Sustainable Triple-A Supply Chains

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In his 2004 article, Professor Hau Lee argues that the best supply chains are not only fast and cost-effective but also \textit{agile}, \textit{adaptable}, and \textit{aligned}. The concept of triple-A supply chains has been extensively studied in academic and trade publications and integrated into numerous operations and supply chain management curricula. It has also influenced the management approach of leaders around the world. Yet since the triple-A concept was first developed, supply chains have become increasingly global, connected, and interdependent. The increased complexity of global supply chains has reduced much-needed visibility, further complicating their management, while the growing connectivity and interdependence among different stakeholders have led to many unforeseen environmental and social issues. As a result, Professor Lee’s emphasis on triple-A supply chains is even more relevant today. In light of these new challenges and demands, we revisit the original triple-A definitions of agile, adaptable, and aligned, expanding these concepts for a more socially and environmentally conscientious world. We also discuss potential enablers of and barriers to sustainable triple-A supply chains.

\textit{Keywords:} Triple-A supply chains; social and environmental sustainability; agility; adaptability; alignment; technology

1. Introduction

In his 2004 article, Professor Hau Lee argues that the best supply chains are not only fast and cost-effective, but they are also agile, adaptable, and aligned (Lee 2004). That is, triple-A supply chains (i) respond quickly to short-term and sudden changes in market demand or supply and handle external disruptions smoothly (\textit{agile}), (ii) adjust their supply networks to meet structural shifts in the market (\textit{adaptable}), and (iii) create incentives for all supply chain partners to achieve better outcomes (\textit{aligned}). Based on this definition, an agile supply chain combines shared, centralized intelligence on demand and supply data with efficient, decentralized execution. An adaptive supply chain requires flexible network relationships alongside a change management focus. Adaptability also involves routine collection of intelligence on market product needs and continual technological evolution. Finally, alignment necessitates clearly defined roles and responsibilities and extended, joint performance measures that adjust risk, costs, and rewards across the supply chain.

Since the publication of Professor Lee’s article, its concepts and examples (such as Zara’s agile supply chain and HP’s adaptation of inkjet printer production over the product’s life cycle) have appeared in academic and trade publications and have made their way into operations and supply
chain management curricula. The article has been cited over 2,000 times and has influenced the management approach of leaders worldwide.

Yet in the past 16 years, supply chains have become increasingly global, connected, and interdependent. The greater complexity of global supply chains has reduced much-needed visibility, further complicating their management. The growing connectivity and interdependence among different stakeholders within supply chains have led to many unforeseen environmental and social issues. Consider the following.

**Agility:** From their outset, Zara and H&M have been recognized for their agility, which is enabled by their underlying fast-fashion models. Historically, fast fashion went against the grain of the fashion industry’s long lead time assortment model by focusing instead on meeting customer demand through the rapid design, production, and stocking of new fashions. Today, however, the environmental implications of fast-fashion models have brought them under scrutiny. Consumers are increasingly demanding more sustainable clothing options (Masunaga 2019), and activists and governments are pressuring fast-fashion companies to reduce their carbon footprint, eliminate waste, and improve sourcing standards (Howard 2019, Lee 2019).

In principle, the short lead times and small production quantities associated with fast-fashion models should reduce waste, a common issue in the apparel industry. However, this does not occur in practice. Fast-fashion models are based on continual assortment turnover and promotion of consumption, which amplify the existing waste issues in the fashion industry. One such issue is water: the industry produces nearly 20% of global wastewater, and this share is only expected to rise as the production of discardable clothing increases. A second issue is textile waste, which is mostly generated after the use phase: less than 1% of clothes are recycled, and the average consumer throws away approximately 70 pounds of clothing every year. Overall, the apparel industry contributes to global emissions more than aviation and shipping combined (Ellen MacArthur Foundation 2017).

**Adaptability:** In addition to reacting to unexpected changes in supply and demand, companies must also be able to adapt their supply chains to more long-term market shifts. Outsourcing can help supply chains become more adaptable by securing economies of scale, providing the flexibility to change sourcing locations and relocate production more easily (Lee 2004). To use the classic example, the success of HP’s inkjet printer was partly due to outsourcing, which allowed HP to reduce manufacturing costs once the technology had matured. Similarly, Microsoft’s successful launch of the Xbox and its ability to compete with market leader Sony on both cost and speed were, in part, due to outsourcing: Microsoft outsourced Xbox’s production to Flextronics, which had production facilities close to Microsoft’s target markets and in lower-cost countries in Asia.

As supply chains have grown in complexity, however, globalization and outsourcing now often lead companies to lose control of their sourcing. Consider, for example, multinationals that source palm oil, a notoriously complex supply chain. Many of these companies have been at the center of controversy after several investigations revealed human rights violations and illegal
deforestation activities occurring at palm oil plantations (Amnesty International 2016, Greenpeace 2018). An intermediary, Wilmar, controls 45% of the global palm oil trade; thus, a single firm (even a large multinational) has very little power to change industry standards. The inability to transform relationships and control suppliers significantly reduces a firm’s ability to adapt its supply chain and make it more sustainable.

Alignment: Lastly, companies must align incentives and share information such that all supply chain partners pursue the same interests and maximize the chain’s performance. For example, Seven-Eleven Japan was famous for its emphasis on alignment, as even before the advent of the internet, it used satellite connections and real-time data on customer preferences to align suppliers, logistics, and retailers. This alignment created time and cost savings for the whole supply chain. Unfortunately, examples like this remain rare, as the greater complexity of supply chains has proven a significant challenge to their alignment. Even if firms know who their upper-tier suppliers are, they rarely have contractual relationships with them (Villena and Gioia 2018). New environmental and social responsibility pressures further complicate the equitable division of cost and risk within a supply chain, especially since these externalities are rarely, if ever, included in cost and risk considerations.

In this context, alignment has become even more crucial. The immediacy of this need is underscored by a recent report released by The Sustainability Consortium, which urges companies to prepare their supply chains for further potential weather-related disruption risks due to climate change (Holbrook 2020). Still, many companies fail to act on opportunities to align the environmental strategies of their supply chains. For example, a 2017 report by the Carbon Disclosure Project found that while major brands have made progress in reducing their own emissions (i.e., Scope 1 and 2 emissions), only 23% of the brands surveyed worked with their suppliers to reduce the suppliers’ emissions (i.e., Scope 3 emissions). Reducing suppliers’ emissions is critical to addressing climate change, as the carbon emissions of upstream supply chains are four times greater than those of companies’ direct operations (Mead 2018). To improve their positions on environmental issues like carbon emissions and to create sustainable supply chains, companies must align the environmental decision-making of entities in their supply chains just as they have done to improve pricing and quality.

In light of the examples and discussions above, Professor Lee’s emphasis on triple-A supply chains is even more relevant today. However, the characterization and operationalization of agility, adaptability, and alignment within today’s global supply chains is a more involved undertaking. Thus, we revisit the triple-A supply chain definitions to investigate how these concepts can be expanded in response to the increasing need and demand for sustainability. We also discuss potential enablers of and barriers to sustainable triple-A supply chains. Throughout, we highlight examples from practice to identify interesting trends that may merit further study by the operations management community. We do not provide an extensive review of the existing sustainable operations management literature; we refer readers seeking such a review to Lee and Tang (2018) and Atasu et al. (2020).
2. Building Sustainable Triple-A Supply Chains

Due in part to the increase in sustainability-related pressures companies face today, the potential meanings of agile, adaptable, and aligned in the supply chain context have evolved since 2004. This evolution creates an opportunity to reframe the definition of each term in the context of a sustainable triple-A supply chain. Our goal in this section is to revisit the definitions of agile, adaptable, and aligned supply chains to highlight, through examples, the additional capabilities needed for social and environmental sustainability (Table 1).

Table 1: Revisiting the definitions of agile, adaptable, and aligned supply chains to incorporate sustainability

<table>
<thead>
<tr>
<th>Agile</th>
<th>The Triple-A Supply Chain (Lee 2004)</th>
<th>Sustainable Triple-A Supply Chains (Erhun, Kraft and Wijnsma 2020)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Respond to short-term changes in consumer demand or supply quickly; handle external disruptions smoothly</td>
<td>Respond to a broader set of stakeholder demands that includes regulators, activists, and employees</td>
</tr>
<tr>
<td>Adaptable</td>
<td>Adjust supply networks to meet structural shifts in the market; quickly spot trends in the marketplace</td>
<td>Develop innovative ways to better control the supply chain; create market trends</td>
</tr>
<tr>
<td>Aligned</td>
<td>Create incentives for all supply chain partners to achieve better performance, both as a whole and individually</td>
<td>Extend alignment to points further up (upper tiers) and down (reverse) the supply chain; broaden the view of alignment to incorporate the consumer perspective</td>
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2.1 Agility

Agility describes a company’s ability to respond to short-term changes in market demand or supply quickly and handle external disruptions smoothly. This definition emphasizes the need for companies to be reactive and make difficult short-term decisions. However, in today’s environment, new demands outside of traditional market forces are compelling companies to revisit this view of agility. In particular, sustainable agile supply chains can no longer solely focus on short-term changes in the market and maximizing shareholder value.\(^1\) Instead, the emphasis must be on reacting to a broader set of stakeholder demands. Companies “must also invest in their employees, protect the environment and deal fairly and ethically with their suppliers” (Gelles...

\(^1\) The pressure to act on sustainability can, of course, be stock-price driven. In 2018, ESG (Environmental, Social, and Corporate Governance) investing grew to over $30 trillion (Stevens 2020). This increasing trend of ESG-driven investment represents a considerable risk for any public company not focused on improving its sustainability performance, as incidents can lead to significant stock value losses. For example, online retailer Boohoo recently saw its shares drop by 12% after reports surfaced about employees at one of its suppliers receiving wages less than half of minimum wage (Mulier et al. 2020). In the US, it is estimated that these types of ESG incidents have erased almost half a trillion dollars’ worth of value from public companies over the past five years (Flood 2019). This level of impact is also why socially responsible investing is considered the next wave of shareholder activism (Driebusch 2020).
and Yaffe-Bellany 2019) and address calls from external stakeholders such as non-governmental organizations (NGOs), activists, and regulators (Gartenberg and Serafeim 2019).

Such stakeholder demand had consequences for Patagonia in 2015, when it was attacked by a PETA video demonstrating animal cruelty at Patagonia’s wool supplier. This animal mistreatment occurred despite the fact that Patagonia, which is forward-thinking on sustainability issues, had worked closely with the supplier to establish the wool operations. Consequently, Patagonia stopped sourcing wool for three years while it corrected its wool supply chain issues (Kapadia 2018). Furthermore, it worked with apparel industry leaders to develop a new Responsible Wool Standard. In this example, an external activist, rather than consumers or a natural disaster, created the shock to Patagonia’s supply (and, in turn, demand).

In addition to advocating for sustainable sourcing in the apparel industry, environmentalists and activists are also pushing brands to improve the industry’s environmental impact by lowering their production and sales volume. Gucci is the first major brand to reduce its offerings and seasons to support a less wasteful fashion system. This move is a clear overhaul of the customer-centric system from which the company has profited in the past (Cartner-Morley 2020). In contrast, Zara’s approach to fashion remains exclusively customer-centric; the company argues that it is ultimately in shoppers’ hands to decide whether and how to purchase (Holgate 2019, Patel 2019). While this viewpoint puts less pressure on Zara to reinvent itself in the short term, the rapidly growing sentiment against fast fashion on multiple fronts (e.g., waste, chemical usage, and carbon footprints) will likely test Zara’s agility sooner rather than later.

Activism is not the only source of sustainability-related external disruption. Regulations on social and environmental responsibility can also test a company’s supply chain agility by posing unique challenges. These challenges are due to constant shifts in regulatory requirements and the extraordinarily complex and political nature of those shifts. One example is carbon legislation. Since 2013, the UK’s emissions regulations have required public companies to report their carbon emissions (Sweet 2013). Requirements were intensified in 2019, obligating both public and large private firms to report their energy use (HM Government 2019). In addition to following these UK regulations (which are so complicated that a previous scheme was discontinued due to its complexity (Chestney 2018)), firms must also monitor and potentially address EU regulations following Brexit. Thus, compliance often requires companies to invest in operational processes and controls for data collection to ensure that their supply chains remain agile to constantly shifting regulatory requirements.

Despite high costs and additional operational complexity, proactive compliance can help firms differentiate themselves from competitors and achieve cost savings through increased awareness of energy use. An agile approach to implementing regulatory changes would mean that teams prioritize investments and operational changes by taking an incremental approach to addressing requirements (Gittfried et al. 2017). One firm that utilized such a strategy is Unilever, which was one of the few firms that complied with the UK regulations earlier than required. Over time, Unilever implemented many of its own Sustainable Living Plan goals, as well as, met Carbon Disclosure Project requirements before they were mandatory (Unilever 2019). This incremental
approach avoided abrupt implementations of costly and often inflexible methods for meeting regulatory requirements. Spotting and planning for these regulatory demands ahead of time enabled Unilever to respond to future requirements and regulatory changes promptly.

Stakeholder pressures are not solely the purview of external stakeholders such as activists and regulators. Internal stakeholders can also place unforeseen demands on firms and cause internal disruption. Consider the recent issues and bad publicity Amazon incurred when word leaked that the company pressured employees not to speak out against climate change. This incident is part of a bigger trend of Amazon employees urging the company to address its environmental impact (Palmer 2020). When companies like Amazon do not manage the internal demands of an increasingly socially conscious workforce, they may face potential operational disruption caused by these dissatisfied employees.

In addition to new stakeholder demands and increased regulations, the growing role of reverse supply chains also affects agility. A company’s reverse supply chain is concerned with retrieving, reusing, and recycling end-of-life products. In this context, social and environmental responsibility violations, such as the illegal export or dumping of waste, frequently occur, exposing brands to compliance and reputation risk while devastating the environment and public health (Wijnsma et al. 2020). For instance, the nonprofit organization Tearfund recently found that four multinational drink companies are responsible for approximately half a million tons of plastic pollution every day in just six developing countries. The nonprofit urged these companies to eliminate plastic packaging waste that currently ends up dumped or burnt due to a lack of recycling infrastructure (Laville 2020). Regulatory demands on the reverse supply chain have also become stricter. Among such requirements, Extended Producer Responsibility regulations place the responsibility for the post-consumer phase of certain goods on producers, which requires an agile reverse logistics system to manage the return and recycling of a large volume and variety of products in varying stages of use (Atasu et al. 2009). For instance, the collection of used electronics will result in a stock of working, repairable, and non-repairable products, of which some will contain hazardous components mixed with precious, recoverable metals.

When handled properly, agile management of the reverse supply chain can create competitive and cost advantages. For instance, through product use-phase data, HP’s Instant Ink service detects when a printer’s cartridge needs to be replaced, allowing the firm to predict and immediately react to demand. It automatically ships a replacement, facilitates the empty cartridge’s return, and reprocesses it in its advanced facilities. This process reduces the carbon footprint of the ink purchase and return by 84% and reduces material consumption by 57% (Leurent and Cronin 2019).

To create an agile and sustainable supply chain, companies must broaden their customer-centric approach to incorporate an expanded set of diverse stakeholders that includes activists, regulators, and employees. In doing so, they must ensure the entire value chain, including the reverse supply chain, can meet these new demands. If they do not, then the additional constraints and requirements arising from issues such as CO2 emissions, waste generation, and labor practices will make companies even less agile in the current landscape.
2.2 Adaptability

Adaptability refers to a company’s ability to spot trends in the marketplace and adjust its supply network to meet these structural shifts. In this regard, adaptability, as compared to agility, emphasizes a more long-term, strategic view. However, creating adaptable and sustainable supply chains requires companies to do more than simply monitor trends and adjust their supply networks as needed. They must further enhance their influence by exploring innovative ways to control their supply chains better.

One way to adapt a supply network is to develop innovative new sources of supply. Consider Dell, which established the first commercial-scale global supply chain for ocean-bound plastics. The firm tackled a significant environmental problem by leveraging its strength in supply chain management and its knowledge of closed-loop recycling of materials from its products. By collecting and upcycling unwanted and harmful plastics, Dell created an environmental benefit and established a less expensive supply comparable in quality to traditional sources of plastic (Anupindi and Hoffman 2018).

Adapting a supply network to become more sustainable may not always require an extensive degree of innovation. Instead, firms are finding value through sustainability by restructuring existing supply networks. Consider Haiti Hope, a public-private partnership between Coca-Cola, Technoserve (an NGO), the Inter-American Development Bank Group, and the United States Agency for International Development (Edmondson and Harvey 2016). The Haiti Hope project was a social development project designed to help Haitian farmers grow mangos more efficiently and secure access to international markets. The project’s underlying economic goal was to raise the farmers’ standard of living and, ultimately, contribute to the Haitian economy’s revitalization after the 2010 earthquake. The partnership invested funds and resources to educate farmers on best practices and improve the local logistics infrastructure. Furthermore, it established a robust intermediary presence between buyers and farmers, which not only strengthened small shareholder farmers’ leverage in the market but also improved the quality and consistency of the product produced. The project benefited not only the farmers and their communities but also Coca-Cola; by developing the supply chain for mangos in Haiti, Coca-Cola reduced its costs and lead times by locally sourcing its fruit juices.

Companies can also adapt their supply chains to be more sustainable through vertical integration, which allows greater control. Consider, for example, the guitar industry, which sources a considerable amount of ebony wood, a key material in guitar production. In the early 2010s, high demand and low supply of ebony led to widespread illegal logging, which exposed many guitar manufacturers, such as Gibson Guitar, to compliance and reputation risks. Gibson’s competitor, Taylor Guitars, sourced its ebony wood historically from the Crelicam mill in Cameroon, which, in turn, sourced its raw wood from several small suppliers in the region. In 2011, the owner of Taylor

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2 In 2009 and 2011, Gibson Guitar was raided for using illegally sourced wood. These raids revealed that the firm had failed to successfully adapt to new sourcing regulations that made US companies responsible for ensuring that their trading partners throughout the timber supply chain obey all laws in all countries.
Guitars, Bob Taylor, traveled to Cameroon to better understand the sourcing process for the ebony wood that had made Gibson the center of controversy. On his trip, Taylor discovered some disturbing facts about the ebony sourcing process. For example, due to the strong industry preference for pure black ebony wood (rather than ebony wood with streaks of color), wood suppliers, on average, cut down ten trees to find one tree with the desired pure black color. Taylor also noticed many ethical issues in the mill’s labor practices.

To mitigate the risks associated with responsibility violations and fix the issues at the mill and with the wood suppliers, Taylor Guitars vertically integrated by purchasing the Crelicam mill. In doing so, Taylor Guitars established labor practice standards at the mill comparable to those found in the United States. The mill began to accept wood with stripes from the wood suppliers at prices equal to those for pure black wood (Taylor Guitars 2020a). Purchasing the Crelicam mill also made Taylor Guitars a supplier to its competitors. Using its position as both a supplier and a producer, the company helped re-educate the market (both consumers and competitors) on striped ebony wood. For instance, the firm launched several campaigns to encourage the adoption of marbled ebony wood and started using it for its highest-end guitars. In this regard, Taylor Guitars did not spot a trend but rather created a trend of striped-ebony guitars (Orsdemir et al. 2019; Taylor Guitars 2020b).

As these examples demonstrate, firms interested in creating an adaptable and sustainable supply chain must look beyond simply adjusting their supply chains and find innovative ways to take more control of their supply networks. This new approach may require disruptive innovation that emphasizes sustainability in products/services, processes, and infrastructure. In so doing, a firm can transcend traditional relationships and establish more cooperative supply networks with fluid roles. These innovations can not only help to educate suppliers and customers but may also create new market opportunities.

2.3 Alignment

When entities within a supply chain are not aligned, siloed decision making can lead to poor overall performance and inefficient outcomes. When a firm aligns its supply chain properly, however, it places heavy emphasis on creating incentives for all supply chain partners to achieve better performance, both collectively and individually. Based on the traditional concept of alignment, such efforts generally focus on the interactions between a firm and its direct suppliers in the forward supply chain. However, the most detrimental sustainability issues usually occur (i) in the upper tiers of supply chains and (ii) downstream in the reverse supply chain after products reach end-of-life or are discarded. Therefore, the demand for more sustainable supply chains

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A study of 3,922 supplier relationships found that Tier 2 suppliers committed, on average, 18% more non-compliances per audit than Tier 1 suppliers; Tier 3 committed 27% more (Sedex 2013). Incidents like the Rana Plaza collapse in Bangladesh in 2013, in which over 1,100 workers died when a garment factory collapsed, not only confirm the findings from the Sedex study but also highlight companies’ lack of visibility into these upper tiers of their supply chains (Yardley 2013). In terms of the reverse supply chain, images of landfills full of discarded garments from known apparel brands frequently cause public outcry (Wicker 2016).
creates additional pressures for companies to extend the idea of alignment further in both upstream and downstream directions. Also, companies are under new pressure to demonstrate that products are being made and sourced ethically. This pressure is forcing them to broaden their view of supply chain alignment to consider the impact and demands of consumers in addition to the alignment between brands, manufacturers, and suppliers.

This shift has significant implications for how companies monitor their supply chains. Specifically, an essential characteristic of an aligned supply chain is that information is shared freely between entities, including suppliers and customers (Lee 2004). As the complexity and scope of supply chains have increased, more and more companies realize the need to gain visibility into and collaborate with the practices of their supply chain partners (Kraft et al. 2018). Yet, establishing visibility into a supply chain (let alone improving suppliers’ and customers’ practices) remains a challenge and requires an extensive commitment of time and resources (Doorey 2011). Companies are making efforts, but examples of success in this regard are few and far between.

In the apparel industry, globalization has led many companies to search for inexpensive labor sources in developing countries. This expansion has challenged firms’ abilities to maintain alignment and gain visibility within their supply chains. More socially conscious apparel brands are now forced to exert further effort to maintain alignment. For example, Patagonia annually audits not only 100% of its Tier 1 suppliers but also a subset of Tier 2 suppliers that constitute 80% of its total material cost (Patagonia 2017). It has even begun mapping its supply chains to the farm level to ensure farms meet its standards (Patagonia 2020b). Following a recommended method for promoting and achieving alignment (Lee 2004), the firm freely discloses its information to customers and vendors (Bateman and Bonanni 2019). An important aspect of Patagonia’s focus on alignment is that it includes downstream stakeholders. For example, in 2019, its fleece vests practically became the new corporate uniform for bankers on Wall Street: an apparent misalignment between customer and company for a firm that prides itself on being a sustainable outdoor brand. To realign its customer base with its corporate strategy, the firm shifted the focus of its corporate sales program to organizations that meet specific environmental, social, and transparency standards (B-Corp), a move that excluded many financial and tech firms.

Another example is Goodio, a Finnish craft chocolate maker that is committed to putting purpose over profit and recognizes the importance of transparency in achieving this goal (Hämäläinen et al. 2020). Goodio bases its business model on “radical transparency,” i.e., creating end-to-end transparency in its supply chain so that consumers know they are purchasing from a brand they

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4 For instance, increased competitive pressures on suppliers to keep prices low have, in part, led to poor labor practices and unsafe working conditions at production facilities. Events such as the 2013 Rana Plaza collapse illustrate the need for increased control by downstream brands to ensure improved, safer labor practices.

5 We distinguish between transparency and visibility. To create a transparent supply chain requires a company to both gain visibility into its supply chain and disclose information to consumers (New and Brown 2011).
can trust. By leveraging its strong relationships with a handful of cacao cooperatives, Goodio both gains visibility into its supply chain and provides consumers with extensive visibility into the social and environmental impact of its work. Goodio’s success in ensuring fair and ethical practices in its cacao supply chain is an example of how smaller, more nimble firms can often be at an advantage when it comes to alignment. In contrast, cacao supply chains within the more mainstream chocolate industry are notorious for poor labor practices and low wages, particularly at the farmer level (de Bassompierre and Jha 2019). Such larger multinationals often lack visibility into their supply chains because they may manage over 100,000 suppliers. As a result, they often fail to uncover abuses (Webb 2016).

Many brands and manufacturers acknowledge that they may not have the internal resources or capabilities for extensive visibility. Such companies are increasingly relying on outside support from NGOs/nonprofits and intermediaries (e.g., cooperatives or supply chain management companies) to ensure the alignment of sustainability practices of upstream suppliers with the overall goals of the supply chain. Consider, for example, the Institute of Public & Environmental Affairs (IPE), a nonprofit based in China. IPE uses publicly available pollution data to map pollution sources and act as an information platform (Sustainable Brands 2018, Russell 2019). The data and transparency IPE provide can enable end-to-end alignment by helping companies to monitor and screen both new and existing Tier 1 and Tier 2 suppliers for environmental performance (Plambeck et al. 2012). It can also be leveraged by a broad set of stakeholders, including consumers, activists, and media, to drive environmental improvements in supply chains (McMahon 2017). Similarly, a recently announced partnership between Google and WWF Sweden aims to create an open-source “data-enriched decision-making platform” to help firms in the fashion industry understand the environmental impact of their sourcing decisions (Google 2020). These interactions with third parties can also lead to knowledge-based spillovers that help a brand improve its supply chains’ sustainability performance over time (Ramchandani et al. 2020).

End-to-end alignment does not stop at the consumer level. It includes points even further downstream in a supply chain, beyond a product’s life cycle. Effective material recovery and closed-loop supply chains require alignment within the reverse supply chain (Gui et al. 2018, Wijnsma et al. 2020) and linking incentives with the forward supply chain (e.g., Agrawal et al. 2015). For instance, in 2019 Amazon introduced a range of plastic packaging that would help it load more parcels on delivery trucks, increasing efficiency in its forward supply chain. However, this packaging solution was not recyclable, leading to excessive waste, clogged recycling centers, and heavy criticism from the public (Brignall 2019).

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Cooperatives, particularly in agricultural sectors, are another proven method for ensuring alignment with upstream suppliers. By aggregating smallholder farmers through cooperatives, downstream buyers of goods such as coffee beans (Joost Guijt et al. 2019) and cacao beans (Pilling 2019) can ensure a more consistent and high-quality supply, while also gaining assurance that suppliers’ practices are sustainable. For farmers, cooperatives not only improve their practices but also provide them with leverage in the marketplace to ensure they receive a higher price and access to a wider range of buyers.
To avoid a siloed approach to optimization that undermines the reverse supply chain, Dell closely collaborates with its recycling partners on materials, labeling, and other design choices to determine what features complicate or simplify recycling. This partnership leads to better recycling incentives and higher quality recycled materials. In turn, Dell can reuse this content in its products (Dell 2020). Considering a product’s entire life cycle in this way aligns the complete process, from production to recycling, and increases profits. Similarly, IKEA announced its goal to be fully circular by 2030 and, as a first step, partnered with logistics start-up Optoro to minimize the waste produced in its reverse supply chain. Optoro creates an end-to-end view of reverse-logistics processes using data analytics and machine learning algorithms, which enables IKEA to divert sellable products from landfills back to retail outlets (Forde 2019).

Alignment requires end-to-end visibility and information sharing. A characteristic feature of sustainable and aligned supply chains is that they secure this alignment through radical transparency that involves all partners in the chain. While Professor Lee actually emphasized this point in his paper, supply chains have made little progress in this direction in the past 16 years. For companies to truly create aligned, sustainable supply chains, there must be a shared understanding and commitment from all supply chain entities, including upper-tier suppliers, consumers, and the reverse supply chain.

3. How to Facilitate the Development of a Sustainable Triple-A Supply Chain

Based on our reframed definition of triple-A supply chains to incorporate sustainability demands, we next discuss ways to facilitate development of a sustainable triple-A supply chain and the challenges companies may face in achieving this goal.

First, establishing and maintaining a sustainable triple-A supply chain requires a firm to innovate and rethink its processes. Doing so can help companies to better adapt and control their supply networks. As discussed in Section 2, Taylor Guitars improved the sustainability practices in its ebony wood supply chain by vertically integrating, and the Haiti Hope project enhanced farmers’ livelihoods and the quality of products sourced by Coca-Cola by reinventing the mango supply chain in Haiti. Note that a company does not have to own part of a supply chain to control it better. For example, in the late 2000s, Patagonia reduced its number of suppliers by 50% to gain more oversight of its supply chain and strengthen individual relationships (Patagonia 2020a). Similarly, companies can leverage their sourcing policies to gain better control of suppliers’ sustainability practices (Agrawal and Lee 2019).

Innovation opportunities are not restricted to the forward supply chain. For example, Dell leveraged its closed-loop recycling knowledge to create a new supply source: upcycled ocean-bound plastics. Relatedly, circular economy models build on closed-loop supply chain foundations to rethink business models and connect forward and reverse operations. Consider the multi-retailer LOOP initiative, which was launched in 2019 by recycler TerraCycle. LOOP reimagines the shopping process by re-introducing reusable packaging and the milkman model; it offers shoppers

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7 For further discussions on circularity, we refer readers to Tse et al. (2016) and Agrawal et al. (2019).
the opportunity to reduce their carbon footprint and waste production by providing products in packaging that can be returned and refilled.

Second, to monitor and improve supply chains’ sustainability performance, companies must gain better visibility into the activities of upper-tier suppliers and reverse supply chains. Such a change can help align the supply chain’s objectives and increase the firm’s capacity for agility. It is not enough for companies to rely solely on audits of first-tier suppliers to monitor supply chain activities. There is a growing sentiment that audits alone are not a strong enough tool to reveal what is occurring in a supply chain (e.g., Plambeck and Taylor 2016). In addition, sustainability incidents are often located not with the first-tier suppliers but with the upper-tier suppliers and the reverse supply chain. To make audits more effective, companies must find ways to extend their efforts further upstream and downstream in the supply chain (like Patagonia has done). Such extension may involve, for example, scaling auditing practices through partnering with competitors (Caro et al. 2018) or nonprofits on joint or shared audits. Approaches beyond auditing are also necessary and may include working with outside parties such as nonprofits or cooperatives to monitor and improve suppliers' practices. In some instances, firms may need to collaborate with competitors and industry partners to establish industry consortiums. For example, Dell initiated NextWave Plastics, an industry consortium dedicated to creating a global supply network for ocean-bound plastics. Besides bringing leading companies together to ensure demand for recycled plastics, the initiative also focuses on visibility by encouraging members to share and replicate best practices (Anupindi and Hoffman 2018).

Another tool for improving visibility is properly applied technology. Technologies such as blockchain (Stein Smith 2018) and the Internet of Things (IoT) (Ellen MacArthur Foundation 2016) can provide consumers and companies with instant insight into, for example, whether a product meets fair trade certification requirements or when a printer cartridge requires replacement or recycling. Such technologies, however, can still be challenging to adopt, even within a relatively small supply chain. For example, although Goodio emphasizes radical transparency, it failed to implement blockchain technology to trace raw materials and money in its supply chain. This failure was due to the fact that blockchain, like many technologies, requires full participation from all supply chain stakeholders – in this case, including small farmers with no technical background – in order to work.

It becomes clear, then, that technology is not a quick fix: leveraging technology to ensure more sustainable supply chains still requires companies and stakeholders to innovate. Without innovation, barriers may exist between supply chain partners, which cause misalignment of interests and make it difficult to improve a supply chain’s sustainability performance. For example, consider GreenBlue, an environmental nonprofit dedicated to increasing transparency related to the chemicals and substances used in products and supply chains (Karaer et al. 2017). In its work, the organization needed to tackle intellectual property (IP) issues, which pose a significant barrier to transparency. Suppliers are often reluctant to disclose their products’ chemical and material makeup to buyers lest they reveal commercial secrets and lose their competitive advantage. To overcome this barrier, GreenBlue built an innovative platform called Material IQ (MiQ), which allows upstream suppliers and downstream buyers to share sensitive chemical-
toxicity information without divulging IP secrets. Suppliers submit sample products to SciVera, a GreenBlue partner and third-party chemical safety assessment provider. SciVera then evaluates and scores the product’s chemical makeup and the associated risks. This information becomes part of MiQ, so buyers who subscribe to the platform can view the potential hazards of the product. Yet since they cannot see enough information to reverse engineer the product, the supplier’s IP remains protected.

Finally, another challenge to creating a sustainable supply chain is the lack of defined business models for motivating brands to become more sustainable and align their supply chains with this goal. Most of the examples we discussed in Section 2 highlight forward-thinking companies, such as Taylor Guitars, Dell, and Patagonia, which took initiative on their own to make their supply chains more sustainable. Such efforts are more the exception than the rule, with many companies still treating sustainability as an operational constraint. Further incentives are needed to ensure that (i) price and quality are not the only drivers of supply chain performance, (ii) brands take responsibility for their reverse supply chains, and (iii) sustainable practices and information are shared freely between supply chain partners. As regulations are often uncertain, highly dependent upon politics, enacted very slowly, or oriented more towards stopgap measures than to long-term change, they can be unreliable and limited in their ability to drive foundational changes within industries. Instead, any shift towards sustainability in the mindset of a company or industry will require commitment from the organization’s leadership and a view that sustainability is not just a standard to be met but is rather an essential input into the organization’s long-term operational planning and corporate strategies. Such a change also means that when a company makes sustainability-related decisions, it should reach beyond the bottom line and customer demands to consider new market opportunities and a broader set of stakeholders.

4. Conclusion and Future Research Directions

In this paper, we revisit the definitions of agile, adaptable, and aligned supply chains in light of the additional capabilities needed for social and environmental sustainability. To create a sustainable triple-A supply chain, companies must broaden their customer-centric approach to agility by incorporating a more diverse set of stakeholders, including activists, regulators, and employees. Firms should also innovate and adapt their processes by developing new ways to take more control of their supply chains, which can help mitigate compliance and reputational risks and potentially create new market opportunities. Finally, enabling a sustainable triple-A supply chain requires alignment, meaning that there is a shared understanding and commitment from all entities in the supply chain, including upper-tier suppliers, consumers, and the reverse supply chain. As such, visibility and transparency are vital to ensuring alignment of sustainability goals across the extended supply chain.

There are many opportunities for operations management research on sustainable triple-A supply chains. For example, while substantial research on the reverse supply chain has focused on reverse logistics (e.g., Dekker et al. 2010) and product design choices (e.g., Gui et al. 2018, Huang et al. 2019), many of these works are cost-driven and process-focused (e.g., on the collection process). Opportunities therefore exist to apply the same exploratory questions used to
examine the forward chain to reverse contexts, which will help researchers better understand what is needed to create a sustainable triple-A reverse supply chain. Potential research topics include responsiveness to social and environmental responsibility violations as well as to demand disruptions in the secondary market (agility), developing structural hierarchies (e.g., integration, control, or delegation) for waste management services (adaptability), and creating transparency and improving coordination through audits and technologies such as blockchain (alignment).

The reverse supply chain must also be studied in conjunction with the forward chain. Alignment of forward and reverse supply chain decisions could be aided by research that studies the interactions between up- and downstream agents, such as suppliers, manufacturers, consumers, collectors, and recyclers. Such work would further illustrate the agility required for the reverse supply chain to support the forward chain. Research into the reverse supply chain would also deal with closed-loop business models and frameworks, which are necessary for sustainable triple-A supply chains (e.g., Ferguson and Souza 2010, Souza 2013, Agrawal et al. 2019). An examination of business models that connect the forward and reverse supply chains would guide the structural and infrastructural changes required for circularity. These models could help to map potential conflicts between chain partners, which can undermine alignment, and trade-offs between sustainability goals, which can inhibit agile responses to different stakeholder demands.

As discussed in Section 3, establishing and maintaining a sustainable triple-A supply chain requires a firm to gain a deeper understanding of the issues occurring in the upper tiers of its supply chain. Monitoring and engaging with upper-tier suppliers in a global supply chain is difficult and requires extensive effort on a brand’s part, and the associated resource requirements cannot be understated. The challenge for companies is then to find ways to either gain control of monitoring and engagement activities or formulate innovative ways to delegate them. While a growing body of work investigates sustainability issues in multi-tier contexts from both empirical (e.g., Wilhelm et al. 2016, Soundararajan and Brammer 2018) and analytical modeling approaches (e.g., Huang et al. 2020, Karaer et al. 2020, Zhang et al. 2020), more research on multi-tier supply chains is needed.

From an upstream perspective, opportunities exist to examine collaboration between horizontal competitors (e.g., industry associations), disruptive supply chain design innovations (e.g., vertical integration), and innovative ways to improve suppliers’ capabilities. Downstream, a broader study of the role consumers play in sustainable triple-A supply chains could help to further illustrate the link between sustainability practices and market performance. Both of these perspectives could then help to shed light on adaptability issues in sustainable supply chains.

The study of the extended supply chain should not be limited to buyer and supplier interactions. Highlighting the role of external stakeholders such as nonprofits and regulators in shaping the sustainability performance of upper-tier suppliers would provide the operations management literature with a more holistic view of sustainable supply chains. Such work would also help to illustrate the new forms of agility necessary to maintain a sustainable supply chain.
Finally, we identified *increased transparency* as critically necessary for improving the sustainability performance of supply chains. Creating a transparent supply chain requires a company to gain visibility into suppliers’ practices and disclose to consumers what is happening in its supply chain (Sodhi and Tang 2019). The study of disclosing sustainability information and making it public is an emerging topic within the operations management literature (e.g., Buell et al. 2019, Buell and Kalkanci 2020, Kalkanci and Plambeck 2020). Still, opportunities exist to understand this dynamic further. For example, it would be valuable to study how technologies like blockchain influence consumers’ awareness of and preferences for sustainability. Conversely, testing the implications of disclosure on upstream suppliers’ decision making could provide helpful insights into suppliers’ behaviors and motives.

Visibility has also become an important topic in the sustainable operations management literature. Research has examined ways to increase visibility into supply chains and make decisions under incomplete visibility (Plambeck and Taylor 2016, Chen and Lee 2017, Caro et al. 2018, Kraft et al. 2020). Improved visibility can help align the sustainability goals of a supply chain, increase a firm’s agility and improve its response to incidents, and enhance a firm’s ability to adapt and innovate processes in its supply chain. While technology and digitization can improve visibility and transparency, technology adoption within supply chains may be slow and incomplete. Thus, research on how to accelerate the adoption of technologies to improve supply chains’ sustainability performance would be useful. Such work could investigate various operational challenges such as heterogeneous users (e.g., brands and farmers), critical mass requirements, and user incentives.

Professor Lee’s landmark work on triple-A supply chains has influenced researchers, curricula, and practicing managers worldwide. The concepts he introduced 16 years ago remain valid and valuable in tackling supply chain challenges. We build on his work by revisiting the definitions of agility, adaptability, and alignment in a nuanced way that considers the new demands of social and environmental sustainability. By combining the original definitions with a broader set of stakeholder pressures, innovative approaches for developing and controlling supply sources, and an expanded view of alignment, the triple-A supply chain concept can provide a framework that helps firms tackle the growing challenges that sustainability and circularity present to their supply chains. Accordingly, sustainable triple-A supply chains will create opportunities for new research directions in the operations and supply chain management literature.

**Acknowledgments:** We would like to thank Dr. Vishal Agrawal (Georgetown University), Dr. Khaled Soufani and Lidia Betcheva (Cambridge Judge Business School), and Dr. Chris Tang (UCLA Anderson School of Management) for their valuable comments and suggestions on earlier versions of this paper.
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