Supply chain sustainability: learning from the COVID-19 pandemic

Joseph Sarkis
Foisie Business School, Worcester Polytechnic Institute, Worcester, Massachusetts, USA and
Hanken School of Economics, Humlog Institute, Helsinki, Finland

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Abstract

Purpose – This paper, a pathway, aims to provide research guidance for investigating sustainability in supply chains in a post-COVID-19 environment.
Design/methodology/approach – Published literature, personal research experience, insights from virtual open forums and practitioner interviews inform this study.
Findings – COVID-19 pandemic events and responses are unprecedented to modern operations and supply chains. Scholars and practitioners seek to make sense of how this event will make us revisit basic scholarly notions and ontology. Sustainability implications exist. Short-term environmental sustainability gains occur, while long-term effects are still uncertain and require research. Sustainability and resilience are complements and jointly require investigation.
Research limitations/implications – The COVID-19 crisis is emerging and evolving. It is not clear whether short-term changes and responses will result in a new "normal." Adjustment to current theories or new theoretical developments may be necessary. This pathway article only starts the conservation – many additional sustainability issues do arise and cannot be covered in one essay.
Practical implications – Organizations have faced a major shock during this crisis. Environmental sustainability practices can help organizations manage in this and future competitive contexts.
Social implications – Broad economic, operational, social and ecological-environmental sustainability implications are included – although the focus is on environmental sustainability. Emergent organizational, consumer, policy and supply chain behaviors are identified.
Originality/value – The authors take an operations and supply chain environmental sustainability perspective to COVID-19 pandemic implications; with sustainable representing the triple bottom-line dimensions of environmental, social and economic sustainability; with a special focus on environmental sustainability. Substantial open questions for investigation are identified. This paper sets the stage for research requiring rethinking of some previous tenets and ontologies.

Keywords Sustainability, Environmental management, Resilience, Supply chain management, COVID-19
Paper type Viewpoint

Introduction

Sustainable operations and supply chains are well-established topics in the operations management discipline. Sustainable supply chain research [1] focuses on a triple bottom-line perspective, with economics and environment playing predominant roles (Hallinger, 2020), and social concerns receiving increasing attention (Nath and Agrawal, 2020; Walker *et al.*, 2014).

The COVID-19 pandemic provides additional evidence that the three sustainability dimensions are inextricably linked. Economic reverberations have occurred with supply chain stoppages across industries – some *non-essential* industries have yet to fully recover. The natural environment is the pandemic source – the virus likely emanated from wet markets selling animal products. New social sustainability norms emerge as people live differently – for example, social distancing has resulted in work from home and fewer physical meetings. Although social and economic sustainability issues appear in our discussion, the major focus of sustainability discussion in this pathways article focuses on environmental-ecological sustainability or greening concerns.

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The objective of this pathway article is to provide insights for sustainable supply chain research and relationships resulting from the COVID-19 crisis. We identify potential research opportunities for future *International Journal of Operations and Production Management* (IJOPM) scholarship based on a number of phenomenological observations. These observations derive from exploratory evidence based on industry practice, expert opinion and academic sources. Our aim is to identify the COVID-19 shocks that face the supply chain and especially the sustainability of supply chain management. Another aim is to provide some thoughts on COVID-19 crisis remnants and what the aftermath means to supply chain sustainability. We consider this evaluation from technological and social innovation perspectives. Another aim is to identify various research opportunities, which appear in the penultimate section of this pathway article.

COVID-19 shocks

The social, political and economic upheaval from COVID-19 is palpable. Global virus containment responses include closing non-essential businesses, social distancing, smaller public gatherings, indefinitely postponing sporting events, canceling conferences and requiring populations to shelter in place.

Operations and supply chain fragility is at the forefront of popular discourse. The great toilet paper drought, cotton swabs for testing deficiencies and personal protection equipment (PPE) privation – became daily news items (Paul and Chowdhury, 2020; Rowan and Laffey, 2020). Global supply chains faltered in delivering needed goods, as their brittleness and lack of operational agility became conspicuous. We heard stories about wheat flour and other commodities being held at national borders to prevent the spread of the virus, disrupting the essential food supply chain.

Globalization, offshoring and lean-based efficiency came under increasing scrutiny. Historically, the research has been replete with efforts to help organizations gain competitive advantage under paradigms of comparative advantage – finding locations with advantages in costs and resources (Schleper *et al.*, 2019). Leanness and efficiency – at least in the short term – were met with animosity, mistrust and misgivings.

The COVID-19 crisis *shocked* supply chains. We observed demand and supply ripples; chaos and resonance effects propagated across global networks (Guan *et al.*, 2020). How many traditional supply chain strategies and policies will survive the COVID-19 outbreak after life *returns to normal*?

What do these events and responses mean in transitions to sustainable and resilient supply chains? What do they mean to environmentally sustainable supply chains, social innovation and technological relationships as they relate to the current COVID-19 pandemic and the various supply chain responses?

There are unprecedented opportunities for this transition to a sustainable post-COVID-19 environment. The author was involved in a number of open forums – naturally held in a virtual setting – that discussed opportunities and barriers for supply chain sustainability (Ellram *et al.*, 2020; Sarkis *et al.*, 2020c). Hundreds of people from throughout the world participated in these open forums.

Methodologically, the observations and perspectives presented in this pathways paper are based on information from these forums and summary reports. Interviews with supply chain professionals and experts based on general concerns related to procurement and operational practices helped to further refine some thoughts. Also, emergent literature, from practitioners, news sources and academic sources were used, although academic sources were based mostly on opinion and exploratory research.

Based on these sources, we present some summary thoughts on what we can expect and the role that our learnings from COVID-19 may play in supply chain sustainability diffusion.

We are at a crossroads – will the pandemic lessons persist over the long run, and what does this all mean for scholarship?

Sustainability and resilience in supply chains

While this crisis provides sustainability opportunities, it could also result in disappointment. From this crisis, we can presage a transition to further supply chain sustainability, although uncertainties and concerns remain. Sustainability strategy and practices contribute to supply chain resilience, e.g. by making sure ecosystem services are maintained, encouraging more sustainable "buy local" actions and building community trust. Risk reduction and crisis responses are reasons that the crisis represents a transformational opportunity by using sustainability to reduce risk and build resilience.

Sustainability has been viewed through multiple lenses. The two most popular views are John Elkington's triple bottom line – profits, people, planet and the multi-generational philosophy born of the Brundtland Report – meeting the needs of the present without compromising the ability of future generations to meet their own needs.

The research in sustainable supply chains – especially the greening focus – has found a permanent foothold in the supply chain discipline. Our discipline should be proud that our community leads corporate and business sustainability research (Hallinger, 2020). We have an opportunity to maintain this legacy.

It is important for us to critically investigate the pressures, roles and outcomes of sustainable supply chains. Although sustainability progress is being made from an environmental and social perspective, it is slow, sporadic, myopic and can easily fall into unsustainable practices.

Often, organizations will take the road of least resistance focusing on *win–win* opportunities in meeting sustainability challenges; sustainability measures that do not result in significant short-term economic results are ignored or discouraged. *Strong* sustainability is required for lasting improvements (Nikolaou *et al.*, 2019).

Given the pandemic, environmental sustainability efforts may face the *crisis rebound effect* – where society's recovery activities will exclusively focus on economic and social sustainability. Previous crises as in this crisis slowed economic growth resulting in some environmental improvements such as decreases in greenhouse gas emissions. Yet, the economic rebound eventually involved unapologetically greater pollutant emissions.

Jobs and economic concerns will be paramount in a recovery – neglecting or removing any semblance for environmental concerns. An economic growth policy has already been proposed by various governments, including rolling back or removal of some environmental regulations. This pattern is worrisome to social and planetary sustainability. The post-COVID-19 rebound may involve worse environmental outcomes. The decrease in emissions due to slower economic activity from the 2008 recession was just a "blip" in long-run industrial emissions (Hanna *et al.*, 2020), an overshoot occurred with lessened ecological concern.

COVID-19 is not an aberration – it may be a *black swan* that has returned. We have encountered similar issues previously. Criticism of fragile cost-efficient supply chains has occurred from previous disruptions, including the 2003 SARS crisis and the Fukushima Daiichi nuclear disaster (Lee and Preston, 2012).

Industry has been responding. One pharmaceutical company we spoke with has been contracting with fourth-party logistics (4PLs) to find multiple available logistics options instead of a single-source logistics provider. This effort builds supply chain agility and resilience, but such selection procedures can also be used to improve sustainability by identifying and selecting logistics providers with improved emissions. That case company has a sustainability strategic policy, these initiatives are encouraged long-run supplier goals.

Some companies, such as New Balance Shoes (New Balance, 2020) and General Motors (Davies, 2020), voluntarily pivoted to provide procurement and manufacturing capacity for PPE and ventilators, respectively. This requires building agility into their manufacturing processes – but may contribute to building additional capabilities to offer byproduct manufacture from excess material and wastes – a sustainable supply chain practice.

COVID-19 will open investigatory avenues for sustainable supply chain practices. Whether all supply chains will encounter pressures to maintain or dissolve environmental sustainability efforts will require careful investigation, analysis and orientation. The choice will be important to supply chain sustainability research for decades. We now provide some thoughts and insights, including trends and hotspots for research where future investigation is needed.

What will happen to sustainability in supply chains – post-COVID-19?

Broad socio-political forces have always played a role in supply chain operations; whether they are from tariffs on goods, new norms related to safety practices or regulations on technological practices (Handfield *et al.*, 2020). Similarly, there will be post-COVID-19 transformation of supply chain practices, but will these transformations stick? Technological and social innovations are important to supply chain sustainability transition.

Technological innovations and implications

Manufacturing technology is trending toward automation and data exchange systems as in *Industry 4.0*. Manufacturers are using Industry 4.0 technologies – cyber-physical systems (CPS), internet of things (IoT), cloud computing and cognitive computing – that can complement human decisions with technologies that can decentralize decision-making. These technologies may take on important long-term roles in response to COVID-19 activities (Kumar *et al.*, 2020a).

A likely major change is data-driven awareness-based collective action (Scharmer, 2020). This action means addressing situations collaboratively, and then adjusting behavior in response to the COVID-19 crisis. As systems begin to fail, especially market and governmental regulatory systems, organizations need behavior adjustment. Similar behavioral adjustments can benefit sustainability.

Organizations and their supply chains require more and timely data during and after the crisis; they will internalize decision-making, develop new initiatives and programs in response to the crisis. This issue became evident in the financial crisis of 2008, as organizations tended to delay or discard some of their short-term and tactical plans to address the immediate crisis (DesJardine *et al.*, 2019). This organizational capacity can enhance sustainability thinking – environmental and social crises will occur but with uncertain timing and levels. Having the necessary data-driven systems – such as big data – can help organizations to respond quickly to crises, especially environmental and social crises.

Collaborative technologies such as blockchain technology allow for sharing of information transparently, reasonably quickly, accurately and widely. Integrating these systems with IoT and artificial intelligence (AI) can alter how supply chain managers make decisions and subsequently operate (Saberi *et al.*, 2019; van Hoek, 2019). Knowing the supply chain capabilities and capacities is critical for building resilience. Effectively identifying supply chain environmental and social vulnerabilities can be completed using blockchain transparency and traceability, paired with big data predictive analytics tools – helping to build the needed capabilities and capacities.

This crisis provides evidence that localized systems are more likely to be robust and resilient than global supply chains (Nandi *et al.*, 2021; Handfield *et al.*, 2020). Localization is also important to environmental supply chain sustainability (Holmstrom and Gutowski,

2017). Local production can mean rapid response to local needs, but with low energy and resources consumption. For example, in the COVID-19 pandemic, many "hot-spots" emerged. Ensuring critical equipment and materials through more agile production and rapid delivery logistics to hot spots can equate to saving more lives or slowing the spread of positive cases – a social sustainability concern. Flexible manufacturing system technologies such as additive manufacturing and robotics can localize production capabilities.

Local additive manufacturing of parts for ventilators or masks were important solutions during the pandemic. In northern Italy, a hospital required replacement valves for its ventilators but could not locate any through its local supply chain. A startup – Issinova – heard of the need and brought a three-dimensional (3D) printer to the hospital, reverse engineered the valve and printed replacement parts within the day. This small example was repeated in multiple locations throughout the world. Smart factories with distributed information, additive manufacturing and integrated Industry 4.0 technology is one solution for building supply chain resilience and robustness through localization (Holmstrom and Gutowski, 2017).

Localized production capability can support sustainable supply chains by producing only what is needed. Less waste, less transportation and less need for inventory storage due to shorter supply chains; each has sustainable supply chain implications.

There are sustainability concerns with some recommended solutions to building resilience in supply chains. Agility in supply networks will likely mean building redundant capacity and capabilities. Redundancy results in wasted resources and energy.

Social distancing, remote work and reduced business travel during the COVID-19 crisis offer sustainable supply chain lessons. Reduced employee commuting and business travel contribute to reduced organizational carbon footprints. Virtual meetings and virtual reality acceptance are likely to increase and become the norm (Sarkis *et al.*, 2020a). In an interview with a machine parts distributing company, they informed us that they will likely require fewer physical supplier location visits due to greater distance communication acceptance.

Unintended negative environmental sustainability concerns may occur. Working from home may not be as sustainable as initially thought. For example, UK researchers have found work from home environmental impact was higher in the winter due to heating individual worker homes versus centralized office buildings (Turits, 2020). Thus, research on the overall lifecycle environmental impact of operational behavioral changes will be needed.

COVID social distancing lessons can provide lessons for future health and safety operational concerns, e.g. when working with hazardous materials. Virtual reality and linked CPS technologies that can help manage operations at a distance. These practices reduce travel to and from locations, resulting in reduced energy resource usage and emissions.

A burst of demand for IoT and e-commerce consumer goods and groceries occurred during the crisis (Wang *et al.*, 2020). Shelter in place and social distancing mandates forced consumers to turn to online sources of goods and services. This behavior had been increasing incrementally over the past two decades – it is likely to become an even more dominant form of consumerism. This event required farmers and local retail outlets to pivot to e-commerce delivery. Shopify, a Canadian e-commerce platform, stepped in to address this need and provided cloud and supply chains services to these local companies, resulting in a shortening of supply chains (Guillen, 2020).

The crisis also identified big data and analytics opportunities. These opportunities can support sustainable supply chains (Hazen *et al.*, 2016; Brinch, 2018). An example is management of food waste in an online grocery situation or food sharing across peer-to-peer e-commerce venues. In our investigation of an online setting, we were offered data from before and during the crisis. These data are currently being evaluated with data analytics tools to investigate supply chain and consumer responses. Food waste, especially for fresh

foods, was a major issue we identified due to the fluctuations and shifts in demand with bullwhip-like characteristics.

Social innovations and implications

Social innovations relate to the technology transformation landscape. Two related social innovations – the circular economy and the sharing economy – can positively impact supply chain sustainability and resilience. Negative outcomes may also occur.

The COVID-19 crisis showed the risk of global supply chains focusing solely on efficiency. As previously observed, localization and redundancy in sourcing can reduce risk. Localization is particularly important for isolated communities. One extreme isolation example is Pacific Island territories that are dependent on global supply chains for food security. In response to COVID-19 disruptions, island nation communities have developed local food markets, sharing activities and bartering. This localization transformation means less food waste and emissions due to cooperatives (Farrell *et al.*, 2020).

Supply chain localization through industrial symbiosis, waste exchanges and utilization of local byproducts are supply chain resilience enablers and circular economy practices (Smart *et al.*, 2017). Questions do arise. Intended for resources conservation, do circular economy principles also help build supply chain resilience and robustness? Can circular economy practices be the solution for joint supply chain sustainability, efficiency and resilience?

Sharing economy issues also arose during the crisis (Hossain, 2020). For example, due to slowdowns and shutdowns, inactive service or delivery vehicles were mobilized to deliver essential goods. One supply chain executive mentioned to us the ability to deliver internationally using passenger and military aircraft due to excess capacity and availability during the crisis. This acceptance and application due to crisis needs may be adopted as a standard crowdsourcing practice for logistics and delivery (Li *et al.*, 2020).

COVID-19 consumer and individual behavioral responses may influence the prospects of both sharing and circular economy social innovations – the consumer behavioral move to online and e-commerce sales is one example (Wang *et al.*, 2020). A major behavioral concern is whether negative reuse and recycling perceptions will emerge. Reuse and recycling – core circular economy practices – imply that a material or good has been used previously. Post-COVID-19, a fraction of the population will perceive recycled goods and materials as contaminated and unsafe. Even before the crisis, there existed an aversion to recycled products due to quality deficiency perceptions – this perception may expand to recycled goods being less sanitary. Additionally, sharing services such as car sharing may be under greater scrutiny, given contagion worries and unsafe close conditions, during the crisis, which can carry on to the post-COVID-19 environment (Köbis *et al.*, 2020).

Research opportunities

Several research opportunities for the overall supply chain management community – and sustainable supply chains – exist during and after this pandemic. It is an opportunity for natural experiments, empirical investigation, field and case studies.

First, some broader questions – the COVID-19 pandemic is a natural disaster, not necessarily man-made. How does a natural disaster differ from a man-made disaster in terms of acceptance of supply chain disruption and resulting supply chain environmental sustainability issues? Will supply chain partners and consumers be more forgiving in crisis responses when environmental damage occurs for the benefit of society and the economy?

After the event, there will be concerns about recovery and returning to normalcy. From a supply chain sustainability perspective, there is concern on whether regulatory policy –

especially environmental policies – will be rolled back, and whether this regulatory roll back supports more efficient supply chain recovery (Kecinski *et al.*, 2020).

Post-COVID-19, emission outcomes and shifts in sustainable supply chain policies are intriguing research directions. Will organizations along the supply chain – including governmental or quasi-governmental agency regulators – reduce oversight, auditing and requirements for sourcing materials, especially with respect to environmental regulations?

Will a crisis-related shift in global politics cause changes in access to materials for green economy products? For example, the USA is blaming China for the pandemic and using it to further instill tariffs. Will these tariffs further disrupt clean energy supply chain and distribution networks dependent on materials and rare metals from China (Temple, 2020)?

How does this pandemic relate to other crises? A comparative analysis may be possible. How do these disruptive global events differ from smaller disruption events? Can the lessons learned at the broader pandemic crisis level be applied to less pervasive disasters and disruptions? Do environmental concerns along the supply chain differ? For example, a localized event may require environmental protections for local residents; a broader event with dispersed and long-term environmental concerns – e.g. climate change – may not be as critical for organizational and supply chain action (Sarkis *et al.*, 2020b).

With newer consumption patterns, does the shift to online purchase and deliveries result in improved or worsened supply chain sustainability outcomes? For example, currently, packaging for online delivery is very inefficient with excess packaging and materials (Wang and Zhu, 2020). As this type of purchasing becomes the new normal, will innovations in packaging occur and thus reduce overall waste?

Last-mile-type studies can be further investigated. For example, the use of drone technology for delivery may mean fewer emissions from vehicular deliveries; will these new technologies become more acceptable and feasible as less human interaction is expected (Kumar *et al.*, 2020b)?

The bullwhip, ripple and resonance effects are likely to occur in hoarding situations during a pandemic, especially after shelter in place orders are announced. What happens in this circumstance (Handfield *et al.*, 2020)? Will the bullwhip effect be more pronounced with greater waste? Overshoot responses means a surplus of inventory, which could prove costly to the company and result in wasted resources. Can this waste be mitigated with some of the localization and social innovation practices? What does it mean for leadership and organizational policy in managing short-term wastes and long-term sustainability of organizations? If the "clockspeed" (Fine, 2000) associated with this crisis has not been experienced previously, what does it mean for sustainability management and future broad-based disruptive events and crises?

The relationships between lean and green supply chains have been investigated (Shou *et al.*, 2020). Will the shift away from lean, toward agile and robust supply chains, also mean a shift in technology, social innovations and environmental sustainability of supply chains?

Many potential transformations are likely to occur; how long these changes remain will likely differ across industries. The relative system shock may determine whether COVID-19-driven shifts toward greater supply chain resilience and sustainability will only be short-run corrections. One supply chain executive – the chief procurement officer of a company employing 100,000 people worldwide – provided one interesting insight. She stated that because her company had a strong sustainability focus, that they did not feel the "short-run" COVID-19 crisis will change anything they do. They felt this short-term crisis will subside and broader sustainability concerns are more critical.

In the emergent literature, the issue of whether supply chain sustainability will be altered by the COVID-19 crisis is receiving attention (e.g. Sharma *et al.*, 2020). The converse on whether a sustainability strategy focus will cause organizations to effectively survive post-COVID-19 remains an important topic for research.

Post-COVID developments	Lessons highlights
Technological innovations	Long-term (strategic) role of Industry 4.0 technologies as an enabler for crisis management Big data is reinforced as a decision planning tool Emergent collaborative technologies such a blockchain technology can help to support sustainability Localization through various technologies used in crisis can support supply chain sustainability Building agility through technological innovations may result in wasted resources burdening supply chain sustainability Social distancing and remote work means greater acceptance of conferencing technology and less travel to supplier locations for monitoring, negotiations, etc. Online sourcing and purchasing of retail and grocery shifts travel and last-mile delivery focus affecting sustainability
Social innovations	Circular economy (CE) (1) Localization can be supported through CE principles (2) Localization can build resilience and be more sustainable (3) Which CE practices – industrial symbiosis, waste exchanges, local by-product usage – may address resilience and robustness Sharing economy (1) Learnings for sharing excess capacity through crowdsourcing (2) Significant issues related to consumer sharing and contagion – carryover to post-COVID
Research opportunities	Exemplary research questions Are natural disasters and crises and their responses in the supply chain relative to sustainability concerns different than responses to man-made crises? Will supply chain and operations environmental sustainability performance and concerns wane during the crisis and during a recovery period? Will the COVID crisis provide greater insights for local or for global supply chain crises and responses (localized environmental crises versus global long-term crises)? What lessons exist for the bullwhip events in a crisis-like situation for general management and waste in the supply chain pipeline? What does a change in lean effort perspectives due to COVID mean to the "lean and green" supply chain outcomes? Are agile supply chains greener than lean? Does a broad-based organizational sustainability strategy will likely mean few changes to operations and supply chain practices and long-term sustainability outcomes?

Table 1.
Summary of potential Post-COVID-19 innovations and research questions pertaining to supply chain sustainability management

Major potential COVID-19 outcomes related to technological and social innovations and their relationships, based on previous section observations, are summarized at the top of Table 1. Exemplary research concerns and questions from COVID-19 and supply chain sustainability relationships are summarized in the bottom of Table 1.

Conclusion

This is an unprecedented time. The world has rapidly reacted to a major crisis. Our previous institutions and worldviews have changed. This pandemic – with its remaining uncertainties – and responses will be topics of discussion for the foreseeable future. The crisis and recovery period provides us with opportunities to observe and study how institutional changes can result in strategic and operational supply chain transformations.

Although the limitations and fragility of global supply chain resilience occurred early in the pandemic, they also highlighted potential transition opportunities and evolution toward

sustainability. For example, the COVID-19 crisis provides lessons for climate shock events (Sarkis *et al.*, 2020b).

We have outlined some general issues on how these major social and technological transformations from the COVID-19 pandemic can change our understanding of supply chains and supply chain sustainability.

It is not clear if after the panic and the crisis we will return to our old ways. After this black swan event subsides, will it be the accountants and financiers who decide how our supply chains operate; will the sustainability flame dim?

We need to carefully examine and study our world; what we learn now and what we implement later can have beneficial or detrimental results for decades and generations. Only looking inwardly to our discipline will be short-sighted; we need to join forces with natural scientists, social scientists, industry, government and civil society to jointly address these issues. This crisis requires transdisciplinary interactions.

Overall, as operations and supply chain researchers, we should not shirk our duties in contributing to recovery and a better – sustainable – world.

Notes

1. We will integrate sustainable operations and supply chain management into sustainable supply chains and sustainable supply chain management, with sustainable operations and sustainable operations management included as part of sustainable supply chains. Unless explicitly mentioned, sustainability is primarily focused on environmental sustainability concerns.

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Corresponding author
Joseph Sarkis can be contacted at: jsarkis@wpi.edu