

Article

Exploring Progress with Supply Chain Risk Management during the First Year of the COVID-19 Pandemic

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Abstract: *Background:* In response to calls for actionable research that considers ongoing pandemic risk dynamics, we explore how risks experienced and risk mitigation techniques used have changed during the first year of the pandemic. *Methods:* We used a survey and studied six cases; data were collected both at the start of the pandemic and one year into the pandemic. This paper offers the first empirical exploration of the first full year of the pandemic and provides data points from both early and one year into the pandemic. *Results:* Our findings indicate that not only are pandemic risks far from mitigated, several types of risks have also increased in severity. Multifaceted and multidirectional approaches have been adopted, going well beyond demand and supply risks (the risks most widely considered in the literature) and much more work remains for supply chain managers to mitigate risks and improve supply chain resilience. *Conclusions:* We find that in addition to the risk management techniques, considering behavioral aspects is key for navigating a pathway towards risk mitigation.

Keywords: COVID-19; risk management; change management



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1. Introduction

During the first year of the COVID-19 pandemic, supply chain managers faced massive demand upswings and supply fluctuations [1]. We experienced empty shelves in retail stores and rapid growth in e-commerce. There were temporary shutdowns of ports and factories in various parts of the world. Fortunately, there are several risk mitigation techniques and strategies available from the literature (see for example [2–4]), including: inventory buffering, diversification of the supply base, digitization and supplier collaboration. It is said that the elements for building a more responsive supply chain are all there, but that they need to be better woven together [5], implying the need to focus on implementation and change management involved in responding to the pandemic. It should be noted, however, that the pandemic presents a unique set of circumstances, different from events in response to which existing techniques were developed [6]. While the elements may be there, traditional elements of a responsiveness strategy may not apply in pandemic circumstances or may apply differently [7], and the change management involved in implementing the response may be slow and complex [8]. Additionally, the risks and dynamics experienced one year into the pandemic may differ and call for different risk mitigation techniques [9].

It is not surprising therefore that Ketchen and Craighead [10] called for research that is actionable (ideas that can be implemented) and focused on what responses to the pandemic might work. The long-lasting risk impact of the pandemic [6] presents a unique opportunity for empirical research that explores the risk dynamics and mitigation approaches over time. In response to this opportunity, we developed the first empirical exploration (to our knowledge) of the unique long-lasting impact of the pandemic, including comparative data covering a year-long period of risk mitigation, and pandemic dynamics and risks. This enables us to study three questions: (1) Have risk levels experienced reduced or changed? (2) What has been the applicability of known risk mitigation techniques in navigating ongoing pandemic dynamics? (3) What are the lessons learned about the implementation of risk mitigation techniques?

2. Literature

The risk management literature and more recent empirical studies of risk management in the context of the pandemic have offered some perspectives on the types of risk, risk mitigation techniques and the implementation of risk management techniques. The list of supply chain risks provided by Christopher and Peck [11] is well known and widely referenced [3]. Risks included are: supply risks, demand risks, control risks, process risks and environmental risks. Supply risks are related to disruptions of upstream sources and inbound supplies. During the pandemic the closure of factories has created major supply risks, initially largely for supply from China and later on from many other regions of the world as well [12]. Demand risks are related to fluctuations in downstream demand. During the pandemic, increases in demand have occurred, for example for PPE. Control risks center around disruptions of internal control and governance systems. The dynamics of the pandemic may have caused the need to reconsider governance [5], implying that control risks may be high. Process risks are those risks related to the reliability of supply chain processes and they drive the need for visibility into bottlenecks and transparency of inventory positions. Given the disruptive nature of the pandemic, it may be assumed that process risks have been high the past year. Environmental risks are external forces that may cause supply chain disruptions and the pandemic is a perfect example of an environmental risk. Ho et al. [13] expanded these sources of risk into a broader supply chain scope by adding manufacturing risks related to the disruption of manufacturing operations, transportation risks related to disruptions and bottlenecks in transportation and financial risks. It may be assumed that the pandemic increased financial strain on companies and that supply and demand risks, coupled with process and control risks, impacted manufacturing and transportation risks. Manufacturing risks may have also been high due to new sanitization and distancing needs [14,15].

The literature offers several possible techniques to manage and mitigate these risks, including inventory buffering to improve responsiveness to surges in demand and reduce the impact of supply risks [16]. Avoiding single sourcing from a limited number of global locations by ensuring multiple, flexible and alternative sources and including near and local sourcing in the supply network are risk mitigation techniques that can help reduce supply and manufacturing risks, improve product availability in response to demand, process and control risks [17]. Near and local sourcing as part of a strategy aimed at reshoring improve responsiveness to demand and reduce risks involved in long transportation pipelines [18]. Guan et al. [19] found that multisourcing can generate higher total profits compared to single sourcing when faced with supply chain disruptions, indicating that multisourcing can also help reduce financial risks.

Chowdhury et al. [20] pointed at the value of collaboration and intensifying interactions in the face of disruptions and Manuj and Mentzer [21] recommended supplier collaboration to share the risks. This may be in contrast with Kovacs and Falagara Sigala [17], who considered that long-term relationships may be less relevant in the face of high dynamics. Additionally, if companies face financial risks they may focus on increasing savings with suppliers.

Digital technologies can play a significant role in improving responsiveness [22]. Quayson et al. [23] called for digital transformation and digital inclusion for building resilient post-COVID-19 supply chains. Specifically, active information-sharing throughout the supply chain can improve responsiveness, enabling the greater levels of openness called for in the context of the pandemic by Ivanov and Dolgui [24]. Pettit et al. [3] also recommended the use of leading risk indicators and event management systems as an alternative to quarterly or monthly reports that provide a “rearview mirror”. The pandemic risks may just be too great and dynamic for managers to be able to wait for the next (financial or supplier performance) reporting cycles. Greater openness achieved with active information sharing and the use of IT and event management systems may lower control and process risks, and improve the supply availability and responsiveness to demand, manufacturing and transportation risks. A focus on collaboration and negotiating

savings with selected suppliers may reduce supply risks and improve product availability in response to demand risks. It may also help compensate for process and control risks. In addition to the assumption that these techniques are relevant in the context of the pandemic, it can also be assumed that these techniques continue to hold relevance in different time horizons, as found in the early stages of the pandemic [25].

Recent publications about risk management during the pandemic indicated that there was more work to do for supply chain managers to reduce risk [9,25]. The reason for the discrepancy between theoretical prescriptions and real-world happenings may be behavioral components [26]. Perhaps the conceptual recommendation to consider moving supply chain governance from deterministic optimization with command and control, towards a focus on navigation, cycles of experimentation and greater levels of openness in intertwined relationships [24,27,28] may not be easily implemented. This may be due to the importance of the human factor in supply chain management and the change management involved in implementing those techniques may be time consuming, as change in supply chains can be [29].

The behavior of supply chain managers in the face of disruptions has been called out as an emerging and promising area [30]. Sitkin and Weingart [31] found a relationship between risk propensity, or the willingness to take risk, risk perception and risk decision making. It may be assumed that in the context of the pandemic, experience with risks increased during the first year of the pandemic and that, as a result, more decision making took place one year into the pandemic. It may be assumed that the decision-making process varies depending upon the type of risks experienced [32]. When it comes to behavioral aspects, the focus has been placed on issues of information sharing to improve supply chain efficiency [33]. Schorsch et al. [27] developed a categorization of information processing in the supply chain, reproduced in Figure 1. They found the largest focus in existing behavioral research to be on information processing, particularly operational information processing, and a lesser focus on perception of future outcomes and the handling of feedback. The least focus in behavioral research was found to be on information acquisition and a much greater focus was found on the firm and dyadic levels than on the chain and network levels. It may be assumed that with a growth of risk propensity during the pandemic, managers are more willing to share information, in particular at the supply chain level, and that their ability to execute changes in the supply chain may improve.

		Information acquisition	Information processing	Perception of future outcome	Handling of feedback
Level of decision making	Operational		Greatest focus in literature		
	Tactical		Greater focus in literature	Focus in literature	
	Strategic		Focus in literature		
Scope of decision making	Firm level		Greater focus in literature		
	Dyadic level		Greater focus in literature		
	Chain level		Less focus in literature		
	Network level		Little focus in literature		

Figure 1. Schorsch et al. (2017) categorization of information sharing and its coverage in the literature.

3. Method

We used both a survey and six case studies to explore risks experienced and mitigation techniques used in the context of the pandemic. Both methods were utilized at two points in time, to collect data during the initial stages of the pandemic and again 1 year into the

pandemic. This enabled us to both develop a longer time horizon of data as well as to include more recent data than in currently available research.

A survey was developed asking respondents for risk levels experienced and risk mitigation techniques used on three timelines: short-term, mid-term and longer-term. The survey was administered online using Qualtrics and distributed in late May/early June of 2020 to 79 supply chain managers, using a convenience approach inviting supply chain managers participating in a certificate program, an EMBA supply chain capstone class and personal industry connections from the authors around the world. Although this was a convenience sample, we were able to engage managers representing companies in a wide range of industries, including logistics, manufacturing and retail, and a range of roles, including chief procurement officer, supply chain managers and supply chain SVP. Respondents originated from both Europe and the US. The same survey was then distributed to the same group of respondents and additional connections nine months later, in March 2021, to increase the total number of respondents to 157. While it is obviously not possible to conduct an in-depth statistical analysis of this survey data, it does provide a further exploration of the topic as beneficial input to the discussions with managers, which is why we engaged six case companies to further explore risks experienced and mitigation efforts.

Initial interviews with case companies started in late May 2020, just after the initial survey data were collected and explored. In April 2021, the case companies were revisited to add to our data about what happened since the early stage of the pandemic and what risks and mitigation techniques were being pursued at that point in time. Table 1 provides an overview of the six case companies and the respondents.

Table 1. Overview of case companies.

	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6
Industry	Tools and DIY products	Electronics	Fitness and outdoor equipment	Vision products	Aerospace	Wood products, tiling and sanitary products
Supply chain position	Manufacturer	Distributor	E-commerce company	Manufacturer	Manufacturer	Manufacturer
Geography	USA	Middle East	USA	USA	Europe	Latin America
Company size	Small-medium	Medium	Small	Large	Large	Large
Respondent	Head of procurement and supply chain	Supply chain manager	Head of procurement	Chief procurement officer	Chief purchasing officer	Supply chain

Although this was a convenience sample, we selected the case companies in an effort to involve multiple supply chain positions (manufacturer, upstream supplier, distributor and e-commerce), industries (electronics, aerospace and equipment) and parts of the world (Europe, the Middle East, Latin America and the USA). While this does not allow for a generalization to any specific part of the supply chain, any geography or industry, it does enable a broad exploration, not limited to sections of the industry or the supply chain. It also enables initial exploration in an international setting, all of which seemed fitting given the global impact of the pandemic, not limited to a specific part of the world or just a few industries or supply chain positions.

Case company 1 is a manufacturer of tools and equipment for the building, construction and DIY industry. The privately held company is medium-sized, sources materials and parts from low-cost countries and has outsourced part of the molding and assembling to domestic suppliers. The company also has its own molding and assembly operations. Case company 2 is a medium-sized distributor of electronics products in the Middle East, working for a number of electronics manufacturers. Case company 3 is a small-to-medium-sized e-commerce company, based in the US, that develops, sources, sells and delivers a variety of steel products for fitness, outdoor living and tractor attachments. The company is privately held and sells exclusively online. It develops (sometimes in collaboration with its suppliers) its products, commissions manufacturing and runs its own warehousing and

fulfillment operation. The company currently only sells in the USA. Case company 4 is a US-based manufacturer of vision products (glasses, contacts) and vision care products, the majority of which are manufactured in China with some of them designed in Europe. Case company 5 is a European aerospace manufacturer that operates around the world and has a fairly complex supply chain with many of the thousands of parts sourced from Asia. Case company 6 is a Latin American based upstream manufacturer. The company has a diversified product range including wood products, tiling and sanitary ware. The company has a large supply base, scattered around the world, of over 7000 suppliers.

4. Changes in Risks Experienced

Figure 2 compares the degree to which respondents experienced different types of risk during the early stage of the pandemic with that one year into the pandemic. Scores are on a qualitative scale ranging from 0 for “not experiencing”, 1 for “somewhat experiencing”, 2 for “clearly experiencing”, to 3 for “greatly experiencing”. At a high level, the data show that all types of risks are experienced but to differing degrees. Demand and supply risks, the risks most frequently discussed in the literature, are prominent but so are financial risks, perhaps as a consequence. Manufacturing and transportation risks are also substantial, reinforcing the relevance of exploring beyond demand and supply risks. Perhaps fortunately, control and process risks are experienced at a somewhat lower level. This may imply that managers do feel they have some control and process robustness to cope with the risk scenarios experienced.

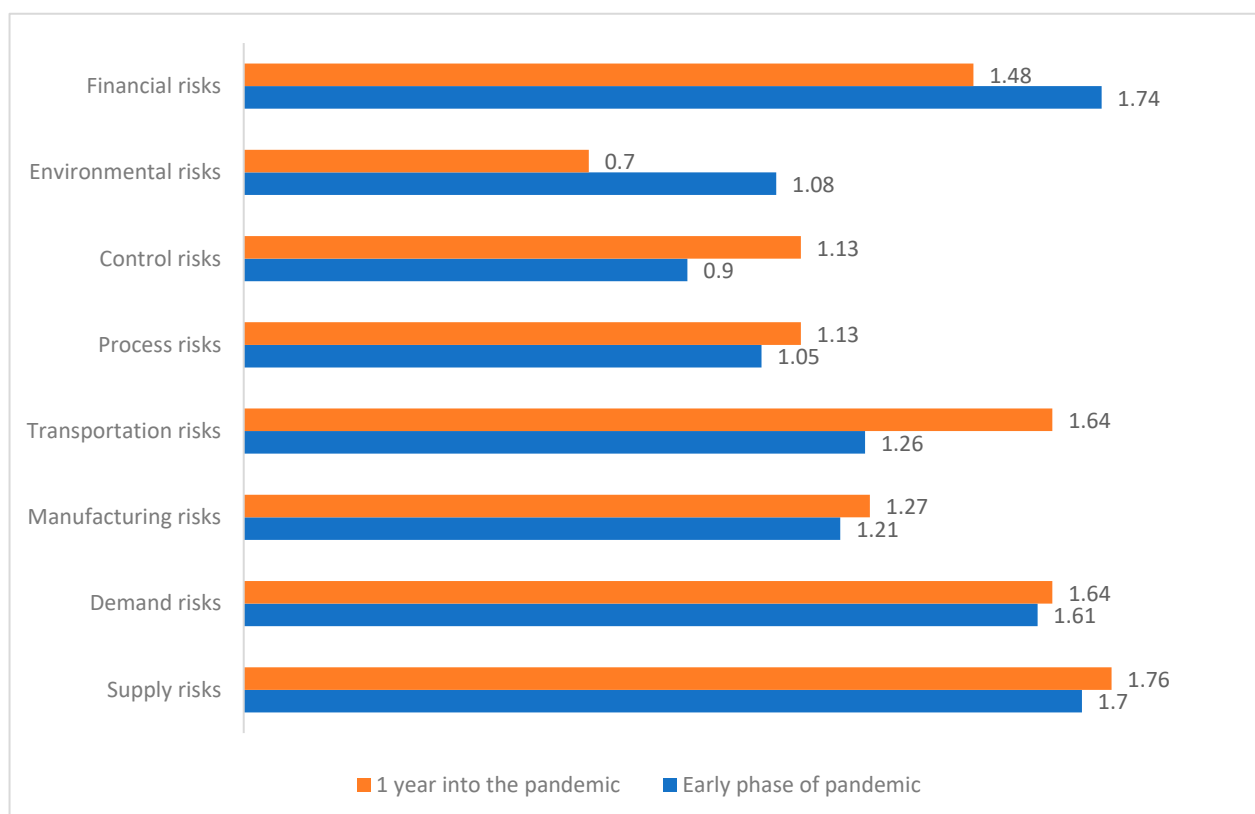


Figure 2. Risk levels experienced in the early phase of the pandemic and 1 year into the pandemic.

The most interesting and newsworthy in this figure is that for the first time we can compare risk levels over the course of the first year of the pandemic. Although all risks have remained present in the second round of data collection, one year into the pandemic, none of the risks have remained at the same level. Figure 3 shows the delta in average scores between the first and the second round of data collection. Bars pointing to the right represent increases in risk levels and bars pointing to the left represent decreases in risk

levels. Six findings stand out. First, all but two types of risk have increased during the first year of the pandemic, indicating that the pandemic impact is far from over and perhaps that, while much work has been done in supply chain management, these efforts have not necessarily led to reduced risk levels. Second, environmental risks show the largest delta across all risk types with a 35% drop. The implication is that risks are now less driven by unexpected outside events, but rather they are happening within the supply chain dynamics. Third, the relatively good news is that financial risks have also reduced so perhaps managers were able to better manage financial consequences of the pandemic. Fourth, the increase in control risks may imply that managers continue to battle with ways to mitigate risks and that they are experiencing limits to their ability to mitigate demand, supply and manufacturing risks, that have remained high. Effectively, perhaps implying that a new governance approach for supply chains is needed indeed. Fifth, the largest increase in risk was experienced in transportation risks and the risk now matches demand risk and is only second to supply risk. This is likely driven by growing scarcity and disruption in transportation during the second half of the first year of the pandemic, and offers a clear further illustration of how risk levels have changed during the first year of the pandemic and of why pandemic risks are far from mitigated or resolved. Finally, counter to the great attention to demand issues at the start of the pandemic, supply risk has become the single most intensely experienced risk.

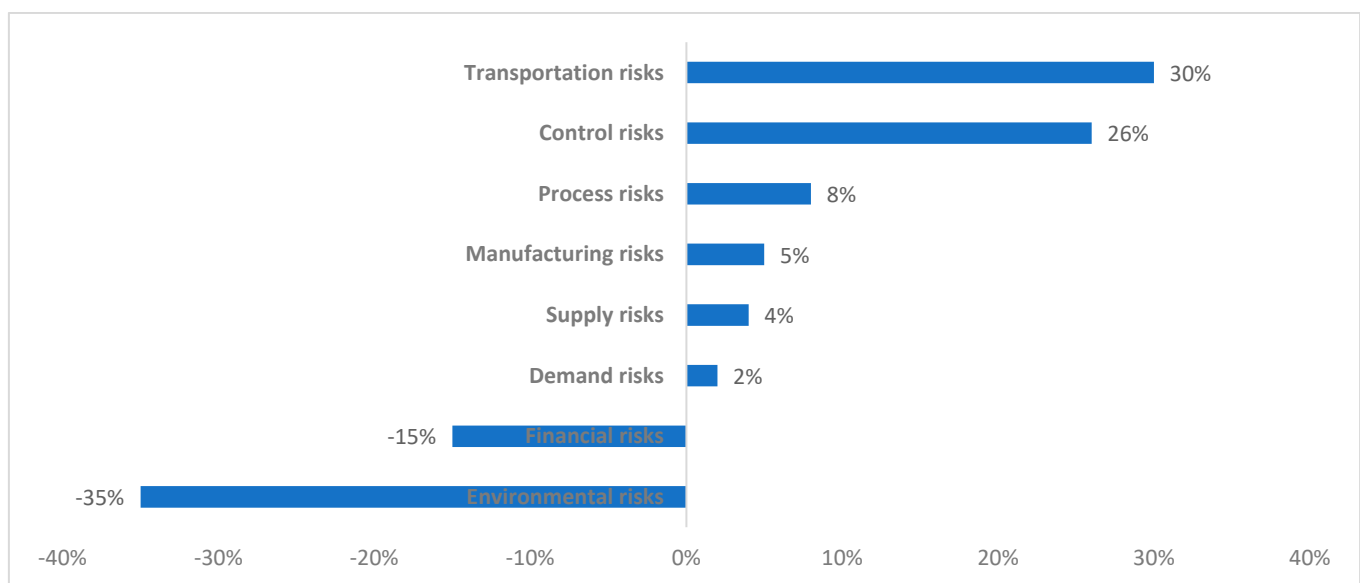


Figure 3. Change in risk levels experienced between the early stage of the pandemic and one year into the pandemic.

Table 2 offers an overview of risks experienced and perceived by the case companies both at the start of the pandemic, as well as a year into the pandemic. The table mirrors the multidirectional and multifaceted changes in the various risks and the case studies help unpack how there are supply chain specific factors at play, beyond drivers that may be assumed based upon the literature. Supply risks have decreased in case 1, 3 and 4. In all these cases, that decrease was driven by the reopening of factories and by countries that were forced to shut down at the start of the pandemic. In addition, cases 1 and 3 pursued supplier diversification techniques to reduce their reliance on a limited number of sources, all of that in line with recommendations from the literature.

Table 2. Risks experienced in the early stage of the pandemic and one year in.

	Case 1— Manufacturer Tools		Case 2— Electronics Distributor		Case 3— E-Commerce		Case 4— Manufacturer Vision Products		Case 5— Aerospace Manufacturer		Case 6— Wood Products Manufacturer	
	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in
Sources of Supply Chain Risk												
Supply risk	+++	+	++	+++	+++	++	+++	+	+++	+++	++	++
Manufacturing risk	++	+	-	-	++	++	+	+	++	+++	+	+
Transportation risk	++	+++	+	+++	+	+++	+	++	++	-	+	++
Demand risk	-	-	++	+++	+++	+++	+++	+	+++	+++	+	+++
Process risk	++	+	+	+	+	+	+	++	++	++	+	+
Control risk	+	++	+	++	++	+	+	+	+	++	+	+
Environmental risk	+++	-	++	-	+++	-	+++	+	++	-	++	++
Financial risk	++	+	++	-	+	-	++	+	++	+++	+++	++

Keys: - do not experience + somewhat experience ++ experience +++ very much experience.

“Production sites opened back up and we have continued to add new suppliers into our portfolio to continue to reduce our reliance on just a few suppliers, located in just a few regions.” Head of procurement and supply chain, case company 1.

But perhaps counter to expectations, supply risks remained high to very high for cases 5 and 6 and even increased in case 2. Case company 5 has faced continued shortfalls in demand and as a result, suppliers are considering discontinuing the collaboration, increasing the company's supply risk. Case company 2 operates in the electronics industry which has been hit hard by processor unavailability, leading to longer lead times and limited parts availability. This has greatly impacted the case company's supply chain organization, not just facing the supplier, but all the way to its ability to meet customer service requests.

“There is a large scarcity of products and it has become an industry wide problem that is making it hard for us to meet our customer commitments.” Supply chain manager, case company 2

Manufacturing risks decreased in case 1, in relation to the reduced supply risk. This illustrates how, through the management of supply risks, supply chain managers can impact not only customer service but also manufacturing operations. It also illustrates the relationship between supply risks and manufacturing risks as a secondary risk. As a further illustration of both of those points, manufacturing risks in case 5 increased due to increased supply risks and the risk of suppliers going out of business;

“With a large number of sole-suppliers on our risk watchlist we face large manufacturing risks; it only takes one of over 4000 parts to not be available and you do not have an engine.” CPO, case company 5.

Transportation risks are one of the main changes for the case companies between the original data collection at the start of the pandemic and the second collection one year into the pandemic. All but case company 5 report an increase in transportation risks. The reason why case company 5 did not experience an increase is that it was facing such a demand shortfall that it had little shipment need. Still, it illustrates that there are no universal tendencies or patterns in the risk dynamics of the pandemic. The transportation risks are also experienced in different parts of the transportation pipeline. Case company 1:

“The ports in LA shut down for a while due to COVID outbreaks and they are still trying to catch up. In doing so they have changed operating procedures several times making it really hard to plan ETA's. First, they did FIFO, then they move to FILO. I have one container that has been in the part since February and currently it is slated for handling in June.”

Case company 2:

“On top of limited supply, the transportation market from Asia is very constrained and we are needing to book capacity in advance in hopes of getting product in shipment when it arrives in the port of origin.”

Case company 3:

“Our final delivery transportation companies are now assigning us limited allotments, a limited number of truckloads, that they are willing to award to us.”

Demand risks evolved in different directions and for different reasons. Case companies 2 and 6 experienced rapid and continued growth in demand, challenging their supply chains' ability to meet demand. Case company 6:

“After one year, there is an important difference: we are reaching records in production because of the demand in the market. All our factories in all our businesses are working in full production. This has driven a great impact in raw materials. One of the inputs that had a great impact, for example, was packaging boxes. We formed an internal committee to analyze short-term alternatives to solve the problems arising from the lack of cardboard boxes from our main suppliers.”

Case company 4 experienced a reduction in demand risks due to demand normalization and supply availability improvement. Case companies 3 and 5 both saw continued high demand risks but for different reasons: case company 3 was experiencing continued growth of demand that the company found challenging to meet with supply, whereas case company 5 faced continued shortfalls of demand and this was placing pressure on supplier relationships and the financial viability of the company and its supply chain partners. Figure 4 maps the changes in demand risk in relation to the changes in supply risks for the six case companies, to advance the conceptual point from Sodhi and Tang [1] that demand and supply risks are involved in the pandemic. The figure adds a dynamic perspective to this notion and demonstrates the rich multitude in change directions experienced.

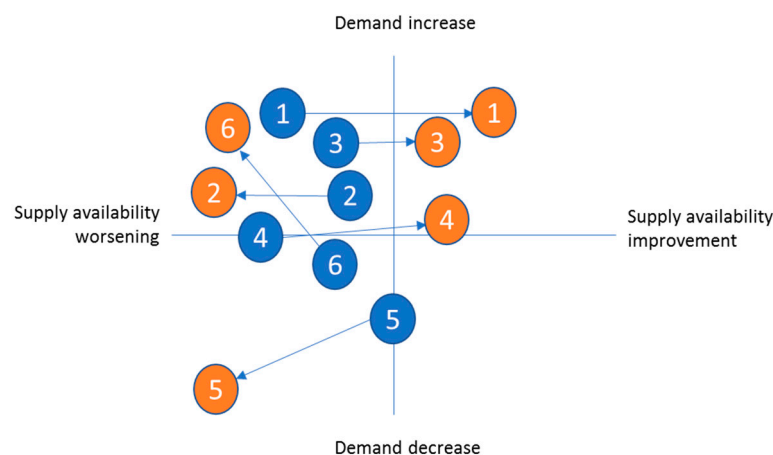


Figure 4. Dynamics in demand and supply risks experienced by case companies 1–6.

As an illustration of process and control risks being more of a consequential risk, case company 1 was experiencing an increase in control risk due to the lack of transportation capacity, as was case company 2. Environmental risks by and large decreased across case companies and this was driven by the pandemic becoming more of a known factor, indicating a possible experience effect impacting risk perception. Financial risks decreased for all companies except for case company 5 that faced a continued demand shortfall. Case companies 1, 2, 3 and 6 were benefiting from demand growth and case company 4 faced a stabilization of demand and supply, improving its financial positions.

5. Change in Risk Mitigation Techniques Used

Table 3 shows the degree to which risk mitigation techniques from the literature were reported as being used, or not, by respondents, with a short-term, mid-term or longer-term time horizon. Respondents were able to pick multiple time horizons and the table presents the percentage of respondents in the initial data collection (top value of each cell) and in the second data collection round (bottom value of each cell). For example, 13.41% of respondents did not use inventory buffering in the early stage of the pandemic while 15.58% did not use inventory buffering one year into the pandemic. Interestingly, almost all scores increased between the first and second data collection, implying a step-up in mitigation actions in the face of ongoing and increasing risks. In addition to their increased efforts, supply chain managers continue to indicate that much work remains in the mid to longer term to build a more resilient supply chain—the impact of the pandemic is indeed far from over.

Table 3. Degree to which risk mitigation techniques were used, by time horizon, in the early stage of the pandemic and one year into the pandemic.

	Do Not Use This	Use This Technique as Part of Short-Term Risk Mitigation	Use This Technique as Part of 3–6 Month Recovery Efforts	Use This Technique as Part of Longer-Term Efforts to Make the Supply Chain More Resilient
Inventory buffering	13.41% 15.58%	42.68% 55.84%	26.83% 35.06%	17.07% 22.08%
Reduce reliance on single/few factories	14.81% 22.08%	14.81% 28.57% *	22.22% 25.97%	48.15% 48.05%
Ensure multiple flexible and alternative sources	3.13% 5.19%	19.79% 29.87%	29.17% 33.77%	47.92% 72.73%
Include near and local sourcing in the supply chain	9.28% 12.99%	31.96% 24.68% *	25.77% 29.87%	32.99% 58.44%
Active information sharing throughout the supply chain	4.03% 6.49%	31.45% 32.47% **	29.03% 35.06% ***	35.48% 71.43%
Use information technology to improve visibility into demand and transparency of inventory	10.66% 16.88%	25.41% 22.08% *	26.23% 28.57% *	37.70% 71.43%
Use event management systems and leading risk indicators	15.38% 38.96% **	26.50% 16.88% *	27.35% 15.58% *	30.77% 44.16%
Focus on ensuring supply and collaboration with strategic suppliers	1.56% 3.9%	21.09% 27.27%	32.03% 41.56%	45.31% 84.42%
Negotiate savings and payment terms with selected suppliers	9.32% 10.39%	27.97% 29.87% **	30.51% 38.96%	32.20% 59.74%

Keys: Independent sample *t*-test: * represents significance at the 0.001 level; ** represents significance at the 0.05 level; *** indicates significance at the 1 level.

Statistically significant changes were found for the increased short-term focus on reducing reliance on a single or few factories and the short-term focus on near and local sourcing. The increase in active information sharing in the short- and mid-term was also statistically significant, as was the use of IT to improve visibility and event management systems. The number of respondents not using event management systems increased significantly, perhaps because of the lack of widely available event management solutions. The focus on collaborating with suppliers did not change significantly and remained high throughout, indicating that collaboration may not have been altered by risks. This is counter to Kovacs and Falagara Sigala [17] who assumed that longer-term relationships may be less relevant in times of disruption. However, the short-term focus on negotiating savings and payment terms with selected suppliers increased significantly; although this may not occur with all suppliers, it might imply a slight return to a prepandemic standard focus area in procurement.

Table 4 offers an overview of risk mitigation techniques adopted by the case companies both at the start of the pandemic, as well as a year into the pandemic. The first three rows reflect supplier diversification, including deglobalization of supply through the inclusion of more near and local sources. Figure 5 shows the use of these techniques in the context of the demand and supply risk dynamics experienced by the case companies. This figure helps illustrate how the implementation of risk mitigation techniques varies among companies. Whereas case companies 1 and 3 experienced improved supply availability as a result of their ongoing efforts to integrate new suppliers and including local suppliers, case company 6 did the same while experiencing worsening supply availability. This is partially explained by the rapid growth in demand that case company 6 experienced, indicating that perhaps demand risks can override supply availability improvement efforts. The figure also illustrates that theory-prescribed risk mitigation techniques do not relate unidirectionally and unilaterally with risks experienced.

Table 4. Risk mitigation techniques used in the early stage of the pandemic and one year in.

	Case 1— Manufacturer Tools		Case 2— Electronics Distributor		Case 3— E-Commerce		Case 4— Manufacturer Vision Products		Case 5— Aerospace Manufacturer		Case 6— Wood Products Manufacturer	
	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in	Initial	1 year in
Risk Management Techniques in the Supply Chain												
Reduce reliance on single/few factories	+++	+++	-	-	++	+++	+	-	++	-	+++	+++
Ensure multiple, flexible and alternative sources	++	++	-	++	++	++	++	-	++	-	+++	+++
Include near/local sourcing in the supply chain	-	+	-	-	++	+++	+	-	++	-	++	++
Inventory buffering	+++	++	+++	+++	-	-	+++	-	+	+++	++	+++
Active information sharing throughout the supply chain	+++	+	+	++	-	++	+	++	-	+++	++	++
Use information technology to improve visibility into demand and transparency of inventory	+	+	-	+++	-	++	+	++	-	-	++	++
Use event management systems and leading indicators	-	-	-	++	-	-	+	++	-	+++	+	+
Focus on ensuring supply and collaboration with strategic suppliers	++	++	++	++	+++	+++	+++	+++	+++	+++	+++	+++
Negotiate savings with selected suppliers only	-	+	-	-	-	+	-	++	-	-	+	+

Keys: - do not use; + use modestly so; ++ use; +++ very much use.

Inventory buffering was found to be largely a short-term risk mitigation technique in the early stages of the pandemic, but one year into the pandemic the technique is still used in a few cases for similar and different reasons. For example, case company 1 is using inventory buffering for transportation limitations. Case company 5 is allowing inventory buffers to grow in an effort to honor part of its order commitments to suppliers, despite the shortfall in demand. The case company is not buffering to improve responsiveness to demand in the face of limited supply. It is instead taking on additional inventory to support suppliers in the face of oversupply. This example shows how a collaborative focus may supersede inventory minimization considerations and how inventory buffering

is not only a technique for improving demand responsiveness but also a collaborative response. This technique further illustrates how there are unique scenarios involved in responding to pandemic risk mitigation needs outside of, and in addition to, prescriptions from the literature.

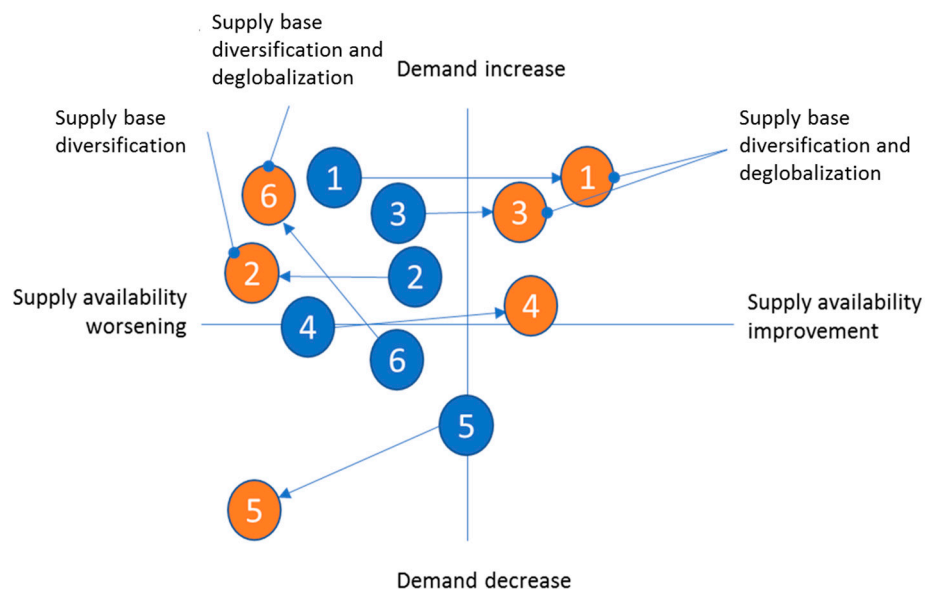


Figure 5. Relationships between supply base diversification, deglobalization and dynamics in supply and demand risks.

The use of information sharing and information technology to improve visibility and the use of event management systems play a differentiated and interesting role that is also partly counter to theoretical prescription. Case company 2 increased its focus on information sharing and IT in the face of transportation risks:

“We started a new initiative to use IoT devices to cases and pallets to improve visibility into real time inventory location and positions. We are using this to improve our ability to navigate through shortages.”

Case company 5 is investing in the development of a homegrown event management system that aggregates information from a number of sources into a risk dashboard that is closer to real time and can alert managers of possible new supply disruptions. These information sharing techniques do not replace but rather complement supplier collaboration efforts. Across all case companies, supply chain managers have focused on working closely with their suppliers to ensure supply and responsiveness to demand risks, while keeping manufacturing, process and control risks under tabs. It is interesting that a focus on negotiating savings, even if only with selected suppliers, seems to be making an initial and tentative return. Case company 4 is actually working with its upstream suppliers to take steps out of the downstream process and integrate them upstream in aggregated operations with factor cost advantages. Essentially this marks the early return of global sourcing for efficiency and costs reasons in a company that is not facing as much supply and demand disruption anymore. Herein reside possibly interesting considerations about the lasting nature of changes in supply chain management and supply chain governance. The next section expands on this.

6. Change Management Experiences

Table 5 provides an overview of behavioral tendencies in risk mitigation, covering context, as well as risk propensity and the acceleration of change management. While the risk context varies across case companies, risk propensity grew in all case companies as the pandemic continued over a year long period and as experiences with risks developed.

Change management accelerated through different risk management decisions. This acceleration took a number of forms and intensity levels. Case companies 1 and 3 accelerated their existing supplier diversification efforts and case company 5 accelerated reforecasting in the face of continued demand shortfalls. Case company 5 also developed a temporal supply chain for the production of ventilators and it did so at a much higher pace than it normally would be able to onboard suppliers:

Table 5. Behavioral tendencies in decision making.

	Case Company 1	Case Company 2	Case Company 3	Case Company 4	Case Company 5	Case Company 6
Context	Increased demand, partially improved supply	Increased demand, worsened product and transportation supply	Increased demand, partially improved supply	Normalized demand, stabilized supply	Continued decrease in demand, supply continuity at risk	Continued decrease in demand, supply scarcity for parts and transportation
Risk propensity	Focus on coping with operational transportation bottlenecks, and supply limitations before that	Focus on coping with operational transportation bottleneck and ensuring product supply, investing in new IT in order to better cope with demand growth	Focus on coping with operational transportation bottleneck and ensuring product supply	Reversal out of crisis mode and partial return to prepandemic focus on cost and process optimization, including through global sourcing	Seeking to improve data feeds and establish a dashboard to improve visibility and capability to mitigate risks in near real time	New task force set up to deal with supply shortages.
Acceleration of change	Supplier diversification was already underway in response to the tariff and accelerated	New technology project to support improved supplier visibility	Supplier diversification was already underway in response to the tariff and accelerated	Responded to pandemic risks quickly but concerns about slipping back into prepandemic strategies	Build temporal supply chains for ventilator and sanitation. Still sole-source for most critical suppliers	Rallying of a new internal team around packaging materials to result shortages fairly quickly

“While it normally takes 12–18 month to get a new supplier integrated, we designed, build, operated and dismantled a temporal supply chain in 12 weeks.” Case company 5.

The company also had to make adjustments to its operations for sanitization and distancing reasons. Case company 6 quickly formed a taskforce to work on improving cardboard availability. The catch is that in addition to accelerating changes already underway and temporal initiatives, additional structural change is limited at this point for most case companies. For example, case company 5 still has a lot of sole-source relationships in its mainline business and these suppliers are at risk for discontinuing the relationship or going out of business due to the ongoing demand shortfall. Despite the company’s temporal achievements, structural risks remain and have in fact grown as the pandemic impact continues.

The risk experience and propensity for risk have led to the initiation of new change initiatives with a few case companies. Case company 3 did not have a strong focus on local sourcing and it has increased efforts to develop over time a greater local source base. Case company 2 has initiated a new IT project that uses IoT devices on pallets and cases to improve real time visibility of product in transit. The project includes the development of a dashboard that can help achieve new control tower capability for the company. Case company 5 has also initiated a new technology project aimed at developing event management capability. The project aims to combine multiple external sources into a closer to real-time view of supplier risks so that information sharing can focus less on rearview mirror indicators and more on leading indicators of risk levels. Additionally, both automation projects aim to reduce the amount of time spent on operational information processing and improve information acquisition. These projects are not completed and neither are the efforts to accelerate existing change projects. Case company 4 offers an example of how in addition to new structural changes being limited at this point, there is a potential of companies reducing risk propensity when faced with a reduction in risks.

The company is looking to further globalize within existing supplier relationships to drive productivity and efficiency—this represents a return to prepandemic approaches.

Table 5 shows how there are unique information sharing approaches involved in responding to the pandemic. The table illustrates how, counter to the focus in the literature shown in Figure 1, case companies are more focused on information acquisition at a supply chain level and less focused on operational information processing at a firm or dyadic level, as shown in Figure 6. The table illustrates how there is not only more but also much wider and comprehensive information sharing in the supply chain. Case company 5:

“We have gone through six joint reforecast together with suppliers, they give us their input and volume expectations, and then we take that to improve our forecast.”

While a focus on operational information is important and may have been the dominant focus at the very start of the pandemic, case companies are not limiting this to internal or dyadic scope. They are sharing in the supply chain, sometimes into tier 2 and 3 suppliers, to improve visibility and perspective. The next two sections further develop and consider these findings.

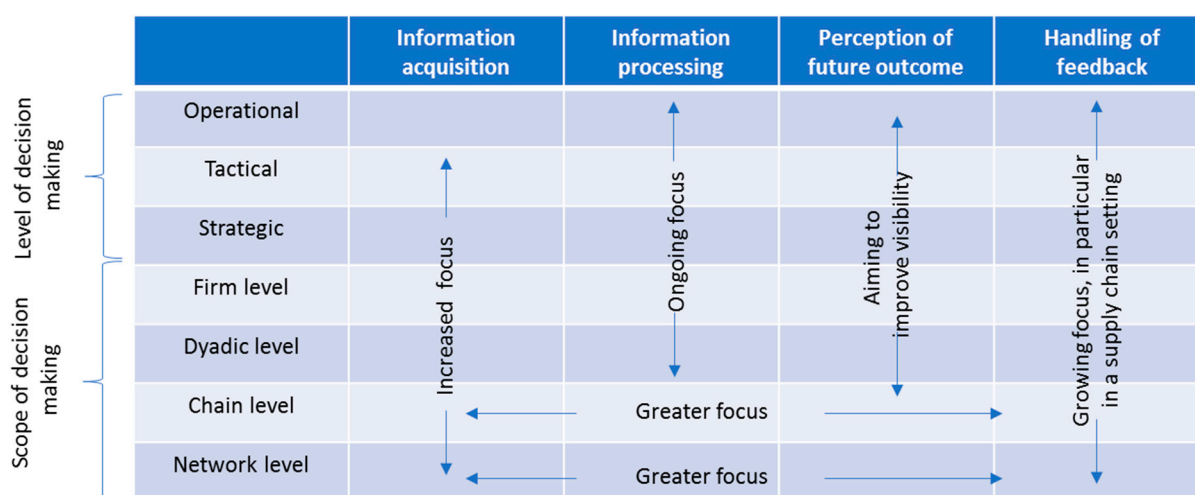


Figure 6. Pandemic information sharing behavior in the Schorsch et al. (2017) categorization.

7. Discussion of Findings

This paper offers the first study using multiple empirical methods and has data covering both the early stages of the pandemic as well as the status at one year into the pandemic. Our work offers a response to the calls for actionable research and is different from earlier contributions as it is empirical, not conceptual. We also explore how risk scenarios have changed during the first year of the pandemic; this enables us to enrich the roadmap for supply chain risk management, and deepen the understanding of specific management approaches used, with perspectives on behavioral aspect.

7.1. Have Risk Levels Experienced Reduced or Changed?

Both survey and case company data demonstrate that risks levels and risk types experienced were high but varied and that they changed during the first year of the pandemic. Fitting with the concept of multiple cycles of navigating and experimentation as suggested by Wieland [28], many companies first had to focus on supply and manufacturing risks, with transportation risks growing later on in the year and prompting new and additional mitigation actions. Through these mitigation actions companies have been able to reduce environmental and financial risks but other risks have remained and have grown in relation and correlation. The pandemic has given rise to multifaceted, complex and dynamic risk scenarios that do not look to be fully mitigated at all after one year. Additionally, case data show that the risks have also been more multidirectional than perhaps suggested in

literature [1] with both demand reductions and increases, improvements in supply and worsening of supply risks. Finally, risks experienced vary between case companies depending upon their supply chain position; the distributor sells in the B2B market where service levels are different from those in the consumer market, that the e-commerce company sells into. That said, transportation risks, for example, are experienced by both case companies. As a result, supply chain position can have an impact on risks experienced but the impacts of the pandemic are experienced throughout the supply chain.

7.2. What Has Been the Applicability of Known Risk Mitigation Techniques?

Our findings indicate that risk mitigation techniques prescribed in the literature are broadly applicable in risk mitigation efforts during the pandemic. The relevance of these techniques varies with risk scenarios experienced and the time period under consideration, in line with van Hoek [25]. However, our findings indicate that during the first year of the pandemic there has also been ongoing learning and navigation that has led to updated roadmaps and risk mitigation plans. For examples, inventory buffering is now seen as of greater relevance beyond short-term mitigation only. All the risk mitigation work done during the first year of the pandemic has only partially reduced risk levels in our case companies, at best. Perhaps this can be explained by the dynamic nature of the risk scenarios and by the fact that respondents and case companies indicate that there is much more longer-term work ahead. However, it also implies that, perhaps counter to Harland [5], risk mitigation does not merely require weaving known and existing techniques together.

In addition to the amount of mitigation work left to do in (case) companies, we also found that the adoption of mitigation techniques occurred for different reasons and in different ways than the literature would perhaps suggest. Case company 5 is using inventory buffering to partially honor supplier commitments during a situation of oversupply, while facing a demand shortfall. Other case companies are using inventory buffering to improve supply availability in the face of demand growth and constrained supply and transportation. We also found that while supply risks remained, collaborating and actively sharing information with suppliers were a main focus in supply chain management, somewhat counter to the expectation of Kovacs and Falagara Sigala [17], who considered that long-term relationships may be less relevant in the face of high dynamics. Most interestingly, we found that risk mitigation techniques prescribed in literature, while relevant, were only a partial solution during the first year of the pandemic.

7.3. What Are the Lessons Learned about the Implementation of Risk Mitigation Techniques?

Our findings indicate that there are several behavioral aspects involved in risk mitigation efforts during the first year of the pandemic. It may well be that the reported increase in risks is driven by growing experience and changing risk perceptions. The pandemic offers a unique risk context that varies between companies but has continued for all. This has enabled learning and experience to grow and has driven greater propensity for risk. This may well help explain the growing focus on most risk mitigation techniques, on multiple time horizons. Risk techniques used vary with risk experienced and despite an overall growth in focus on most techniques, specific approaches are developed depending upon context. While the techniques prescribed in the literature are of relevance, they are not only partial solutions at best, they also need targeted decision making, reinforcing the relevance of considering behavioral aspects.

Change management has accelerated against prepandemic roadmaps and approaches but the largest change focus has been on navigating initial disruptions (such as supply disruptions) first and disruptions that followed (such as transportation bottlenecks) after that. The nature of changes introduced has been largely of temporal nature (such as shorter-term inventory buffering), coupled with the acceleration of existing initiatives (such as supplier diversification). Additional new structural changes (such as the development of previously unplanned information technology projects) have been initiated in a few

areas but they are far from completion for most and risks that existed in supply chains prepandemic remain unmitigated to date (such as the sole sourcing in case company 5). On top of that, there is a possible tendency to return to prepandemic global sourcing strategies after the reduction of supply risks and the normalization of demand risks. While not widely found yet, this tendency raises the possibility that certain structural changes and a lasting improvement and change in supply chain governance may be at risk.

The increase in information sharing during the first year of the pandemic offers an interesting contrast to the main focus in the literature on information sharing found by Schorsch et al. [34]. While initially the sharing may have been largely operational, using existing processes and tools in dyadic interactions, case companies have quickly expanded into much enriched information sharing, at a supply chain level, improving information acquisition to gain better perspectives on the future outcome of risk mitigation efforts. The feedback and input from suppliers have played a key role in the process of reforecasting, realigning supply and sources and managing the flow of goods. These tendencies reflect what Ivanov and Dolgui [24] call the “rich exchange in intertwined supply networks”. Information sharing has indeed been a key factor in growing the collaboration, as expected.

8. Implications for Managers and Research

Our findings imply that the roadmap for navigating pandemic risks can be much enhanced with behavioral recommendations and implications for managers as shown in Figure 7. Managers have learned a lot during the first year of the pandemic, they have driven very rapid temporal changes and accelerated change efforts underway. Further new structural changes have been initiated to develop more lasting resiliency into the supply chain. An enrichment and broadening of information sharing and collaboration with suppliers can be complemented with new digitization and automation efforts, to reduce the focus on operational dyadic exchange and achieve scalable visibility at a supply chain and supply network level, including the acquisition of more leading risk indicators, to improve the perspective on future outcomes of risk efforts. The additional benefit of these new automation efforts is that information sharing can continue to grow but with a reduction in manager time allocated to the sharing. The sharing does not only enrich supplier collaboration, but the automation can also grow risk experience and risk propensity; less time spent chasing orders and supply means more time for structural change. The later may be particularly important to ensure the new risk experience and learning persist and that risk propensity does not drop with the reduction of risks experienced. While there has been a lot of navigating and experimenting in the first year of the pandemic, a lasting improvement in resiliency and supply chain governance is yet to be fully achieved and may be at risk if risk propensity begins to decline.

While our research only offers initial exploration at two points in time, the richness of findings and multiple nuances with respect to the literature imply a rich domain for further research. Potential questions include: Is automation of information sharing a pathway to growing information sharing, with a smaller time commitment for managers or will they perhaps use the information more, in a move towards deeper supplier collaboration? How to incorporate behavioral learnings of accelerated temporal change into lasting and structural changes? How to do that without introducing too much operating rigor and deterministic approaches? What do the learnings from the first year of the pandemic imply for supply chain curricula and education? How to avoid the risk of reverting back to prepandemic comfort zones, while ensuring that managers can regroup and enjoy a reduction in disruptions and risks? The methods used in our paper have limitations, including a limited number of case studies and a relatively small number of respondents from a convenience sample. While rich in findings the richness of method can be enhanced in further research and we hope that our findings may help inspire such research.

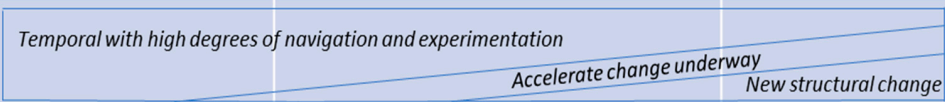

	Short term	Mid term	Longer term
Change focus			
Information sharing focus	Operational information processing	Improve information acquisition to improve perspective on future outcomes and handling supplier input and feedback	Deploy digitization to make increased information sharing more scalable and less operational and crisis focused
Information processing	Largely operational and dyadic on product and inventory availability at first	Move to greater chain-wide perspective quickly	Part automate to improve processing capability
Information acquisition	Largely within existing ordering and shipping processes	Expand sources and information items, include more network information about capacity and materials availability	
Perception of future outcome	Initial focus on immediate risk response and crisis resolutions with temporal solutions such as inventory buffers and booking speculative transportation capacity	Accelerate initiatives underway to improve visibility and transparency	Develop event management systems to achieve leading indicators about possible future outcomes
Handling of feedback	Additional information largely originates from suppliers	Active engagement around joint-reforecasting and joint risk planning and mitigation	
Time spend on information sharing	Near instant increase	Continued high level due to enriched information sharing	Reduction due to digitization and improved information acquisition, while amount of information sharing continues to increase
			
Risk experience	High degree of real-time operational navigation	Increased focus on learning and acceleration of change initiative underway	Need to sustain learning
Risk propensity	Crisis mode and immediate response focus	Increased focus on risk mitigation with several structural changes put on a longer time horizon and a degree of shortterm focus remaining due to changes in risk (ex: increase in transportation risk)	Risk of desire to revert back to old comfort zones

Figure 7. Behavioral enhancement of the roadmap for navigating pandemic risks.

9. Conclusions

This paper offers, to our knowledge, the first multiple-point empirical exploration of pandemic risks and risk mitigation techniques used in industry, during the early stages of the COVID-19 pandemic and one year into the pandemic. We uncovered that supply chain managers navigated and experimented with risk mitigation to great effect as well as with partial risk mitigation, placing traditional deterministic and cost-minimizing global sourcing strategies and supply chain governance approaches on pause, to the side or partially on hold as recommended by Flynn et al. [27]. The lasting and dynamic nature of pandemic risks has driven the need for multiple cycles of navigation as recommended by Wieland [28] and the existing risk mitigation techniques have proven of relevance, as suggested by Harland [5]. We found that several risks increased, transportation in particular, while others decreased (environmental and financial risks). Based upon our case studies we found that these changes were experienced somewhat differently depending upon the supply chain position of the company but that there were many overlapping

risks, illustrating how the pandemic impacts were experienced throughout the supply chain. This demonstrates how risk scenarios are dynamic and helps explain how risk management approaches have evolved also.

We found that several risk management techniques were focused on more aspects one year into the pandemic than at the start of the pandemic, including, for example, supply base diversification and information sharing with suppliers. Additionally, we found that behavioral aspects of information sharing, risk experience and risk propensity played an important role in risk mitigation efforts.

The pandemic provides a unique context for learning and advancing information sharing well beyond the typical focus of the literature. We were able to enhance the roadmap for navigating pandemic risks with behavioral aspects in order to improve its managerial implications and to identify rich areas for further research. Finally, we would like to encourage our peers to continue actively focusing on research in this domain, as the risk of managers reverting back to prepandemic strategies and governance and sacrificing all the learnings and accomplishments, already begins to loom, before the pandemic is even over.

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