When Triple-A Supply Chains Meet Digitalization: The Case of JD.com's C2M Model

Ho-Yin Mak *

Saïd Business School, University of Oxford

Zuo-Jun Max Shen †

Department of Industrial Engineering & Operations Research

University of California at Berkeley

Abstract. The Triple-A supply chain (Lee, 2004) has become one of the most influential concepts for practitioners and researchers in supply chain management. It stipulates that supply chains should strive to improve along the dimensions of agility, adaptability, and alignment, as opposed to focusing exclusively on cost and efficiency improvements. While various strategies have since been adopted across different industries to foster the Triple-A, the digitalization movement poses both new challenges and opportunities for developing Triple-A supply chains. In this article, we shall discuss an emerging mode of supply chain innovation, known as the consumer-to-manufacturer (C2M) model, and how it enables new possibilities for achieving Triple-A "digital" supply chains. C2M establishes digital links between end consumers and upstream manufacturers and product designers, and provides a variety of tactics to shorten the information flow process of the supply chain. Our discussion focuses on the implementation of C2M at JD.com, a leading online retailer in China.

Keywords. Consumer-to-manufacturer, Triple-A supply chain, Digitalization, Agility, Adaptability, Alignment, Online retail

1 Background

In his seminal Harvard Business Review article, Lee (2004) identified the Triple-A supply chain as the Holy Grail of supply chain management and the driver of sustained competitive advantage. Since the publication of the original article, significant advances have been made in the theoretical understanding of the

*Email: ho-yin.mak@sbs.ox.ac.uk

†Email: maxshen@berkeley.edu

essential attributes of Agility, Adaptability, and Alignment (the Triple A's), as well as strategies to achieve them in practice. While the Triple-A concept remains timeless, the business landscape has transformed over the past decade and half, and thus the three A's now intersect with a much different set of strategic considerations than in the early 2000's. Notably, supply chain executives now place a strong emphasis on subjects such as sustainability, resiliency, and digitalization. This article discusses the intersection of the triple-A concept and digitalization. In particular, we shall discuss the implications of innovative strategies, underpinned by digital technology and big data, that enable firms to achieve the three A's in ways that were not possible in the 2000's. The discussion will build on the concrete example of JD.com's consumer-to-manufacturer (C2M) platform.

The 2020's will be remembered as the era of digital technology, big data, and artificial intelligence. Take the retail industry as an example. Two decades ago, supply chain planning decisions were largely supported by sales data and forecasts at the (geographic) regional, quarterly, (product) categorical, and brand levels, which were not always digitalized. Today, retailers possess much more granular and precise data at the individual consumer and product levels in real time, not only on purchases, but also searches and clicks (on online stores), and views, follows and likes (on social media); in addition to a wealth of contextual data, ranging from demographic information, social network connections and past purchase history of consumers, to specific product attributes (down to the pixel level of product images). Employing contemporary machine learning tools, retailers are now able to identify complex relationships between product and consumer attributes, and purchase behavior. These insights can help firms make better informed planning and operations decisions along the supply chain, from product design to manufacturing, and from sales and fulfillment.

A core tenet of supply chain management is that material and information flows (as well as financial flows) are equally important and must be carefully coordinated. Traditionally, such coordination is reflected through the strategic choice between push and pull processes. Push-based supply chains favor scale economies and planning efficiencies that lead to cost reductions, at the expense of lower agility, as the forecast-driven production and distribution planning fails to take advantage of evolving demand information. Pull-based supply chains are demand-driven, but may suffer from cost inefficiencies (e.g., due to small production batch sizes) and longer lead times. Lee and Tang (1997) suggest that delayed differentiation, i.e., deferring the stage of the supply chain after which work-in-process/ products assume their unique identities and thus lose substitutability, enables a push-pull structure that can improve agility without jeopardizing cost efficiencies. They propose to achieve this with three design strategies, namely, standardization, modular design, and process restructuring (postponement). These strategies effectively define a push-pull boundary at the late-production or assembly stage – upstream to this boundary, material flow (of work-in-process inventory) is governed by a push process driven by forecasts of downstream demand; whereas flows (of finished products) downstream from the boundary are governed by a pull process driven directly by downstream needs.

Delayed differentiation of material flow helps the supply chain take advantage of updates in demand information. In the digital age, with the aid of machine learning-supported forecasting and real-time automated decision making, supply chains are able to push this concept to new frontiers. For example, Lim et al (2017) propose fulfillment network design strategies that rely upon real-time informational pooling of inventory for online retailers. Such strategies are able to simultaneously improve agility and efficiency of fulfillment operations. More generally, Acimovic et al. (2018) discuss how digitalization has enabled retailers to move on from the traditional trade-off between speed and price to the broader pursuit of agile supply chains. Later in this paper, we shall discuss examples of how an online retailer is able to leverage its digital platform to effectively place the push-pull boundary further upstream while maintaining operational efficiency. While globalization has significantly increased the physical lengths of supply chains since the 1990's, the latest digitalization development has countered by shortening the informational lengths of supply chains. As a result, even though material flow lead times have become longer in many cases (especially under the slow steaming development in maritime logistics, e.g., Fransoo and Lee, 2013, Lee et al., 2015), the informational lead times through supply chain stages have significantly shrunk, often to effectively zero. This important development makes way for supply chain designers to reimagine the three A's, as we shall discuss in Section 2. In this paper, we discuss an emerging supply chain paradigm known as the consumer-to-manufacturer (C2M) model, and how this novel framework, when harnessed carefully, exemplifies the Triple-A supply chain in the digital age.

C2M refers to a family of supply chain strategies based on direct digital links between end consumers and upstream manufacturers, often through e-commerce platforms as virtual intermediaries. These links enable direct consumer input on not only demand forecasts, but even for product and assortment design. In part due to the geographical concentration of manufacturers, C2M is pioneered by Chinese e-commerce platforms such as JD.com and Alibaba. However, this new paradigm has potential to make waves across the world. Conceptually, C2M is an example of *structural transformation* in supply chain management enabled by big data and digitalization capabilities (Lee, 2018).

To illustrate the C2M idea, consider the case of Pinduoduo (PDD), a Chinese startup founded only in 2015 and went public on NASDAQ in 2018. PDD's business model is often compared to Groupon's (e.g., Fortune, 2018), in that both enable consumers to group-buy products at discount prices, but with two fundamental differences. First, PDD seamlessly marries the group buying platform with social networks, and thus takes advantage of social influence in both understanding and shaping purchase behavior (e.g., a viral video on a product could turn into viral group purchases). Second, PDD employs a C2M strategy by enabling consumer groups to interact directly with manufacturers over digital media, and even order products with tailor-made specifications. This enables manufacturers to design and produce the right products with a guaranteed demand on the one hand, while engaging consumers and fulfilling their specific needs at low prices on the other.

In this paper, we shall discuss the C2M model in the context of JD.com (JD), a major Chinese online retailer often drawing comparisons to Amazon. Like the case of PDD and Groupon, JD's supply chain strategy differentiates with Amazon's in that it has much closer links with manufacturers, in part thanks to the geographic concentration in China. This enables JD to initiate a variety of supply chain innovations and implement them through the entire supply chain. In Section 2, we shall first briefly review the Triple-A concept and how it has evolved in practice in the digital age. Then in Section 3, we shall outline the elements of JD.com's C2M initiative and how it fosters the three A's. Finally, in Section 4, we shall provide specific examples to highlight how these strategies work in practice.

2 Triple A Supply Chains in the Digital Era

The concept of the three A's have transformed significantly in the past one-plus decade. We shall briefly review the concepts of agility, adaptability and alignment as introduced by Lee (2004), and discuss how these pursuits have evolved under the rapidly changing business landscape. In particular, Lee (2004) discussed supply chain strategies of various firms in the 90's-00's period that intersected with the strategic imperatives at the time, including outsourcing and offshoring; as well as provided great foresight into the importance of the internet and digital technology in building sustained supply chain excellence (see, e.g., Johnson and Whang, 2002, for a discussion of key operations issues in the early phase of e-business). We shall build on these insights by drawing connections to modern digital technologies.

2.1 Evolution of Agility

Lee (2004) defines agility as the ability to *respond to short-term changes in demand or supply quickly, and to handle external disruptions smoothly*. To enable agility, it is essential for a supply chain to carefully integrate the management of material and information flow. As soon as changes in demand/supply status are detected at any stage, the supply chain must be able to quickly and transparently share such information with other stages, and come up with quick maneuvers in response, such as changing production plans, rerouting shipments, repurposing capacity across products, and so on. Such responses necessitate collaborative relationships and willingness to share (often proprietary) information across stages of the supply chain.

Careful and coordinated choice of product and supply chain network designs is integral to fostering agility. Lee (2004) discussed the successful example of fast fashion companies like H&M and Zara, and the less successful example of Compaq. In fast fashion, time-to-market time is minimized from the product design stage. Designers start ordering fabric even before the designs are finalized, to mitigate long supply lead times; once reliable sales and demand data from stores are shared upstream, they quickly finalize designs and production plans. In the case of Compaq in the 90's, a long design cycle combined with a long supply pipeline led to rigidity as demand for new products evolved, and eventually lost market share.

Lee specifically pointed out delayed differentiation as a key implementation strategy for agility. Product and supply chain designs with delayed differentiation enable firms to quickly reroute or repurpose supplies as demand information evolves over time. Lee and Billington (1995) and Feitzinger and Lee (1997) discuss the (now) well-known case of Hewlett-Packard employing the postponement strategy to vastly improve the agility of its printer supply chain. More generally, Lee and Tang (1997) model the cost-agility trade-off of delayed differentiation in a supply chain, which can be achieved through postponement, standardization, or modular design. With these strategies, the segment of the supply chain downstream from the point of differentiation can be reconfigured as a highly-responsive pull process, which empowers agility.

In the digitalization era, shortened product life cycles and fickle consumer tastes call for supply chains to become more agile than ever. Fortunately, data analytics and digital platforms offer new ways to implement agility. Lim et al. (2017) discuss a distribution network design framework that enables online retailers to embed agility into fulfillment operations. By integrating advanced demand forecasting, real-time sharing of demand and inventory data, and nimble allocation of fulfillment routes, an online retailer is able to perform virtual pooling of inventory across geographically-dispersed facilities, and thereby achieving agility without jeopardizing efficiency. While this strategy maintains the push-pull boundary at the fulfillment stage, the pull-based fulfillment logic expands horizontally across the geographically-dispersed fulfillment network, which unlocks agility.

Digital platforms have also unlocked new possibilities for supply chains to extend agility further upstream, by integrating the manufacturing and product design functions. JD utilizes its consumer data at the retail level to learn and predict changes in consumption trends, feeds such forecasts digitally through its supply chain, and engages partners at different stages of the supply chain to take coordinated action. Thus, new products (or modifications to existing products) are developed, manufactured and distributed to meet new demand agilely. We shall discuss this further in Sections 3 and 4.

2.2 Evolution of Adaptability

Lee (2004) framed adaptability as the ability to *adjust a supply chain's design to meet structural shifts in markets*, and to *modify supply networks to strategies, products, and technologies*. In contrast with agility, which pertains mainly to the tactical- and operational-level decisions, adaptability is a strategic-level attribute of a supply chain. In the late 90's to early 00's, a key strategic consideration of many supply chains was whether to offshore production to lower-cost countries (often China), and to expand sales to emerging markets. The companies who were able to capitalize on these structural shifts were those with the adaptability to deftly pivot their strategic supply networks. Key to enabling adaptability is to develop awareness of strategic and technological shifts, the changing needs of end consumers, as well as the alignment of product and technological cycles. To implement adaptive strategies, a supply chain must build relationships with suppliers and partners (including intermediaries) with access to a wide range of markets and manufacturing/logistics bases, and be flexible in product designs.

Even at the relatively early stage of e-commerce, Lee (2004) already pointed out the importance of learning from data in uncovering these structural shifts and taking corresponding action. He discussed the example of Microsoft's (and contract manufacturer Flextronics') launch of Xbox in 2001, where the supply chain quickly shifted from the strategy of manufacturing close to key markets (in Mexico and Hungary), which favored time to market, to one of offshoring to China to squeeze out cost savings. The key was Microsoft's observation that the competitive priority shifted from speed to cost, and its adaptability in swiftly changing course.

Digitalization has posed both new challenges and opportunities for supply chains to explore novel adaptability strategies. On the one hand, the breadth and depth of market and consumer data made available by digital platforms, together with advanced machine learning tools, equip firms with unprecedented capabilities to detect and predict structural trends in markets as (and even before) they happen; On the other hand, these capabilities are now largely democratized and thus those who fail to capitalize them to respond and adapt to market shifts will be left behind. A prime example is Netflix, who started as an online DVD rental by mail service that competed with Blockbuster. While its original subscription-by-mail supply chain motivated interesting operations innovations (e.g., Bassamboo et al., 2009), it detected the structural shift of the entertainment market moving toward digital delivery. Starting from 2007, it shifted its focus from the physical DVD rental system to the online streaming model, which delivers the same entertainment content to consumers through a completely virtual supply chain. This drastic supply chain overhaul, from physical to fully virtual, was enabled by Netflix's strategic adaptability attributed to its digital prowess.

In physical supply chains, digital capabilities also enable supply chain networks to adapt to structural changes in ways not possible before. The network redesign effort of LEGO in the early 2010's may serve as an example. With its production capacities traditionally concentrated in Europe, LEGO faced challenges in meeting its strong demand growth in Asian and North America, due to long lead times. To address this structural problem, LEGO redesigned its global network and added new plants in China and Mexico to specifically serve the Asian and North American markets. The vital companion to this physical redesign is its concurrent investment in digital and data analytics capabilities that enable LEGO to quickly adjust production plans to evolving demand forecasts. Without the digital component of this redesign strategy, LEGO would not be able to take advantage of the reduced production lead times of the redesigned network.

2.3 Evolution of Alignment

Lee (2004) described alignment as the ability to *create incentives for better performance*. This refers to aligning incentives of different players in the supply chain to ensure that every stage optimizes its operations under the common objective of maximizing supply chain's (rather than each stage's) performance. Besides aligning objectives, Lee also emphasized the importance of sharing knowledge and information freely among parties in the supply chain, a practice particularly important in the digital age.

In the supply chain operations literature, various mechanisms and contracts have been proposed and implemented to achieve alignment (see, e.g., Cachon, 2003 and Lariviere, 2016). These mechanisms aim to align the objectives of different stakeholders along the supply chain such that they benefit from improving the supply chain's overall performance rather than from marginalizing each other. Besides using operational contracts as an alignment device, the topic of supply chain financing is also key. In particular, careful use of instruments such as trade credits (see, e.g., Yang and Birge 2018) can help foster alignment by reducing the financing costs of smaller players.

Alignment can often be achieved through the use of supply chain intermediaries. In the pre-digital age, intermediaries (such as Li & Fung in the textiles industry) were important in providing financing (due to their lower capital costs) and facilitating trust between supply chain parties. In the digital age, intermediaries often take the form of digital platforms. A prime example is Chinese e-commerce giant Alibaba, runs the world's largest (by transaction volume) online shopping marketplace Taobao. Following Alibaba's asset-light business model (Taobao does not own products sold on its platform, but instead facilitate transactions between consumers and independent sellers), distribution and fulfillment operations for Taobao are handled by third-party logistics providers (3PLs). To improve alignment of the downstream supply chain, Alibaba launched the Cainiao smart logistics platform. The platform operates as a "digital control tower" to coordinate the distribution and fulfillment process. While the fulfillment process typically involves multiple independent players (seller and one or multiple 3PLs), the platform aims to ensure tight digital integration between the logistics and e-commerce platforms to achieve high efficiency and agility. This model contrasts sharply with JD's model of (downstream) vertical integration, where the online retailer owns much of the distribution logistics infrastructure.

3 Consumer-to-Manufacturer (C2M) Model

The prevalence of digital technologies and the rise of a new generation of digital-savvy consumers have posed novel challenges for supply chain executives. Influenced by social networks and digital media, consumer preferences and demand are evolving and proliferating at unprecedented pace. As consumer experiences become visible and shared rapidly over social networks, it is now as critical as ever for supply chains to uphold their service levels and meet consumers' needs. This calls for high levels of agility and adaptability, as supply chains must respond to both fluctuations and structural shifts quickly and even proactively, as well as alignment, as information from end consumers must pass through the entire chain quickly and for the chain to take coordinated action. The C2M model provides a novel framework for supply chains to build a direct link between the final consumers and the upstream production stage.

In this section, we discuss the implementation of JD's C2M platform (referred to as JC2M hereafter). JD's core vision in supply chain innovation is that future supply chains will be fully demand driven under a pull logic, rather than production driven under a push logic. To build demand-driven supply chains with high service levels, digitalization is vital. Like other leaders in online retail (such as Amazon), JD has invested heavily in digitalizing its downstream operations, e.g., forecasting, pricing, sales, distribution and reverse logistics. In addition, its proximity to the Chinese manufacturing base has enabled it to integrate and digitalize the upstream operations of its supply chain, in ways often inaccessible to its Western counterparts. This setup enables JD to build digital links between downstream sales operations and upstream manufacturing and integrate the chain seamlessly. The JC2M platform enables JD to reengineer its supply chain, switching away from traditional production-driven configurations toward demand-driven ones.

JD is China's largest retailer and largest internet company by revenue ($83.4 billion in 2019, Forbes, 2020). As of June 30, 2020, JD had 417.4 million active users, and recorded a 29.9% year-on-year growth rate. In June 2020, JD.COM's average daily active mobile users increased by 40% year on year (JD.com, 2020). This massive user and transaction volume empowers JD with two distinct advantages. First, it gives JD the scale economies it needs to operate the supply chain efficiently, as well as the leverage to push innovations through the supply chain. Second, it provides JD with a wealth of consumer preference and behavior data that informs its digital supply chain innovations, particularly under the C2M framework. Figure 1 illustrates the conceptual framework of the JC2M model, where bold and line arrows represent material and information flow, respectively. Below, we shall discuss how this conceptual framework is embodied by the four core functions of JC2M model, and how these functions help enable a digital, triple-A supply chain.

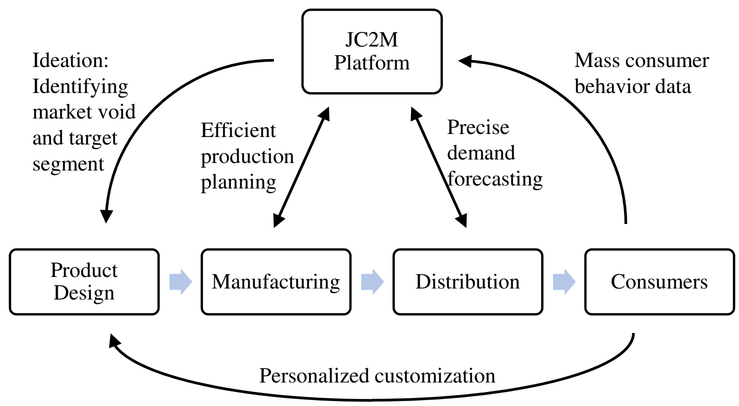

Figure 1: Conceptual Framework of the JC2M Platform

3.1 New Product Design and Simulation

The new product development process (Krishnan and Elrich, 2001, Kavadias and Elrich, 2020) involves the firm identifying and/or anticipating an unfulfilled need of consumers or a void in the competitive market. The JC2M platform helps manufacturers accomplish this through a digitalized process. First, through machine learning on its massive user data, JD is able to identify combinations of product attributes with unfulfilled potential. While this concept is not entirely new, what makes JD's approach unique is that its models are able to produce four-dimensional recommendations for product design: potential product styles/attributes, potential price points, potential buyers, and potential sales forecasts. That is, in uncovering an opportunity for a new product design, the manufacturer already knows how much to sell it for, whom to sell it to, what volume (and when) it expects to sell, and how to market it.

This process greatly reduces the need for trial and error in the product design process, which leads to lower product development costs and streamlined development and planning cycles. With the support of the JC2M platform, brands have been able to reduce their product demand research time by 75% and shorten their new product launch cycle by 67%. What's more, the platform gives the supply chain a massive head start once the product design is adopted by a manufacturer, as plans for production, pricing, and distributions can be derived digitally according to these systematic forecasts. JD also leverages this "reverse product development" process to deepen its collaborative relationships with upstream brands and manufacturers, thereby gaining access to better-quality, customized products, more favorable purchasing costs and marketing resources.

Besides big data analytics, the JC2M platform also engages in "small data" studies to gain insights into new product releases. Ahead of product launch, JD is able to pinpoint specific target consumer groups and roll out simulated product trials (e.g., A/B testing). Feedback from such small-scale but highly-targeted experiments help JD to gain deeper insights into purchase behavior and consumer preferences with regard to the new product, validate demand and pricing predictions, and to optimize the purchase experience.

Compared with conventional processes, the C2M reverse product development framework offers potential to strengthen the supply chain along the adaptability and alignment dimensions. First, leveraging its massive online transaction volume to learn consumer trends, JD gains the key capability to detect (nowcast) and forecast structural shifts in consumer needs. The C2M framework enables these insights to penetrate through the entire supply chain in real time. As a result, JD is able to react to these changes not only by adjusting its consumer-facing operations, but by bringing new products to market. With a high degree of alignment through digitally-coordinated operations across firm boundaries, these new products reach consumers promptly. Through feeding end-consumer insights directly to manufacturers, JD also provides strong incentives for manufacturers to coordinate its development, production, and marketing efforts with downstream players, thus strengthening alignment of the supply chain.

3.2 Targeted Product Trials

Product trials are a must in today's marketing campaigns. They facilitate communication between manufacturers and consumers – the former learns about consumers' preferences and feedback on products, and the latter learns about features and value of the manufacturers' offering. Trial campaigns are crucial in both attracting new customers and retaining existing ones. Due to the expensive nature of product trials, they must be directed to the optimal audience to maximize returns.

JD's product trial platform aims to precisely identify target consumers for trial campaigns. Based on past consumer purchase data, JD is able to label consumers based on user background (user portrait), purchase behavior (behavior portrait), and their affinity for related product categories and brands. A key innovation of JD's product trial platform is that it integrates supply chain operations into planning of product trials. For example, in selecting target customers by geographical location, the platform evaluates not only the conversion and learning potential for the target geographical market, but also the logistics implications (i.e., stock availability in distribution hubs, shipping costs and lead times). Manufacturers can also monitor the distribution of trial products on the platform in real time, as well as detailed, multidimensional feedback on customer conversions.

Integrating marketing and operations considerations in product trials efforts have two important implications. First, this ensures cost consciousness in the selection of target customers to maximize not only effectiveness, but also efficiency, of consumer acquisition. Second, this enables both customers and manufacturers to learn about not only the product-customer fit, but also the entire purchase experience. For example, Luo et al. (2020) find that, on online retail platforms, the quality of logistics services can significantly alter consumer demand. Such insights into the purchase experience, in addition to the product itself, provides yet another opportunity for the supply chain to enhance its alignment dimension.

3.3 Personalized Customization

Perhaps the most salient feature of the C2M model is that it enables an end-to-end "pull" process through the entire supply chain, from product design to end consumers. Modern (especially Gen-Y and Gen-Z) consumers tend to value both product quality and personalization. This poses a tough test on a supply chain's agility, as consumers expect their personalized needs to be met swiftly. The JC2M platform addresses this by a personalization service that enables consumers to place customized orders directly with manufacturers, and ensures manufacturers fulfill these orders responsively and efficiently. The service provides system tools to support customization orders in both B2C and B2B scenarios, such as customization of product attributes and product volume, as well as customization for enterprise customers.

Traditionally, the make-to-order system tends to be a niche supply chain configuration only applicable to limited product categories. While the advantages of the make-to-order model, i.e., better match of consumers' needs and reduced reliance on demand forecasts, are obvious, so are its shortcomings, including long lead times. Digitally-integrated supply chains have found new ways to overcome these shortcomings. In the case of the JC2M platform, big-data-driven forecasts underpin operations planning at every stage of the supply chain. Even in a make-to-order setting, this integrated planning process prepares both upstream manufacturing (e.g., planning of work-in-process inventory) and downstream distribution (e.g., scheduling of shipment lots) ahead of order placement, and streamlines operations by dynamic allocation of production and shipping capacity in real time. This capability allows the supply chain to vastly shorten lead times, once orders are confirmed.

Conceptually, the integration of digital forecasting and planning equips the supply chain with high digital agility that enables the make-to-order system to work as efficiently as a make-to-stock system, but with more flexibility in product configuration. This digital agility is conceptually analogous with the virtual pooling concept in fulfillment networks studied in Lim et al. (2016). In both cases, digital coordination of operations across the boundaries of facilities and supply chain stages enables them to operate as one virtual entity, thus achieving quick response to customer demand as well as efficient operations.

3.4 Smart Factory

Smart manufacturing builds on key digital technologies in the Industry 4.0 movement (Olsen and Tomlin, 2020), including the Internet-of-Things (IoT), artificial intelligence, additive manufacturing and automation. In a digital supply chain, it is vital to extend smart control beyond the factory boundaries through the span of the supply chain. One of the core services of JC2M is its smart factory platform that integrates digital production planning with the rest of the supply chain.

The primary aim of the smart factory platform is to leverage digital integration to achieve intelligent control of rapid-response, low-inventory, efficient small-batch production operations. It provides services such as product quality management, factory production docking, supply chain collaboration, capacity pre-sales, order aggregation and order dispatching. The front end of the smart factory platform provides consumers with a variety of customization purchasing scenarios to meet the diverse, personalized and customized shopping needs; whereas the back end coordinates the upstream processes to respond to demand quickly, following a pull-type supply chain model.

The use of the smart factory platform to integrate operations of the supply chain can be considered digitalized extension of the supply chain intermediary strategy discussed in Lee (2004), which is key to fostering alignment. It is known in the literature (e.g., Belevina and Girotra, 2012) that intermediaries provide transactional benefits (by improving efficiencies such as lowering financing costs and aggregating orders to achieve economies of scale) and informational benefits (i.e., aggregating information from different parties to inform better planning) to the supply chain. In addition, Belevina and Girotra (2012) further show another benefit of intermediaries such as Li & Fung in the apparel industry: by pooling the sourcing needs of multiple buyers, it is able to align the supply chain by providing sourcing commitments to suppliers, while at the same time responsively adjust its supply base. The smart factory platform achieves similar benefits using a novel innovation known as capacity pre-sales – it allows the platform to pre-commit to purchasing production capacities from manufacturers in advance of actual orders. This model helps create a pull process with quick response time and low finished inventory requirements, and streamlines supply chain financing (especially with small manufacturers).

4 Successful Cases of JC2M

In this section, we shall discuss several successful cases of JC2M, spanning a range of product categories. In each case, the four core services of JC2M enable the supply chain to identify new trends or opportunities in the market, and to address customers' needs in an agile, adaptive, and aligned manner.

4.1 Home Refrigerators

As discussed in Section 3.1, JD leverages its massive consumer data and machine learning technologies to generate proposals for manufacturers to develop, upgrade, and customize their products. This helps the supply chain respond agilely to meet ever-changing consumer needs.

Recently, JC2M completed a market study on the customization of new refrigerators, in collaboration with a household appliance brand. Through mining JD's transaction data, the study highlighted a number of key insights into the refrigerator market. In particular, though the market has enjoyed stable growth in volume, consumer demand is drifting toward upgraded specifications and lower price points. Strong consumer preferences are detected for four aspects of specification upgrade: in exterior design/style (e.g., preference for multi-door designs and stainless steel panels), capacity (e.g., 300L and above), energy rating, and refrigeration mode (e.g., air-cooled systems). Meanwhile, JD found that average consumer spending on refrigerator products declined from the previous year, and unit prices are moving toward the middle range. Geographically, the market is concentrated in Tier-one and Tier-two cities of China. Due to smaller living spaces in Tier-one cities (e.g., Beijing and Shanghai), the demand for high-capacity (exceeding 300L), multi-door units is relatively small; whereas demand for such units is high in cities with lower housing costs. There is also a growth in demand for customized upgrades such as intelligent control, micro-crystallization, odor purification and wet/dry storage.

In view of the aforementioned market trends and with the brand's existing product offering, JC2M recommended redesigning the product line to capture the high potential market segments, namely, high-capacity (501-600L) and medium-capacity (301-400L) models with side-by-side doors, and small-capacity three-door models, featuring first-rate energy efficiency, intelligent control, micro-crystallization, odor purification and wet/dry storage. Since the launch of these new products, sales figures of the brand in June reached six times the category average.

4.2 Ultrawide Monitors

Adaptability and alignment help supply chains to weather fluctuations in volatile consumer markets. In today's digital landscape, these two attributes are deeply intertwined, and both rely upon in-depth collaborations among supply chain players, from retailers and distributors to manufacturers and component suppliers. In the case of JD, these relationships enable the retailer to coordinate with key partners and take collaborative actions to address market changes, and even transform these challenges into opportunities to deliver new growth. We shall discuss an example based on the supply chain of ultrawide (21:9) monitors.

Until recently, the market of ultrawide monitors was monopolized by a single major brand, resulting in high prices and unmet consumer demand. JD's market research has identified a brand new market for monitors, the population of gamers, who is showing rapidly-growing demand for ultra-wide curved-screen monitors. To address this emerging market, it was crucial to assess the supply chain's capability to deliver such a new product category. In particular, the key technological component is the LED screens. These screens are manufactured in large panels and then cut to specific sizes, a process that leads to significant cutting wastes. In researching manufacturing capabilities, JD collaborated with LED screen manufacturers and devised a novel solution to the problem of making 21:9 screens with minimal cutting waste, by providing an efficient solution to the difficult two-dimensional cutting stock problem (Gilmore and Gomory, 1965). This further enabled JD and the screen manufacturer to cater specifications to user needs and determine pricing levels. Thus, the identification of a downstream market shift has driven innovation in the far-upstream component manufacturers. This would not be possible without a digital supply chain integration infrastructure like JD's. Concurrently, to bring the products to market, JD collaborated with a number of monitor brands to test product designs and configurations. The screamlined development and testing processes enabled the products to be launched in accelerated cycles. This helped the brands gain significant market shares as new entrants, and even establish pricing power over the market incumbent.

The ultrawide monitor example showcases how an aligned and adaptive supply chain is able to speed up the new product development and launch cycle. Under the traditional supply chain model with serial development processes, it would take six months to develop new screen panels, four months for the OEM to manufacture and deliver the monitors, and an additional two months for the brand owner to ship the final products to the retailer. In the digitally-aligned supply chain, however, these processes occur in parallel. As the screen manufacturer makes the screens, the OEM develops the mold for the monitor synchronously, while the brand owner applies for product qualification, and the retailer launches the advertising and pre-sale campaign simultaneously. This effectively shortens the time-to-market from over twelve months to about six months. Thus, digitally-enabled alignment also enables the supply chain to be adaptive (in changing its production configuration) and agile (in bringing products to market quickly).

4.3 Laundry Detergent Pods

The next example, involving laundry detergent pods, showcases a product innovation driven by supply chain motivations, and enabled by sound understanding of consumer needs and preferences.

Laundry detergent pods, while quite common in Western markets, are relatively new to the Chinese market. In its analysis of the market of laundry detergents, JC2M found that the product category has been a loss leader despite strong (40% year-on-year) growth. Through analyzing the supply chain, JC2M identified the high logistics costs, due to the bulky nature of the liquid-form products, as a major reason. On the other hand, market intelligence revealed that consumers for laundry detergent are primarily interested in product functionality and show little preference over product form. Thus, laundry pods, with compact packaging, show promise as an emerging product.

As discussed in Section 3.1, JC2M aims to identify potential product attributes, potential price points, potential buyers, and potential sales volume for new product recommendations. For laundry pods, based on user behavior data from JD, the platform produced the representative user portrait: young white-collar workers engaged in social media platforms such as Douyin (the Chinese version of TikTok) and Xiaohongshu. Based on this, JC2M estimated that 30% of the detergent sales volume could switch to laundry beads, suggesting a potential market 15 times its existing size. Based on this recommendation, JC2M carried out product simulation trials with targeted consumer groups to test the possible responses to alternative price bands.

Once the new product recommendation was adopted, JC2M carefully engaged with manufacturers in choosing product attributes with potential demand implications, such as concentration, shape, color, packaging and logistics, and analyzed cost accounting for different stages of the supply chain. To better segment the market, JC2M created a low-end generic product with the detergent manufacturer, and a high-end product in cooperation with established brands. The results were promising: the first three laundry pod products launched quickly ranked among top ten in sales of laundry products, and the market share of laundry beads soared from 3% to 8%. Overall, the new product category recorded high sales growth (198% year-on-year) and net positive margins.

5 Discussion and Conclusion

The digitalization movement has unlocked myriad innovations in supply chain management practice. Revolutionary technologies, such as smart-phone-based retail, mobile payment, machine learning and artificial intelligence, automated manufacturing, industrial IoT have moved from nascent to ubiquitous in the span of a few years. With adoption of every new technology, some conventional supply chain management practice becomes obsolete. As our community strives to develop new theory that inform our understanding of these advancements, we shall also revisit the foundational concepts, such as the Triple-A supply chain, that remain timeless but are embodied in new forms.

By drawing digital links from end consumers to manufacturers (and through the intermediate supply chain), the C2M concept enables inventive strategies to accomplish the three A's: agility, adaptability, and alignment, some of which were unimaginable just a couple decades ago. In theory, C2M prepares the supply chain to operate as an end-to-end pull process that responds to consumers (changing) needs while maintaining high efficiency and speed. This can be the start of a paradigm shift – while the traditional push-based supply chain epitomizes the conventional firm-centric philosophy of business, a truly pull-based supply chain is a move toward a consumer-centric model that provides solutions to consumers' problems.

Thus far, C2M is pioneered by Chinese tech companies like JD, Alibaba and PDD. These firms are in a somewhat unique position due to their geographical and industrial proximity to massive consumer markets as well as manufacturing base. This is not to say that C2M is an exclusively Chinese strategy. About a decade ago, LEGO offered a make-to-order service, known as LEGO Design byMe, which allowed consumers to create their own LEGO sets digitally with a software and order them. The program was discontinued in 2012 due to operational inefficiencies of the make-to-order process. LEGO now offers a different program, known as LEGO Ideas, that solicits digital design ideas from consumers. Instead of allowing consumers to order these sets, LEGO allows other consumers to vote on them, and produce only the most popular sets. This strategy retains the consumer-driven design element of the Design byMe program, but overcomes its operational efficiency, since the voting system serves as a filter that assures a high-enough demand volume for the designs selected for production. While these strategies are rather unique to the case of LEGO, who operates a vertically-integrated supply chain from product design to retail, they showcase that non-Chinese and non-retail supply chains can also benefit from C2M innovations.

Recent events, including the COVID-19 pandemic, have caused firms to rethink their global supply chain network design, and it is plausible that future supply chains will at least partially diversify away from the current high concentration in the East Asia region. At the same time, the Chinese tech giants are also seeking to expand their e-tailing businesses globally. Therefore, we expect C2M to become a truly global phenomenon in the coming years. This will bring about new challenges, as the increased geographical distances (longer physical lead times) and consumer cultural heterogeneity (difficulty to forecast demand) will be important obstacles to overcome in C2M operations.

The technology further progresses, the theory and practice of supply chain management will continue to evolve in imaginative ways. For example, emerging technologies such as the Blockchain and smart contracts (see Olsen and Tomlin, 2020, for a discussion) could open up new possibilities for alignment, building on the concept of digital trust. This may, for example, pose a challenge to the intermediary business model. Smart contracts and automated manufacturing may also hold the key to fostering digital agility, as orders and transactions can be completed and verified digitally without human intervention. Thus, the legacy of Hau Lee's Triple A supply chain will continue to inspire practitioners and researchers in supply chain management in the years to come.

Acknowledgements

The authors are grateful to Professor Hau Lee and Professor Chris Tang (special issue editor) for their insightful feedback, which helped improve this paper. The authors also thank Mr. Chen Lin (JD Intelligent Supply Chain Y Business Unit leader), and JD colleagues Hao Hu, Xiaotong Wang, Longyu Zhang, Ruixue

Zhou, and Danping Liu for helpful discussions.

References

Acimovic, J., Lim, M., & Mak, H.-Y. (2018). Moving beyond the speed-price tradeoff. *MIT Sloan Management Review*.

Bassamboo, A., Kumar, S., & Randhawa, R. S. (2009). Dynamics of new product introduction in closed rental systems. *Operations Research*, *57*(6), 1347–1359.

Belavina, E., & Girotra, K. (2012). The relational advantages of intermediation. *Management Science*, *58*(9), 1614–1631.

Cachon, G. P. (2003). Supply chain coordination with contracts. *Handbooks in Operations Research and Management Science*, *11*, 227–339.

Feitzinger, E., & Lee, H. L. (1997). Mass customization at Hewlett-Packard: the power of postponement. *Harvard Business Review*, *75*, 116–123.

Forbes. (2020). *JD.com (JD).* Retrieved from `https://www.forbes.com/companies/jd/#5009783f4f20`

Fortune. (2020). *The Groupon of China Is Going Public—and It's More Expensive Than Alibaba, Snap, or Facebook's IPO.* Retrieved from `https://fortune.com/2018/07/26/pinduoduo-ipo-alibaba-facebook-groupon-amazon/`

Fransoo, J. C., & Lee, C.-Y. (2013). The critical role of ocean container transport in global supply chain performance. *Production and Operations Management*, *22*(2), 253–268.

Gilmore, P. C., & Gomory, R. E. (1965). Multistage cutting stock problems of two and more dimensions. *Operations research*, *13*(1), 94–120.

JD.com. (2020). *Press Release: JD.com Announces 2020 Second Quarter and Interim Financial Results.* Retrieved from `https://ir.jd.com/news-releases/news-release-details/jdcom-announces-2020-second-quarter-and-interim-financial`

Johnson, M. E., & Whang, S. (2002). E-business and supply chain management: an overview and framework. *Production and Operations management*, *11*(4), 413–423.

Kavadias, S., & Ulrich, K. T. (2020). Innovation and new product development: Reflections and insights from the research published in the first 20 years of Manufacturing & Service Operations Management. *Manufacturing & Service Operations Management*, *22*(1), 84–92.

Krishnan, V., & Ulrich, K. T. (2001). Product development decisions: A review of the literature. *Management Science*, *47*(1), 1–21.

Lariviere, M. A. (2016). Om forum – supply chain contracting: Doughnuts to bubbles. *Manufacturing & Service Operations Management*, *18*(3), 309–313.

Lee, C.-Y., Lee, H. L., & Zhang, J. (2015). The impact of slow ocean steaming on delivery reliability and fuel consumption. *Transportation Research Part E: Logistics and Transportation Review*, *76*, 176–190.

Lee, H. L. (2018). Big data and the innovation cycle. *Production and Operations Management*, *27*(9), 1642–1646.

Lee, H. L., & Billington, C. (1995). The evolution of supply-chain-management models and practice at Hewlett-Packard. *Interfaces*, *25*(5), 42–63.

Lee, H. L., et al. (2004). The triple-a supply chain. *Harvard Business Review*, *82*(10), 102–113.

Lee, H. L., & Tang, C. S. (1997). Modelling the costs and benefits of delayed product differentiation. *Management science*, *43*(1), 40–53.

Lim, M. K., Mak, H.-Y., & Shen, Z.-J. M. (2017). Agility and proximity considerations in supply chain design. *Management Science*, *63*(4), 1026–1041.

Luo, J., Rong, Y., & Zheng, H. (2020). Impacts of logistics information on sales: Evidence from Alibaba. *Naval Research Logistics*.

Olsen, T. L., & Tomlin, B. (2020). Industry 4.0: opportunities and challenges for operations management. *Manufacturing & Service Operations Management*, *22*(1), 113–122.

Wall Street Journal. (2013). *Predicting Holiday Sales Poses Issues for Lego.* Retrieved from `https://www.wsj.com/articles/predicting-holiday-sales-poses-issues-for-lego-1386942182`

Yang, S. A., & Birge, J. R. (2018). Trade credit, risk sharing, and inventory financing portfolios. *Management Science*, *64*(8), 3667–3689.