asked to indicate if, in their opinion, they managed their supply chain risks effectively prior to the COVID-19 pandemic. The majority of the 221 respondents ($n = 148$, i.e. 67%) indicated that they agree or strongly agree with the statement that they managed their supply chain risks effectively prior to the pandemic. These respondents are grouped together

TABLE 3: Respondent profile ($N = 221$).

Variable	n	$\%$
Job title		
Director	44	19.9
Owner or president or vice president	52	23.5
Senior managerial position	52	23.5
Manager	41	18.6
Supervisor or supply chain officer	18	8.1
Other	13	5.9
No response	1	0.5
Years experience		
More than 10	143	64.7
6–10	42	19.0
≤ 5	33	14.9
No response	3	1.4

as Group A in the discussion of the findings. The other respondents (n = 73, i.e. 33%) stated that they either disagree, strongly disagree, or were neutral. These respondents are grouped in Group B. The findings of this article will be discussed primarily from the responses of the respondents in each of these two groups, namely Group A and Group B.

It is interesting to observe that prior to the COVID-19 pandemic, the firms in Group A consistently collaborated more between their internal departments and with their suppliers and customers than the firms in Group B. The respondents from the firms in Group A also indicated that they met their performance targets across their supply chain to a larger extent than the firms in Group B. This is highlighted in Table 4. A five- point Likert response type scale was used to measure these items.

Supply chain risk mitigation strategies during the COVID-19 pandemic

Six measures were used to determine how firms – in general – were managing the supply chain disruptions that resulted from the COVID-19 pandemic. The six measures are included in Table 5. A five-point Likert type response scale was used to measure the level of agreement with statements (where 1 = strongly disagree to 5 = strongly agree). In all six measures, the firms in Group A had mean scores of above three point five (i.e. M > 3.5), which means that, on average, they tend to agree with all the statements. The differences in the means of the two groups were statistically significant ($p < 0.001$) for all these six measures.

It is interesting to observe that the firms in Group A, not only managed their supply chain risks more effectively prior to the COVID-19 pandemic, but also: (1) had an adequate risk

management programme in place for the pandemic and (2) recovered more quickly to their pre-COVID-19 performance levels than the firms in Group B. Based on these findings, it is necessary to investigate if there were significant differences in terms of how the firms in Group A and B managed the upstream, internal and downstream disruptions in their supply chains.

Upstream supply chain disruptions and risk mitigation

The disruptions caused during the COVID-19 pandemic impacted the firms in both Group A and Group B. Respondents were asked to indicate whether their firms experienced an increase or a decrease in certain practices on a 7-point Likert type response scale, where 1= huge decrease and 7 = huge increase. Table 6 shows the results.

The firms in Group A and Group B differ, statistically significantly, regarding supplier uncertainties, supplier prices, and inbound logistics challenges ($p < 0.05$). Both groups experienced, on average, an increase as all mean values are above 4.6 for Group A and above 4.25 for Group B. Group A also consistently experienced a larger increase in these measures than Group B. Furthermore, differences were observed regarding suppliers' stock availability ($p < 0.1$) and suppliers' reliability ($p < 0.01$), with both groups experiencing a decrease and Group B experiencing, on average, a larger decrease than Group A. The firms in Group A experienced, on average, a very neutral to slight increase tendency, while the firms in Group B experienced a neutral to slight decrease tendency in terms of suppliers' quality and suppliers' flexibility. In other words, a decrease in Group B for supplier quality and supplier flexibility meant that the firms in Group B were potentially experiencing disruptions in these areas.

Both groups showed a tendency towards an increase for their flexibility in terms of sourcing and inbound logistics, as well as collaboration with their upstream supply chain

TABLE 4: Collaboration and performance.

Collaboration and performance prior to the COVID-19 pandemic	Mean	
	Group A	Group B
Collaboration with suppliers to achieve win-win synergies**	4.07	3.58
Suppliers' performance at least met set performance standards*	3.84	3.24
Internal collaboration among departments*	4.11	3.38
The firm met its set performance targets*	4.18	3.25
Collaboration with customers to achieve win-win synergies*	4.14	3.45
Firm at least met the set performance targets with customers*	4.14	3.52

*, Indicates statistical significance ($p < 0.001$); **, Indicates statistical significance ($p < 0.005$).

TABLE 5: Supply chain risk mitigation during the COVID-19 pandemic.

Supply chain risk mitigation during the COVID-19 pandemic	Mean	
	Group A	Group B
The firm had an adequate risk management programme for the pandemic*	3.55	2.69
The firm was agile and flexible to effectively respond and adapt tactics to manage the disruptions*	4.01	3.08
The firm effectively managed supplier (inbound) disruptions*	3.78	3.17
The firm effectively managed internal (process) disruptions*	4.09	3.31
The firm effectively managed customer demand (outbound) disruptions*	3.90	3.10
The firm recovered relatively quickly to its pre-COVID performance position*	3.79	3.17

*, Indicates statistical significance ($p < 0.001$).

TABLE 6: Upstream supply chains during the COVID-19 pandemic.

Supply chain risk mitigation during the COVID-19 pandemic	Mean	
	Group A	Group B
Upstream supply chain disruption		
Supplier uncertainties**	4.60	4.25
Supplier prices**	5.28	4.97
Inbound logistics challenges**	5.44	4.88
Suppliers' stock availability*	3.83	3.35
Suppliers' reliability***	3.99	3.60
Suppliers' quality in terms of specifications**	4.10	3.65
Suppliers' flexibility	4.15	3.83
Upstream supply chain risk mitigation strategy and supplier performance		
Flexibility in terms of sourcing and inbound logistics***	5.11	4.35
Collaboration with upstream supply chain partners***	5.24	4.41
Supply base*	4.24	3.89
Accurate information sharing between the firm and suppliers**	4.57	3.93
Suppliers' performance***	4.27	3.70

*, Indicates statistical significance ($p < 0.1$); **, Indicates statistical significance ($p < 0.05$); ***, Indicates statistical significance ($p < 0.01$).

partners (with group A showing, on average, a larger increase). The firms in Group A slightly increased their supply base, while the firms in Group B slightly reduced their supply base. There was also a slight increase in accurate information sharing between the firms in Group A and their suppliers and a slight decrease for the firms in Group B. Suppliers' performance slightly increased for the firms in Group A and slightly decreased for the firms in Group B.

Internal supply chain disruptions and risk mitigation

During the COVID-19 pandemic, several disruptions were experienced within firms' internal supply chains. The implementation of risk mitigation strategies was also measured. A seven-point Likert type response scale was used to determine whether a decrease or an increase was experienced. Table 7 shows the results.

The firms in both groups experienced, on average, a moderate increase in operations (or production) complexities. None of the other disruptions were statistically significantly different between the groups and are thus not discussed. Several internal strategies were implemented to manage the internal disruptions experienced during the COVID-19 pandemic as indicated in Table 7. Five supply chain risk mitigation strategies were statistically significant, with Group A consistently scoring a higher mean score across the firms than Group B. The strategies as implemented by the firms in Group A are: (1) increased stock or safety stock, (2) to reposition stock across the supply chain to optimise operations, (3) increased collaboration across departments, (4) increased investments in new technologies to enhance operations and visibility across departments and (5) a focus on employee health and safety.

Downstream supply chain disruptions and risk mitigation

Ten measures were used to measure the extent of firms' downstream disruptions and whether there was an increase or a decrease in terms of specific attributes. A 7-point Likert type response scale was used. Both groups indicated an increase ($M > 4$) in all 10 of the measures used, and Group A had a higher mean than Group B in all of these measures.

TABLE 7: Internal supply chains during the COVID-19 pandemic.

Supply chain risk mitigation during the COVID-19 pandemic	Mean	
	Group A	Group B
Internal supply chain disruption		
Operations (or production) complexities*	4.85	4.46
Internal supply chain risk mitigation strategy		
Stock levels or safety stock*	4.28	3.83
Repositioning of stock across the supply chain to optimise operations**	4.66	4.14
Internal collaboration across departments**	5.25	4.77
New technology investments to enhance operations and visibility across departments**	5.08	4.66
Focus on employee health and safety**	5.66	5.21

*, Indicates statistical significance ($p < 0.1$); **, Indicates statistical significance ($p < 0.05$).

A significant difference between the two groups was found in four of the measures used. These measures are tabled in Table 8. Both groups experienced an increase in: (1) customer demand uncertainties, (2) changing buying patterns from their customers, (3) forecasting complexities and (4) downstream (outbound) logistics challenges.

Eight strategies to mitigate downstream disruptions were measured as part of the research. In all eight measures, Group A scored a higher mean score than Group B. Group A also indicated that there was an increase ($M > 4$) in terms of all the factors being measured. Group B indicated an increase in seven of the eight measures. There was a statistically significant difference in six of these measures (refer to Table 8). Both groups indicated that there was an increase in their customer satisfaction (which implies that they were managing these disruptions satisfactorily for their customers). It is noteworthy that this measure was also statistically different between the two groups.

## Lessons learned from the pandemic for future disruptions

In addition, Group A and Group B indicated that several lessons were learned during the COVID-19 pandemic. Some statistically significant differences were observed between the firms in Group A and Group B in terms of lessons learned from the pandemic. These lessons will enable them to better prepare for and respond to future disruptions. Ten measures were used to determine which lessons were learned, and firms were asked on a Likert type response scale to what extent they agree or disagree with statements (where 1 = fully disagree; 5 = fully agree). The differences in responses between the two groups are shown in Figure 2.

From Figure 2, it is evident that both groups at least agreed that lessons were learned ($M > 3$). In addition, there are significant differences between Group A and Group B in terms of all the lessons learned in managing supply chain risks. For example, when analysing the mean scores of the two groups, the firms in Group A seem to better understand

TABLE 8: Downstream supply chains during the COVID-19 pandemic.

Supply chain risk mitigation during the COVID-19 pandemic	Mean	
	Group A	Group B
Downstream supply chain disruption		
Customer demand uncertainties*	5.28	4.67
Changing buying patterns from customers**	5.25	4.85
Forecasting complexities*	5.42	4.97
Downstream (outbound) logistics challenges*	5.05	4.52
Downstream supply chain risk mitigation strategy and performance		
Collaboration with strategic customers**	5.51	4.68
Negotiations with customers*	5.30	4.80
Flexibility with delivery to the customers**	5.21	4.48
Use of agile solutions to meet customer demand**	5.49	4.75
Promotions (or incentives) offered to customers**	4.55	3.98
Investments in technology to enhance customer demand information visibility*	5.04	4.55
Customer satisfaction***	4.89	4.53

*, Indicates statistical significance ($p < 0.05$); **, Indicates statistical significance ($p < 0.01$); ***, Indicates statistical significance ($p < 0.1$).
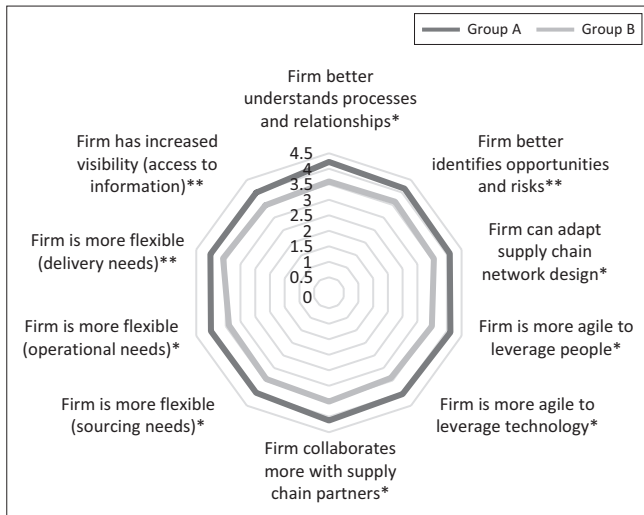
*, Indicates statistically significant ($p < 0.001$); **, Indicates statistically significant ($p < 0.005$).
FIGURE 2: Lessons learned during the COVID-19 pandemic.

their supply chain and have more visibility across their supply chains. The firms in Group A also appear to collaborate more with their supply chain partners across the supply chain and in terms of agility and flexibility across their upstream, internal and downstream supply chains. Group A also, on average, consistently scored very high in these categories and significantly higher than Group B as well.

Conclusion

Supply chain disruptions can have various impacts on supply chains and therefore supply chains need to be resilient. Firms need to be prepared for potential disruptions to – if possible – prevent them from happening, or at least be able to respond to enable the firm to recover as quickly as possible. Supply chain disruptions can happen upstream, internal or downstream from the firm and often these disruptions have an impact on various parts of the supply chain. Applying the DCs theory to the research as part of the theoretical foundation, it became evident that firms need to assess and adapt quickly to seize opportunities and overcome threats by enabling capabilities and resources. For this reason, supply chain risk mitigation strategies can be implemented in the upstream and downstream parts of a firm's supply chain as well as internal to a firm.

Upstream supply chain risk mitigation strategies

In the firms' upstream supply chain, there was a significant difference between Group A and Group B in terms of:

- **Agility and flexibility:** Flexible sourcing (and inbound logistics) arrangements.
- **Collaboration:** Collaboration with suppliers (and accurate information sharing).
- **Redundancy:** Increasing the supply base (i.e. number of suppliers) during a disruption.

In all these three cases, the firms in Group A, on average (as opposed to the firms in Group B), used more suppliers,

collaborated more with their suppliers and had more flexible sourcing arrangements. These three strategies are clear examples of the broad supply chain risk mitigation strategies selected for this research, namely, agility and flexibility, collaboration and redundancy strategies in the firms' upstream supply chains. Therefore, hypothesis H_{2a} is supported for the strategies mentioned above.

Internal supply chain risk mitigation strategies

In the firms' internal supply chain (and if analysing the mean scores of both groups), there was a significant difference between Group A and Group B in terms of:

- **Agility and flexibility:** Repositioning of stock across the supply chain to optimise operations.
- **Collaboration:** Increased collaboration across internal departments, as well as new technology investments to increase visibility across internal departments.
- **Redundancy:** Increased stock levels and a focus on employee health and safety.

Again, in all these cases, the firms in Group A (as opposed to the firms in Group B) had higher mean scores. The repositioning of stock across the supply chain to optimise operations is an example of being agile and flexible, while increased stock levels is an example of redundancy. Also, in the firms' internal operations, the broad supply chain mitigation strategies selected for the research are implemented in a statistically significant manner. Therefore, hypothesis H_{2b} is also supported for the abovementioned strategies.

Downstream supply chain risk mitigation strategies

There were statistically significant differences in the downstream supply chains of the two groups too. These differences were:

- **Agility and flexibility:** (1) Flexibility with delivery arrangements with customers, (2) promotions and incentives offered to customers, and (3) agile solutions to meet customer demand.
- **Collaboration:** (1) Collaboration with strategic customers, (2) negotiations with customers, and (3) investments into technologies to improve visibility of downstream customer demand.

In each of these measures, the firms in Group A had higher mean scores and the differences between the groups were significant. Two of the three supply chain risk mitigation strategies selected for this research were implemented in the firms' downstream supply chains (and redundancy was not specifically measured for downstream supply chains). Therefore, hypothesis H_{2c} can also be supported.

Lessons learned

Successful supply chain risk mitigation is based on the premise of preparedness, response and recovery. Several

supply chain risk mitigation strategies can be implemented during the response phase. Several lessons were learned that firms could implement to be better prepared for future disruptions. The lessons learned during the COVID-19 pandemic by firms to mitigate risks during the disruption were (with significant differences between Groups A and B and Group A scoring higher on average with each lesson) the following, namely that the firms in Group A:

- had a better understanding of their processes and relationships
- were better equipped to identify opportunities and threats
- could adapt their supply chain network to meet demand
- were more agile in leveraging people and technologies
- collaborated more with supply chain partners
- were more flexible in terms of sourcing, processes and delivery
- had increased visibility across the supply chain.

Supply chain risk mitigation strategies to implement during disruptions

The conclusions from the findings also suggest that the following supply chain risk mitigation strategies can be implemented during disruptions. Firms can use the lessons learned from the COVID-19 pandemic to:

- Be agile and flexible and adapt tactics to effectively respond to disruptions in terms of upstream sourcing and logistics, internal processes and downstream deliveries.
- Use better understanding and visibility of their supply chains to collaborate and manage disruptions more effectively in terms of suppliers (inbound processes), internal processes, and customer demand (outbound processes).

The strategies include utilising redundancy as tactic to mitigate risks. Based on the findings of the research, the following conclusions can be made:

- **Conclusion 1:** An effective supply chain risk mitigation strategy implies a focus on agility and flexibility across the entire supply chain during disruptions.
- **Conclusion 2:** An effective supply chain risk mitigation strategy implies a focus on collaboration with supply chain partners across the entire supply chain during disruptions.
- **Conclusion 3:** An effective supply chain risk mitigation strategy implies a focus on implementing redundancy strategies when necessary, during disruptions.
- **Conclusion 4:** It is implied that an effective supply chain risk mitigation strategy with a focus on: (1) agility and flexibility, (2) collaboration, and (3) implementing redundancy where necessary, may assist firms to recover relatively quickly to their normal position prior to the disruption.

Figure 3 provides a summary of the conclusions made above.

Managerial implications

Paul et al. (2021b:316) state that previous research shows that four in five firms that did not have appropriate risk mitigation strategies in place during major disruptions had to close their business within 2 years after the major disruption. The frequency of major disruptions has increased during recent years and not only in terms of epidemics and pandemics but also in other areas of the macro environment. Firms across the world, including South Africa, have recently faced numerous major disruptions. The findings in this research clearly show that firms that had an effective risk mitigation strategy in place recovered, on average, quicker to their pre-COVID-19 positions as opposed to firms that did not have an effective
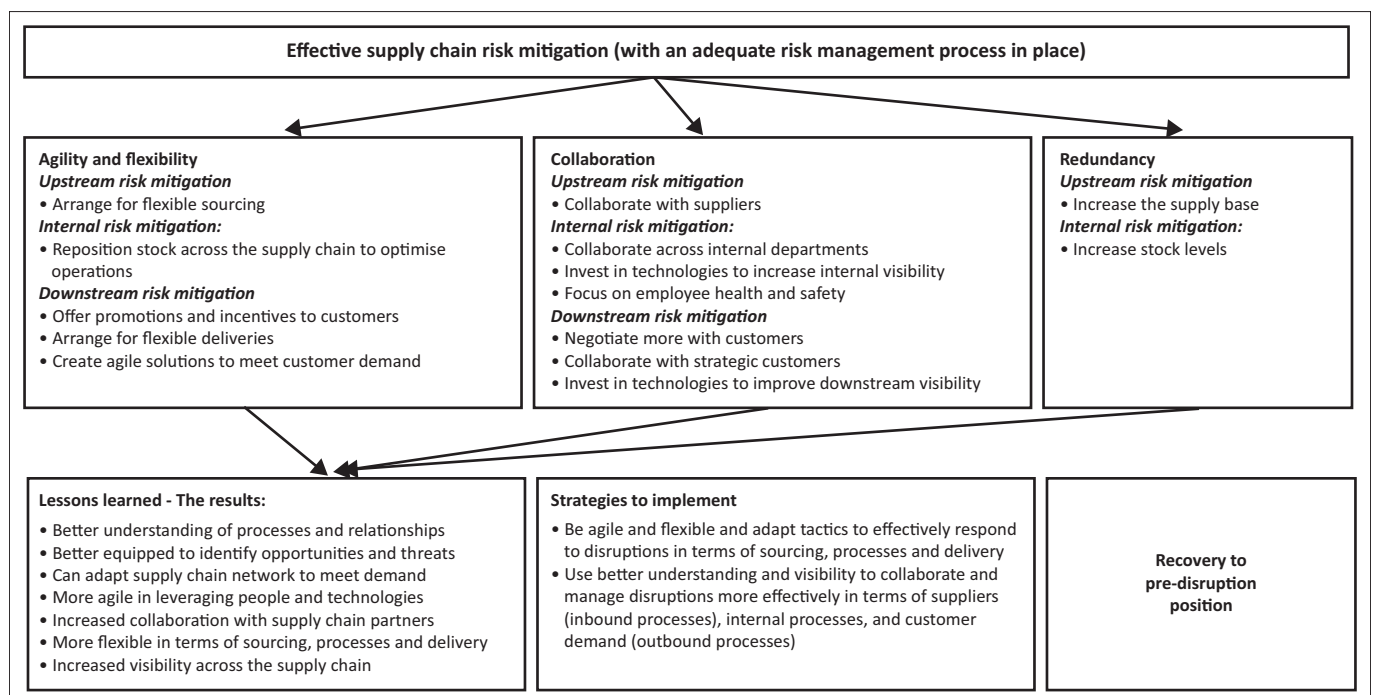

FIGURE 3: Effective supply chain risk mitigation.

risk mitigation strategy. Supply chain risk mitigation strategies can be implemented across the supply chain (i.e. the upstream, internal and external supply chains). Numerous supply chain risk mitigation strategies have been identified. This article focuses on three specific strategies, namely agility and flexibility, collaboration, and redundancy. The research has shown that – during disruptions – firms need to collaborate with their supply chain partners across the supply chain. This includes collaboration with their upstream and downstream supply chain partners as well as collaborating between departments in the firm. The research also showed that firms need to be agile and flexible to adapt and offer agile solutions to the challenges that disruptions present. Lastly, the research also showed that redundancy can be used very effectively in the firm to manage supply chain disruptions.

Limitations of the research and future research

The findings of this research cannot be generalised to the broader supply chain population. Yet, the findings do provide some valuable insights. It seems as if there are some key characteristics that firms may adopt to assist them in managing risk events in terms of implementing agility and flexibility, collaboration and redundancy as supply chain risk mitigation strategies. The nature of different disruptions requires different risk mitigation strategies. Therefore, a so-called blueprint or template risk mitigation strategy cannot be designed for all disruptions.

It would be interesting to know if the supply chain risk mitigation strategies discussed in this research apply across different industries or for different sized firms. In addition, it would be interesting to determine in more exact terms what agility, flexibility and collaboration entail for different firms in different industries and exactly how each of these strategies impact each other.

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Competing interests

The author declares that no financial or personal relationships exist that may have inappropriately influenced them in writing this article.

Author's contributions

J.D.N. declares that they are the sole author of this research article.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of Pretoria Faculty of Economic and Management Sciences Research Ethics Committee (No. EMS027/23). An opt-in database was used in which respondents willingly agreed to partake in this research. The objectives of the research were specified clearly and anonymity as well as confidentiality were assured. Respondents could withdraw at any stage of the research. They were allocated a number based on the order of when the responses were received.

Data availability

The data that support the findings in this research are available from the author, J.D.N., upon reasonable request.

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