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Responding to COVID-19 Supply Chain Risks—Insights from Supply Chain Change Management, Total Cost of Ownership and Supplier Segmentation Theory

Remko van Hoek

Sam M. Walton College of Business, University of Arkansas, Fayetteville, AR 72701, USA; rvanhoek@uark.edu

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Abstract: The COVID-19 pandemic is causing risks and disruptions in most supply chains. As supply chain managers are responding to these risks, several theories may inform those efforts. In this paper, we explore across seven companies in different industries, supply chain positions and countries, how lessons from total costs of ownership, supplier segmentation and supply chain change management theory may apply to efforts to respond to COVID-19 supply chain risks and disruptions. The findings indicate that the pandemic forces companies to consider total costs more holistically, beyond the purchase price, and that collaboration with suppliers and developing new sources of supply is of growing importance to reduce risk in the supply chain. However, the change involved in responding to risks will take time, and for many companies, the hardest work is still ahead. Our findings also paint a more nuanced and complex picture than offered in the popular press; the focus on nearshoring does not necessarily mean leaving China and the switch in total costs of ownership may only be partial and temporal. Limitations of the theories considered are identified and resulting suggestions for managers and further research are developed.

Keywords: COVID-19 response; total cost of ownership; supplier segmentation; change management

1. Introduction

The COVID-19 pandemic has challenged logistics and supply chain management substantially. In the words of Rick Blasgen, president and CEO of CSCMP:

> *"To say that everything changed is an understatement. Before the COVID-19 pandemic struck, supply chains were lauded for their ultra-efficient, single-source and just-in-time capabilities. Now, the logistics field will need to construct entirely new levels of supply chain resilience."*

The chief supply chain officer of Unilever said in mid-July 2020:

> *"Resilience is around sourcing, where do you get your products from? How many markets do you source from?" (https://www.supplychaindive.com/news/unilever-csco-agility-forecasting-coronavirus/581323/)*

In exploring how companies are targeting resilience improvements, van Hoek [1] shows that companies are looking beyond factor costs benefits of a few highly rationalized global sources and considering costs more holistically. This is very much in line with the total cost of ownership theory which suggests factoring in indirect costs and cost drivers beyond the purchase price [2]. Additionally, Handfield et al. [3] suggest a segmented contingency approach with suppliers, pointing at the Kraljic [4] supplier segmentation that suggests factoring in risks and supplier dependencies into supplier

management. Perhaps the pandemic provides a classical burning platform for change management as the above quote implies, but research suggests that change management in supply chains may be complex and slow [5], so the question is how companies can effectively respond to the risk challenges that the pandemic poses.

Ketchen and Craighead [6] state that in the context of the pandemic scholars can add significant value with research that is actionable (ideas can be implemented) and empirically measurable, in particular in inquiries focused on what responses to the pandemic might work. The purpose of this paper is to respond to this call and to empirically explore how companies are responding to the COVID-19 pandemic, to what degree lessons from the total cost of ownership, supplier segmentation, and supply chain change management theory may inform those efforts and, finally, to suggest actionable implications for managers and suggestions for further research.

The remainder of this paper is structured as follows: the next section will introduce lessons from the literature that may inform efforts in the industry. Next, we introduce the qualitative method used in this paper, followed by an overview and interpretation of findings. We end with implications for managers and further research.

2. Guidance from Literature

As mentioned, at least three streams of supply chain research can provide input to coping with supply chain risks of COVID-19; total costs of ownership (TCO), supplier segmentation and supply chain change management. Using these theories as a foundation for the study of the supply chain disruptions caused by the pandemic is relevant for two reasons. Firstly, Pournader et al. [7] conclude, based upon a very recent and comprehensive literature review, that there is a shortage of research in supply chain disaster relief management and responses to significant disruptions. Secondly, the authors suggest that beyond traditional studies of risk levers, behavioral studies of risk are on the rise. In considering these theories we both explore what decisions might be expected from a TCO and supplier segmentation angle, as well as what behavioral process may be involved in the decision making from a change management perspective.

2.1. TCO

The total cost of ownership (TCO) theory suggests considering not just the purchase price of a product or service but also all related costs factors [2]. The benefit of this approach is a more holistic cost perspective [8–10]. This is relevant in the context of the pandemic, as Pournader et al. suggest that the costs of resilience need to be considered more, in addition to the benefits of resilience. TCO is considered particularly relevant for procurement and sourcing decisions [11,12] and factors suggested for consideration beyond the purchase price include delivery and transportation costs, tariffs, follow up and correction, as well as the costs of qualifying sources and adding suppliers to internal systems [13]. Additionally, it is suggested that logistics costs and cost drivers are taken into specific consideration, including the costs of instability in freight rates, on-time delivery, availability and the area that goods are ordered from [14]. These may be particularly relevant in the context of the pandemic as this has driven supply shortages, changes in transportation costs and delivery challenges for supply from China and other low-cost sources. This reasoning is consistent with a recent study by Hasan et al. [15] that uses TCO to develop recommendations for stakeholders in high-risk, low-cost country supply chains.

TCO theory implies that for risk management in the context of the pandemic there is a need to not only focus on purchase price but to also consider indirect and related costs such as those of unreliable delivery due to plant closures and higher delivery costs due to a reduction in shipments. These costs may reduce the benefit of low-factor costs involved in manufacturing in low-cost regions. Hence the pandemic may shift TCO consideration away from low factor cost country sourcing.

2.2. Kraljic Supplier Segmentation

The Kraljic supplier segmentation has been credited as being one of the best tools for procurement strategy [16]. The segmentation uses supply risk as one of its two dimensions and calibrates the impact of suppliers on costs with the risks involved in the supply line. While for leverage products (products with a high impact on costs and little supply risks) a focus on competitive bidding and cost minimization is appropriate, for bottleneck products the reverse applies. These products and services have great supply risks involved and the focus needs to be on ensuring supply, instead of negotiating prices. Strategic products both face supply risks and hold major cost implications and as a result focus should be on collaborating with suppliers to ensure supply while maintaining a focus on cost levels. Padhi et al. [16] state that risks may change and evolve and suggest three measures to inform the supply risk positioning in the segmentation; the impact of product purchase on market risk, performance risk and complexity risk. Hesping and Schiele [17] consider as risk drivers: the availability of alternative suppliers in case of capacity bottlenecks, supply problems or if a supplier is eliminated.

Handfield et al. [3] indicate that COVID-19 has shifted products towards a greater risk profile in the supplier segmentation. The implication being that a greater focus on supplier collaboration and less of a focus on supplier costs may be warranted [1].

2.3. Supply Chain Change Management

While the theories that we consider might suggest that the COVID-19 pandemic will lead to a greater focus on supplier collaboration and a reduced focus on manufacturing in low-cost countries, the process of making this change will co-determine outcomes. Boffelli et al. [18] studied reshoring decision making in four cases and found that this process involves high levels of complexity in which companies adopt flexible approaches with decision making not well defined. Pournader et al. [7] stress the need to consider behavioral aspects of risk management (see, for example, [19]). The coordination required to successfully implement supply chain initiatives suggests that supply chain management change processes may possess some unique characteristics. Yet empirical studies are scarce to support this logic [20]. On top of that, limited consideration tends to be given to behavioral aspects of supply chain management [21]. Harrison et al. [22] offer change management rules including:

- The need to prepare for the long run as change processes tend to take an extended period of time to fully implement throughout the supply chain
- Approaching change as a journey of discovery as there tends to be a fair amount of learning that needs to take place during the change process and no upfront clear cut templates fully apply
- The need to approach change integrative across functions but recognize that not all change needs full integration and selective cross-functional engagement may suffice.

These rules may particularly apply in the context of the pandemic given the suggestion that behavioral aspects may include complexity, flexibility and undefined decision making [18]. Additionally, the TCO theory suggests the inclusion of several functions in the consideration, including logistics but to varying degrees from one case to the next [14]. All of this implies the relevance of the above change management rules.

Table 1 summarizes guidance from literature as a basis for our research.

Table 1. Anticipated impact of COVID-19 on supply chain based upon theories considered.

Theories Considered	Anticipated Implications of COVID-19 Impact on Supply Chains Based upon Theory Considered	Selected References
TCO	Beyond purchase price delivery and other logistics costs become more important supply chain cost consideration	Ellram (1993); (1994); (1995); Fawcett et al. (2007); Handfield et al. (2020); van Hoek (2020); Hasan et al. (2020)
	Negative TCO impact of the pandemic makes low-cost country sourcing less favorable	
Supplier segmentation	Pandemic has driven a greater supply risk focus; more bottleneck and strategic suppliers	Kraljic (1983); Padhi et al. (2012); Hesping and Schiele (2016); Handfield et al. (2020); van Hoek (2020)
	Collaboration and ensuring supply focus of growing importance over cost competition	
Supply chain change management	Change may take an extended time window	Frankel et al. (2008); Geer and Ford (2009); Van Hoek et al. (2010); Harrison et al. (2014); Mena et al. (2019); Pournader et al. (2020); Boffelli et al. (2020)
	Need for learning during the change process	
	Cross-functional engagement important but potentially limited to a few functions	

3. Method

Our research offers one of the first qualitative explorations of how companies in different industries, countries and supply chain positions are approaching supply chain risk management in response to COVID-19. In this section, we offer a justification of our method, an overview of our research method and an introduction of our qualitative dataset.

3.1. Justification of Method

Based upon a recent and comprehensive review of supply chain risk literature Ho et al. [23] call for more empirical research that includes manufacturing companies, this echos earlier calls for more empirical research on supply chain risk management by for example Roa and Goldsby [24]. In the limited amount of research published on COVID-19 and supply chain risk management, there is limited empirical content. Singh et al. [25] conduct a theoretical simulation, Ivanov [26] simulate one case study, van Hoek [10] offer workshop findings and Handfield et al. [14] use interviews with 2 supply chain executives of manufacturing companies in two industries, one based in the US, one based in Europe, to develop early lessons learned about COVID-19 and implications for supply chain research. In this paper, we aim to respond to the call for more empirical research on supply chain risk management and add to the initial empirical efforts by interviewing supply chain managers and executives about how they are responding to the risk consequences of the COVID-19 pandemic. We aim to build upon existing work and advance early empirical efforts by offering findings from companies, involving different industries, different parts of the world and different parts of the supply chain. While not implying complete coverage of the supply chain or the globe, we do aim to broaden the perspective given that the pandemic is global in nature and has impacted almost all supply chains.

3.2. Explanation of Method Used

In an effort to explore along the supply chain, across industries and regions of the world we reached out to supply chain managers in our professional network. While we realize that this may introduce bias we believe this is offset by the access and the broad scope of our empirical dataset. In total seven interviews were conducted using a 5 step process;

(1) A personal invitation to engage in our research was emailed to participants including a clarification of the objectives and focus of the research. Interestingly enough, all contacted managers agreed to participate. The combination of the use of a personal network, the importance of the topic and the relevance of the research appear to drive very high levels of industry engagement. Perhaps there are some implications for researchers in this and we will revisit this later.

(2) As a next step, participants were sent research questions in advance of the interview to help them prepare.

(3) The interviews were semi-structured using the questions from the interview protocol listed in Table 2. Interviews were conducted over video-conference given the inability to travel and the "work from home" environment.

(4) After that the interviews were documented and coded by the interviewer.

(5) These notes were shared back with participants and quotes were also shared seeking feedback on the correctness of documentation and any possible missing points from the conversation.

Table 2. Example interview questions.

TCO	Are you considering factors beyond purchase price more or less in the current environment?
	How is supply chain design being reconsidered in the current environment? Are you considering more near shoring and local sourcing?
Supplier segmentation	How are you engaging suppliers in your risk management efforts?
	Are you seeking collaboration, focusing on ensuring supply focus? Are you more or less focused on payment terms and cost competition?
Supply chain change management	What changes are you able to make short term?
	What changes are you targeting for the mid- to long-term?
	Do you have a pre-developed approach or is there a degree of discovery needed in de-risking the supply chain?
	Which other parts of the company are involved in those changes?

Data was collected in May, June and early July of 2020. At this stage, the COVID-19 pandemic had reached the status of impacting supply chains around the world for several weeks and companies were in full swing responding and addressing supply chain risk challenges. It should be noted that the pandemic at the time of writing this paper obviously was far from over and that efforts reported on will evolve and continue beyond our period of data collection. This leads to suggestions for further research that will be addressed later in the paper.

3.3. Overview of Qualitative Dataset

We are excited to be able to report on one of the first empirical explorations across different industries, across different supply chain positions and different parts of the world. Table 3 offers an overview of the dataset and the respondent profiles.

4. Findings

In this section, we introduce case company findings as a basis for cross-case interpretation in the next section. Table 4 provides an overview of the findings in the context of the theories considered.

Table 3. Overview of dataset.

	Company 1	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**	**Company 7**
Industry	Tools and DIY products	Electronics	Fittness and outdoor equipment	Vision products	Aerospace	Flooring	Wood products, tiling and sanitary products
Supply chain position	Manufacturer	Distributor	E-commerce company	Manufacturer	Manufacturer	Manufacturer	Manufacturer
Geography	USA	Middle East	USA	USA	Europe	USA	Latin America
Company size	Small–medium size	Medium-sized	Small-sized	Large-sized	Large-sized	Medium-sized	Large-sized
Respondent title	Head of supply chain	Head of logistics	Head of supply chain	Head of procurement	Head of procurement	Head of supply chain	Supply chain manager

Table 4. Overview of findings.

	Company 1	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**	**Company 7**
Beyond purchase price delivery and other logistics costs become more important supply chain cost consideration	++	+++	++	+++	+++	++	++
Negative TCO impact of the pandemic makes low-cost country sourcing less favorable	+++	-	++	++	++	++	+
Pandemic has driven a greater supply risk focus; more bottleneck and strategic suppliers	+	+	++	++	+	++	-
Collaboration and ensuring supply focus of growing importance over cost competition	+++	++	+++	+	+	+++	-
Change may take an extended time window	+++	+++	+++	++	++	+	++
Need for learning during the change process	++	++	+	+++	++	++	++
Cross-functional engagement important but potentially limited to a few functions	+	+	++	+++	+	++	+

Company 1 is a manufacturer of tools and equipment for the building, construction and DIY industry in the US. The company is medium-sized and sources materials and parts from low-cost countries, traditionally China, and has outsourced part of the molding and assembling to domestic suppliers. The company also has its own molding and assembly operations. At the start of the pandemic, the company mostly suffered from supply issues, initially as a result of factory closures in China. Fortunately, the company had started developing additional sources outside of China in response to tariffs and as a result, it was able to switch order volumes away from China.

> *"When the tariffs kicked in, we accelerated supply base diversification to reducing our reliance on Chinese sources. We included suppliers in India for example. When China went into shut down because of COVID-19, we were able to shift orders from Chinese suppliers to those new suppliers in India and Southeast Asia. By the time India and Southeast Asia went into shutdowns Chinese suppliers where back up and running so we could shift orders back to China. This gave us a huge dividend on our diversification efforts,"* Procurement director.

This discontinuity of supply impacted the company's manufacturing operations and its logistics pipeline. Not only did the company ran short on supplies at times, it also needed to realign transportation flows and it had to deal with (temporary) scarcities in transportation capacity during periods of demand peaks. Clearly, this demonstrated the importance of looking beyond purchase price benefits from sourcing in China and the need to consider TCO more holistically. Additionally, it showed that some adjustments to the supply line could be made fairly quickly but only because there was already a change management process underway in response to tariffs. These changes to the supply line take a longer time horizon, and in many respects, the pandemic presented the next phase in the journey of discovery the company already was on.

Company 2 is an electronics distributor operating in the Middle East. The company has faced several challenges with product supply and it has responded to those by buffering inventory. Clearly, this implies that supply risks were also experienced further downstream in the supply chain from company 1. A more holistic consideration of TCO was needed when inventory policies are reconsidered. On top of that, the company also suffered from a lack of transportation capacity out of China and as a result faced airfreight at much higher costs (a factor 4X). In response the company needed to explore shifting to ocean freight where customers are not willing to pay for the transportation surcharges, resulting in slower delivery pipelines. The company is not able to shift supply lines as it represents manufacturers as a distributor and it can only focus on improving collaboration with suppliers to try to ensure supply. Digitization of the supply chain is recognized as a valuable strategy. However, this is not seen as a change that can not be implemented overnight at all and it is an area where there will be more learnings ahead;

> *"Digitization does not help in the short term, if it will help in the future, we will see"* Logistics manager.

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 almost exclusively sourced from China and tried to accelerate the development of a new Indian supply base as well as considered ramping up its small domestic supply base in response to factory shutdowns and transportation challenges from China. The company found that for certain higher-end products, consumers are certainly willing to pick up part of the additional costs associated with domestic manufacturing in return for the faster delivery and product availability;

> *"Sourcing product domestically can be 2X our manufacturing cost in China but with demand right now customers are willing to pay extra to get it a bit faster."* Head of the supply chain.

The company also found that paying its Chinese suppliers faster than normally enabled these suppliers to invest in additional capacity and to secure materials in a scarce market;

> *"We reduce from net 60 days payment terms to paying upon shipment so that suppliers could use the early payment to secure material in the market and turn to our next order right away. We are doing what we can on our end to get priority and ensure supply."*

By investing in the collaboration and improving terms to the advantage of the suppliers the company aims to navigate part of the pandemic storm in the short term. The change process of diversifying the supply base geographically will take a longer-term horizon and the involvement of key peers, most notably product design and development. Not all peer functions need to be involved in this process however, marketing and sales, for example, do not need to weigh in on the supply network development.

Company 4 is a US-based manufacturer of vision products (glasses, contacts) and vision care products, the majority of which are manufactured in China. The company, fortunately, had a supply chain transformation program initiated aimed at considering its supply lines and supplier relationships. At the start of the pandemic, the company was able to accelerate this program as it quickly became of even greater importance and business relevance. COVID-19 was an unforeseen reason that provided a greater burning platform for a long-term change process. In the process, there is a fair amount of opportunity to learn while underway:

> *"We learned that a fair amount of spare capacity in the system can be very beneficial when you are disrupted and that is something we need to consider in our future supply chain design."* Chief procurement officer.

In considering the benefit of bringing part of the supply chain back into the market the company is considering increased transportation costs, extended lead times and customer service challenges, while balancing possible purchase price implications. Responding to the pandemic challenges does require the involvement of several parts of the supply chain but the effort is not necessarily fully integrated:

> *"Our teams went back to excel to plot out forecasting scenarios when we were just not getting good forecasts from the commercial teams. It is understandable that it is hard for these teams to forecast in this environment but we needed to get going and so we ran with it."* Chief procurement officer.

Company 5 is an aerospace manufacturer from Europe that has a fairly globalized supply chain that is heavy on Asian sources and one that involves 4,000 parts for certain products, introducing many bottleneck supply situations;

> *"Our supply-base is somewhat Asia-heavy and we need to reconsider that. If I am missing 1 out of 4000 parts in a product I do not have a finished product."* Director of procurement.

In responding to the pandemic, the company worked with suppliers and its own plant management to adjust operating procedures for sanitation and personal distancing. In doing so, it had to invent several extra process steps and mini-operations such as sanitization and sanitizer mixing. This altered the total costs of ownership and drove indirect costs and consequences of the pandemic. Beyond these short-term changes, there are more long-term changes and lessons to be learned but the director of procurement flagged that there is a risk of "recency bias";

> *"We have a tendency to focus on current issues and let past issues slip to the background of our efforts and this might mean that we never get to make some of the harder changes or learn some of the more difficult change lessons to be learned."* Director of procurement.

Company 6 is a US-based flooring manufacturer that has two main supply lines; one that is domestic and one that is China-based. The domestic supply-line initially was not impacted by the pandemic, the Chinese supply-line was. In response to supply shortages in its Chinese base, the company changed

supplier terms in favor of the suppliers. The company started paying faster, in an effort to seek prioritization of its orders. While it did not directly engage in adjusting the geographical footprint of its China supply-line, several of its Chinese suppliers have decided to start-up operations in the US in order to avoid tariffs and meet the growing demand for volume and speed of company 6. This may represent an interesting twist to the geographical rebalancing of supply lines widely considered today; if not the manufacturer, it may be the suppliers driving this. Company 6 found that this may accelerate the change process, provided collaborative working relationships with key suppliers. In coping with the pandemic, there also was a fair amount of discovery within company 6 around new safety and sanitation protocols for example. The company's chief supply chain officer indicates that this is just the start of a longer change process;

> *"There is a lot of hard work ahead of us still."*

Company 7 is a Latin American based upstream manufacturer of wood products, tiling and sanitary ware with a large supply base, scattered around the world of over 7000 suppliers. This geographic diversification reduced the company's risk profile; it could shift orders between sources and geographies as the pandemic unfolded. Initially, the largest impact of the pandemic was on the demand side and in response to slowing demand and growing inventories the company did choose to push out payment terms;

> *"In the beginning of quarantine, negotiations about payment terms played a decisive role to recovery our cash flow"* Supply chain manager.

Further into the pandemic, the company did however begin to seek additional support leveraging its existing supplier management program to ensure continued supply and revenue protective measures, as such displaying a degree of learning while changing.

5. Discussion

Across the three theoretical inputs, there are interesting and varied findings. Table 5 summarizes confirmative findings and critical reflections by theory and these are detailed below.

5.1. TCO

Table 5 offers an overview of TCO cost drivers suggested in the literature [10,14] and changes in relevance experienced in the case companies. The table paints a diverse picture in which not only initial purchase price matters as expected but where there are also pros and cons to developing alternative and nearshore sources. Logistics costs are a frequently experienced factor due to the changes in shipping costs and lack of capacity in certain modes. The initial purchase price is a consideration in particular for those companies that are considering near-shoring and alternative sources of supply in order to be able to meet demand more reliably; purchase prices may be higher but customers may be willing to pay for part of that in return for more reliable and faster delivery. The cost of identifying and qualifying new suppliers disfavor the consideration of new near-shore suppliers

The fundamental premise of TCO theory, that purchase price is only part of the supply chain costs to consider, is highly relevant in the context of the pandemic. For companies manufacturing in China, the purchase price benefit of doing so has been challenged by lack of product availability, increase shipment costs and supply scarcities. As a result, considering to reduce dependence on Chinese low-cost manufacturing is highly relevant. For those companies that have started to diversify their supply-base geographically in response to tariffs, this provided an opportunity to accelerate this effort and an additional benefit of having started that change process in advance of the pandemic. For those that did not yet, alternative sources, including near and in market sourcing are relevant considerations for reducing reliance and shipment costs, while improving product availability.

Table 5. Changes in relevance of total costs of ownership (TCO) drivers experienced by case companies

	Company 1	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**	**Company 7**
Initial purchase price	++		++	+		++	
Operating costs					+	+	
Quality							
Logistics	+++	+++	++	+++	++	+++	++
Technological advantage							
Supplier reliability and capability	+++		++	++	++	++	++
Maintenance							
Inventory costs		++		+	++	+	++
Life cycle							
Customer-related (satisfaction, etc.)	++	++	+++				
Opportunity costs (costs of overhead and money)							
Miscellaneous (taxes, flexibility of the supplier, support costs)	++		+				
Costs of qualifying and selecting suppliers	+++		++				

Company 3 found that geographic rebalancing of the supply-base may not be fully justified by TCO. It found that factor costs increases involved with in-market manufacturing are higher than the added cost of transportation and inventory buffering for supply from China. However, it also found that customers were willing to pay for part of those additional costs in return for the fact that products would be available for delivery. As a result, the revenue and customer satisfaction perspective may be more important than that of TCO. An interesting version of geographical repositioning of the supply base was found in case 6 where it is actually the Chinese suppliers that are setting up in market manufacturing, the implication is that while there is value in nearshoring and in market sourcing, this does not mean that it has to be with different suppliers, far-source suppliers may also be part of the geographic rebalancing. Additionally, the question that can be asked is if this is going to be a temporary change in TCO or a structural one. Transportation costs, for example, are highly dynamic and can change again in the near future.

5.2. Supplier Segmentation

Table 6 offers findings from case companies on the supply risk dimensions suggested in the literature [16,17]. The focus on developing alternative sources and suppliers is frequently driven by bottlenecks in capacity and supply performance issues. Risk related to supplier elimination is less of a concern as new sources are approached rather as a complement to scares supply, for different reasons. Company 3 has been experiencing growth in sales during the pandemic and is seeking alternative sources to add capacity and meet growing demand. Company 5 on the other hand has been scaling back its volume forecasts, including many customized and unique parts for which it may only have one or two suppliers. As a result, the company faces risks with suppliers potentially discontinuing or even going out of business;

> *"We are worried that when we need to ramp volume back up the suppliers may not have the capacity or capability to do so anymore."*

Participating companies do report that the pandemic did drive an unplanned increase in supply risk and that suppliers from China became more of a bottleneck or even strategic concern with supply uncertainty increasing. This was not limited to Chinese suppliers; company 5 reported dependencies on suppliers in other countries once the pandemic spread and company 1 moved orders back to Chinese suppliers when they reopened and suppliers in other countries were forced to shut down operations. This risk triggered a lot of collaborative tendencies in companies interviewed and a focus on working with existing suppliers to ensure supply. Payment terms are a concrete mechanism to support this; by paying earlier, suppliers are in a better position to buy scares materials and to allocate capacity and ensure supply in the experience of companies 3 and 6.

Company 7 is positioned further upstream in the supply chain and it extended payment terms to its suppliers in order to manage its cash position. As a result, it may be that collaborative tendencies between the customer and tier 1 suppliers do not extend into tier 2 suppliers. Additionally, the risk of focusing on collaboration to ensure supply in the short term is that without preexisting relationships with suppliers it is hard to achieve collaboration. The question is also whether or not with the eventual disappearance of bottlenecks as a result of moving towards new and additional sources of supply, the focus on collaboration is going to water down or not.

Table 6. Changes in relevance of supply risk drivers experienced by case companies.

	Company 1	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**	**Company 7**
Market risk			+++		++		++
Performance risk	++	++	++	++		++	++
Complexity risk							
Availability of alternative suppliers in case of capacity bottlenecks	++		++	+	+	+	+
Availability of alternative suppliers in case of supply problems	+++		+++	+		+	+
Availability of alternative suppliers in case a supplier is eliminated							

5.3. Supply Chain Change Management

The supply chain change management implications of the pandemic are possibly the most interesting findings from across the three theories. Companies do confirm that as the pandemic challenges their supply chain, there is only a degree of change in response to this that can happen in the short term. Company 6 indicates that there is a lot of work still ahead and company 2 indicates that while digitization is rightly an approach widely called for, the transformation involved in digitization takes a long time. As a result, we might conclude that companies have a lot of hard work still ahead of them, well after coping with the initial short term risk challenges. While companies are beginning to make changes to their supply-base and total cost of ownership structures, they are learning a lot while this is underway. The pandemic presents a very dynamic environment where cost factors, delivery circumstances and supply conditions change frequently. Company 5 also indicates that it had to develop new sanitization practices and mini-operations while coping with the pandemic. While these changes may end up being far-reaching and continuing for some time to come, they are not necessarily approached fully integrally. Company 4, for example, indicated that they were trying to cope with the lack of a good forecast from sales by developing a forecast without sales.

While change in supply chains may be slow, companies 1 and 4 did have supply chain transformation programs already underway and they were able to accelerate those in response to the pandemic. Responding to the very dynamic environment that the pandemic presents supply chain managers with does create the need to discover while journeying but the question will be, given the recency bias suggested by company 5, if companies are going to continue with the hard work still ahead when conditions change. Furthermore, while not all peer functions may need to be involved in these change efforts, the involvement of key suppliers is key to ensuring supply.

6. Implications for Managers and for Research

Table 7 offers implications for managers and research and it may read like an action plan for supply chain managers. Clearly, our research provides the opportunity to learn from peer efforts and an opportunity to calibrate supply chain plans against those of participating companies. Selected implications for managers include:

- The need to reconsider the respective weight assigned to factor costs in supply chain design,
- The need to reduce the reliance on a single design (with highly concentrated supply from a limited source) and to consider these not just in the short term but also over time and in relation to service and revenue considerations,
- The active utilization of payment terms as a mechanism to enable bottleneck and strategic suppliers in their upstream efforts to meet the supply needs of customers, while bearing in mind that this mechanism may not translate to further upstream payment terms for tier 2 and 3 suppliers,
- The relevance of focusing on supplier management so that when supply chain risks require collaboration, the relational foundation and capability is in place,
- The need to plan for the long run and for a longer journey of discovery that does not need to involve all peer functions but should involve key suppliers.

The summary of findings in Table 7 also holds lots of implications for further research. The Chief supply chain officer of company 3 said:

"It is important that we have research that helps us connect the dots."

Table 7. Interpretation of findings by theory.

	Confirmative Findings	Critical Reflections
TCO	(1) Shifts in supply chain costs due to the pandemic do favor a reduction in concentrated low-cost country sourcing in favor of near-shoring, in market sourcing and geographical diversification of supply (2) The tariffs on Chinese goods had triggered a start to this process and companies may accelerate that effort due to the pandemic	(3) Are these temporary shifts in TCO factors only? (4) Costs of in-market sourcing may be justified by revenue and customer satisfaction more than by TCO (5) Geographical repositioning may not be at the expense of Chinese suppliers, they may be party to the repositioning in-market
Supplier segmentation	(1) Greater dependencies and supply uncertainties experienced do drive a focus on collaboration with existing suppliers to ensure supply and seek supply priority (2) This is not limited to Chinese suppliers (3) Payment terms are a concrete mechanism to use	(4) Collaborative tendencies with tier 1 suppliers may not transfer to collaboration between tier 1 and tier 2 suppliers (5) Supply collaboration does require the pre-existence of a supplier management capability and track record (6) Supply risks may be temporal, and the question is if collaborative tendencies will decrease when the supply-base is diversified
Supply chain change management	(1) Responding to supply chain challenges resulting from the pandemic will take a longer time and the hardest work may still be ahead (2) There are a lot of lessons to be learned underway and there is no single template or solution (3) Not all peer functions need to be fully integrated into this change process	(4) Where there are relevant change efforts already underway these can be accelerated in the short term (5) As conditions change away from the pandemic supply chain risks will companies step away from the hard work still to be done? (6) While not all peer functions need to be integrated, critical suppliers do need to be an integral part of efforts to ensure supply

Perhaps this most strikingly articulates the value of conducting research at the very frontier of industry challenges, particularly in a time of discovery and with a long change journey ahead. This is almost a moral call for supply chain researchers. While we may not be able to invent a vaccine, we sure can support supply chain managers in their learning, discovery and change efforts. In addition to that, the change management complexities experienced by companies certainly indicate the relevance of focusing the change management process itself, not just on the solution to the challenges but on how to get there. Certainly, it will be interesting to add to our dataset and to revisit with our case companies as they continue to battle the supply chain risks caused by COVID-19. Further specific research questions worthy of consideration include:

- While the purchase price is not to sole cost consideration as suggested by TCO theory, it does remain crucial; will the shift in favor of alternative sources nearshoring and in market sourcing be permanent or partial to those companies that face growing demand and customer willingness to pay higher prices or temporary until log costs normalize again?
- How to balance TCO frameworks, traditionally used to make longer-term investment decisions, to very dynamic supply chain circumstances?
- How to ensure that they can be balanced with the relevance of non-cost factors such as customer satisfaction?
- How to approach supplier segmentation as a more dynamic approach in which suppliers may change position in the segmentation,
- And how to evolve supplier relationships over time, accordingly?
- What, beyond payment terms, are other mechanisms that can be used as part of collaborative efforts and
- How to consider that collaborative efforts with tier 1 suppliers may not be matched with those with tier 2 and 3 suppliers?
- To what degree can existing suppliers be part of the process to diversify the supply base geographically vs. are companies going to decrease the relevance of collaboration with these suppliers by introducing alternative sources of supply?
- How to consider the human factor in the change process involved in derisking the supply chain in response to COVID-19; how to manage with empathy across the supply chain and how to balance goal orientation with empathy in times of disruption?
- What talent management tools will be most effective short-term (communication and empowerment?) and longer-term (training and new role definitions?)

7. Conclusions

Our research makes a contribution by offering actionable and measurable findings on the pandemic as called for [6] we offer consideration of changes in supply chains widely discussed in the popular press, providing theoretical foundation and consideration, leading to a much more nuanced picture of supply chain risks management during the pandemic. Our research studies how the supply chain impact of the pandemic is felt around the world, throughout the supply chain and across industries. We contribute to the very small initial set of empirical findings of how supply chain managers are responding to the pandemic and identify several key directions for further action and research. All three theoretical inputs considered in this paper offer meaningful input to supply chain managers' efforts to respond to the pandemic and several critical reflections can also be made. These provide input to further research and efforts in the industry.

Total costs of ownership are changing in favor of nearshoring and in market sourcing but some of the cost drivers, such as logistics costs, may be temporal in nature. The costs and change involved in identifying, qualifying and implementing new suppliers add costs and time, while customer satisfaction about product availability may outweigh higher purchasing costs involved with nearshoring only in the short term until general product availability improves.

Supplier risks, particularly pertaining to supply availability, have increased during the pandemic and companies are reporting active efforts to add near-shore and in-market additional and alternative sources as a mechanism to reduce dependency and supply risk. These new sources may not be eliminated but rather complement existing suppliers and counter to some of the discussion in the popular press "leaving China" may not really be the agenda, as opposed to geographical diversification. For some companies, the pandemic has grown the relevance of accelerated diversification that had already started in response to tariffs on Chinese products. However, efforts to find, implement and ramp up suppliers will take time, partially due to change management complexities and the need to collaborate with suppliers.

Selecting a hot topic that is very much in focus with supply chain managers makes it easier to drive industry engagement and participation in research. Managers and executives participating in this research were keen to review interview notes and research findings, to learn about research findings from other companies and to stay informed about findings and the next steps. Clearly, this implies that there is a benefit for researchers to operate at the frontier of industry practice and challenges. Doing so will also enable greater societal return on research, particularly in a time of pandemic-scale challenges.

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