Chapter

Industry 4.0: The Tenets of the Next Generation of Supply Chain Management

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Abstract

The supply chain industry is at the crossroads of the business revolution through the Fourth Industrial Revolution (4IR), impacting business activities across industries. The transformative elements of 4IR offer individual consumers, corporations, and governments unprecedented opportunities to link, collaborate, process, and manage rising consumer and business data to boost decision-making, efficiency, and productivity. Evidence shows that have applied a mix of collaborative and innovative technologies to internal and external activities to manage supply chain disruptions. The groundbreaking technological advancements paved the way for the supply industry to shift supply business prototypes from traditional supply chain models to supply web models. The shift has helped firms resolve national and global supply chain disruptions. The present chapter introduces the Supply Web (SW) concept and its distinctive tenets by adding to the growing body of the evolving Industry 4.0 field, knowledge to help advance the field. The author calls on governments, the global supply industry, and academia to consider embracing the new SW paradigm evolving under 4IR to help resolve societal and consumer challenges emerging in the 21st Century.

Keywords: Industry 4.0, supply web, supply web management, SWM, fourth industrial revolution, 4IR, supply chain management, supply, SCM, artificial intelligence, big data, IoT, Internet of Things, innovation

1. Introduction

The coronavirus pandemic 2019 (COVID-19) and the 2021 delay of cargo ships along the California coastline illustrated recent challenges facing the supply industry and governments across the globe. Evidence shows that supply and demand challenges in the last years resulted from improper collaboration. The global supply industry saw nearly half a million containers of goods stuck off the coast of Southern California as state seaports operated below optimal capacity due to the coronavirus 2019 (COVID-19). The delay of containers disrupted services and delivery of goods in the United States and globally pre-2021 holiday season. Cargo ships could not return to their ports of origin to drop off or pick up more goods

while customers canceled orders impacting business bottom lines. Meanwhile, much of the global supply chain difficulties anticipating to anticipate COVID-19 pandemic-induced lockdowns and closures, which reduced the ability of firms to satisfy global market demands.

At the pick of COVID-19 and the Los Angeles seaport congestion, many firms satisfied consumer demands by utilizing a series of innovative digital technologies which include the Internet of Things, big data to machine learning (ML). COVID-19 pandemic and the California seaport crisis demonstrate the challenges facing firms that applied 20th century supply chain models to 21st-century problems. Today, evidence suggests that companies that employed a blend of new technologies during recent crises registered efficiency and productivity by addressing customer or industry needs in real-time (Imran Ali). The concoction of new technologies gave many firms opportunities to increase productivity and efficiency through big data, intelligent software, Internet of Things (IoT), and hardware. The 4IR is setting to disrupt orthodox supply chain knowledge by offering groundbreaking ways to meet and satisfy customer needs amid crises [1].

Meanwhile, many countries and firms still lack the basic infrastructure desirable to reap the benefits of the 4IR despite the usefulness and potential for the supply industry. The succeeding sections provide a background, methodology, results and discussion introducing the concept of the Supply Web and its tenets.

2. Literature review

2.1 Earlier industrial revolutions and supply chains

History shows technological innovation has always been at the center of business productivity and social emancipation. It brought individuals and firms to mass-produce by moving from manual and small-scale trade activities to mechanization and large-scale engineering productions. Material and services that evolved from the revolutionary innovations impacted every aspect of economic activities [2]. Makers of goods and service providers from agriculture to factories practiced primitive forms of trades to address the challenges and conditions of their respective eras. Previous industrial transformation exacerbated economic activities and created processes and concepts suitable to describe and resolve enduring challenges.

Business concepts relating to earlier supply chain activities, procedures, and actions did not develop until later. The academia, industry, and governments described the activities associated with the phenomenon after they had already happened [3]. However, identifying and describing developing innovative technologies and related processes offered the supply industry concepts and procedures to structure and shape future business activities.

Figure 1 illustrates the typical model of the supply chain showing the association between firms from raw material to end-use. While the linear nature of the supply chain models was suitable to satisfy earlier business practices, it is no longer practical to address problems facing value chains in the 21st Century.

For instance, as figure one illustrates, end-users lack the capability or option to collaborate with material (A), Transformation (B), and so forth if they were a desire to do so. The absence of these options in the linear supply chain model reduces the potential of firms to collaborate within a broader supply chain at the national or global scale.

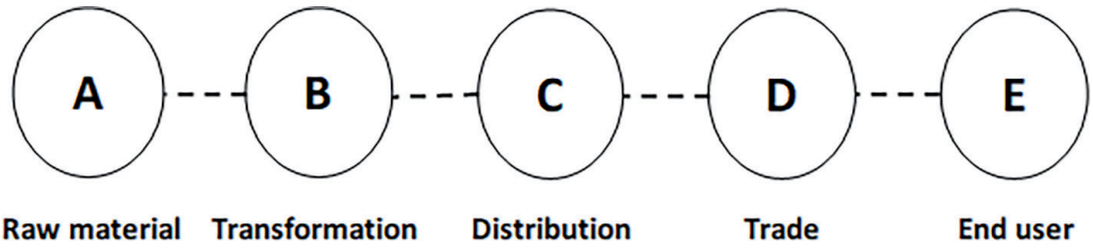

Figure 1.
Supply chain architype.

2.2 Paradigm shift

To understand the urgency to shift supply paradigms, one must grasp the current business environment. The global population doubled since the 1980s when only a handful of companies utilized computers for business. Many companies used computer technologies for small tasks, ranging from storing essential inventory data to chart display. At the time, most firms only performed business activities without computers due to the affordability of the technology. Nevertheless, the business industry and its concepts still evolved along with the adoption of computer technology. For instance, the radio frequency identification (RFID) technology helped the retailer industry and governments describe policies and procedures associated with tracking and tracing consumer products. Hence, though RFID technology did not exist earlier, most producers and retailers could still manage data and track and trace goods through traditional bookkeeping.

Meanwhile, as consumer demand evolved, so did the supply industry by adopting technologies such as RFID in various applications, including product recalls [4]. Referring to the linear supply chain (**Figure 1**), RFID sensors in most retail products often connect trade and distribution, removing end-users from collaboration despite the ability of the technology to do so. However, the linear supply chain paradigm does not envisage a collaborative transaction between the consumer and the manufacturer.

As civilizations progress, the global supply industry and governments must adopt emerging technologies and concepts to address current challenges. Industry 4.0 not only gives governments and the global supply industry the necessary tools and ideas to manage challenges, but it equally provides consumers the prospect to be a part of the solution. The current supply chain models have not successfully predicted and evaded supply chain-related predicaments. The failure is arguably in how the concept of the supply chain itself.

Today, while most supply chain firms employ computer technologies, many still lack the essential technology to collaborate successfully with partners. While many firms remain indifferent in linking their pieces of machinery with others, the speed of technology advancement equally makes it difficult to address security shortfalls as they occur. Nonetheless, a partner's lack of understanding and awareness of existing technological innovation will lead firms not to take advantage of the innovative technologies despite the rationality. In one instance, a farmer revealed during an interview to have never heard of blockchain or cloud computing [5], which many have come to consider as the cornerstone of business security and operations. Since a lack of coordination and collaboration could result in the absence of visibility and synchronized strategy between partners, firms not adopting the industry 4.0 technologies would become the gateways to substandard products and services [6]. The inability of a farmer or supply partner to

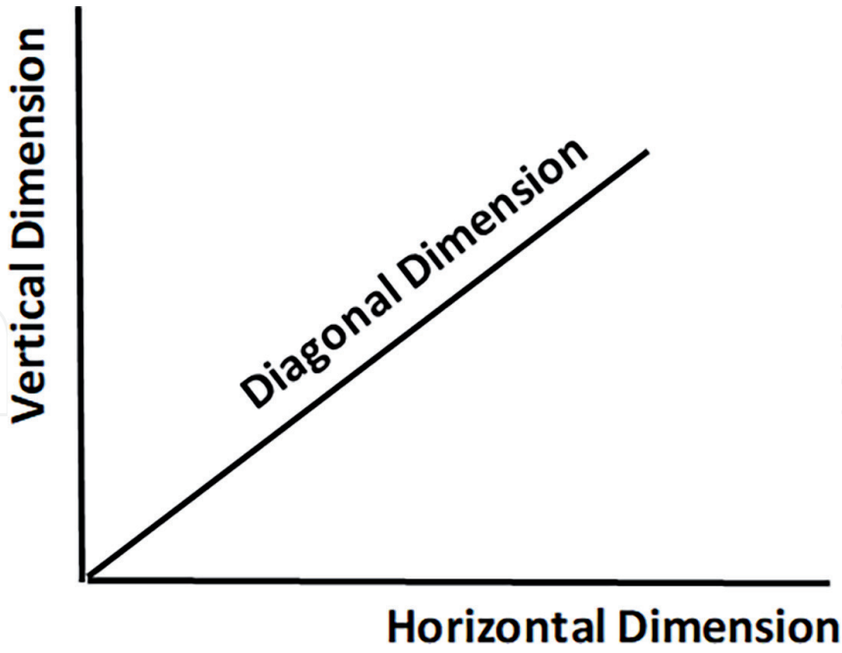

Figure 2.
Three-dimensional collaboration.

successfully and securely collaborate with others at various ends of the supply spectrum could only negatively impact the resiliency of the chain.

Linear supply chain models do not provide the necessary collaboration needed to connect valued chains at various levels of the industry. The current consumer and business data necessitate supply firms connect not only with businesses but also with consumers; hence, the necessity for multidimensional collaboration. As **Figure 2** shows, Industry 4.0 allows firms to exercise cooperation in terms of vertical, diagonal, and horizontal dimensions. When supply firms implement the 4IR technological tools, they enhance their ability to exchange business data internally, externally, and between partners beyond primary products (PBPP).

2.3 Dimensional collaboration

The Horizontal Dimension denotes the breadth of internal transactions within the main production effort. These transactions represent activities that enhance the internal collaboration between firms with direct equities on the primary production effort. Firms could have a mutual horizontal dimension when one adds value directly to the product line. For instance, tire, and windshield manufacturers add value to producing a motor vehicle a car. The three companies from the tire, windshield and carmaker have internal transactions that impact making a motor vehicle. A new motor vehicle would necessitate, among others, tires and a windshield for it to be complete. In this instance, the business transactions from the windshield and tire manufacturers make up the internal transaction of motor vehicles (main production effort).

The Vertical Dimension denotes the scope of transactions external to the main production effort. The transactions represent activities that enhance the external collaboration between firms having indirect equities on the primary production effort. Firms have a mutual vertical when one adds value indirectly to the main production effort. Using the motor vehicle example from the Horizontal Dimension, car dealers

and transportation services do not directly add to the main production effort. In this instance, neither transportation services that take the finished car from the plant to the dealership nor the car dealership adds directly to the main production effort. While car dealerships and transportation services could negatively impact production, they do not generate the main production effort. However, they add value to the overall supply web production of the motor vehicle.

The Diagonal Dimension symbolizes the breadth of transactions that could occur internally and externally to the main production effort. These transactions represent activities that enhance both internal and external collaboration between firms having direct and indirect equities on the primary production effort. Firms have a mutual diagonal dimension when they complement value directly and indirectly to the primary production effort. In the above example of a motor vehicle's main production effort case, the tire, windshield, and carmakers would add value to one another when engaged in active (direct) or passive (indirect) joint activities that enhance firms' resiliency and purpose. Meanwhile, the Diagonal Dimension also includes other value partners supporting internal and external business transactions. The value partners range from financial, government, security, and others supporting institutions that directly or indirectly impact the firms' overall business operation value.

The global supply industry no longer relies on the next mile or the input from the value chain to remain resilient and anticipate the next medical shortage or cargo ships bottleneck crisis. As COVID-19 pandemic and the Los Angeles cargo crises proved, the global supply industry needs better tools and concepts to anticipate an evolving global turmoil. As opposed to employing linear supply chain models, supply firms desiring competitive advantage at the international stage should implement supply web models that integrate horizontal, vertical, and diagonal dimensional business models.

3. Methodology

This chapter intends to explain how Industry 4.0 innovative technologies impact the supply industry and introduce the tenets of the next generation of the supply chain. A qualitative exploratory design method helped to gather Industry 4.0 technologies and related concepts with impact on the supply industry to find patterns in data [7]. The mining of associated technologies and ideas was achieved utilizing codes and developing terms, which helped analyze and describe emerging themes [8]. The data used in the analysis originated from government, non-government, business, and peer-review texts.

4. Results and discussion

4.1 Results

The Supply web is the next generation of a supply chain that integrates valued chains horizontal, vertical, and diagonal dimensions through collaboration. Through Industry 4.0, supply web management (SWM) would allow firms to perform a hundred times better at fractions of the price similar firms achieved nearly fifty years ago. For instance, an iPhone device can store terabytes of data and process hundreds

of business transactions in fractions of the time it would have taken a hundred 1980-era computers housed in a large building. In so far, not only the device holds a storage capacity of over a hundred earlier computers, but it is also capable of executing thousands of transactions in a record time. Modern technology has enabled businesses, individuals, and governments to conduct virtual meetings miles away, real-time monitoring of product manufacturing and delivery using automation. The current technology innovation has changed societies and demonstrates a 'creative destruction' currently trending to extinguish old industries [9]. Experts believe that Industry 4.0 is comparably helping developing countries as mobile phones did with personal communication. The use of trucks and drones to deliver goods in secluded and urban areas across the globe showed efficiency in developing countries [10]. Industry 4.0 enabled real-time vendor and subcontractors monitoring to manage rapid change and inventory [11] and reduce supply–demand misalignment [5]. Evidence suggests 4IR technologies or Industry 4.0 enhance visibility, interoperability, modularity, decentralization, virtualization, and service orientation [12].

Nonetheless, despite the potential of 4IR in the global supply industry, challenges remain without a deeper understanding of barriers and drivers. While a business' lack of collaboration, awareness, and organizational inertia bare, among others, its ability to execute supply web, a firm likewise needs to master and adopt processes and tools that add value to the supply web. For instance, a firm's plan to adopt strategies that address the reduction of supply–demand misalignment, fast-changing consumer needs, threats of legal penalties, and cost optimization could enhance its Implementation [5].

By addressing the barriers and implementing the drivers to Industry 4.0, the global supply industry would benefit of the 4IR [11]. In the interim, the adoption of Industry 4.0 necessitates investment. In contrast to small firms during the first industrial revolutions, today's small enterprises can reap the benefits of evolving technologies at affordable costs [12]. For instance, a small firm could subcontract its operations or services to large and specialized corporations. Businesses source several activities to lower operating costs, increase market access, enhance scalability, and diminish risks [11, 13].

4.2 Supply web: The next generation of supply chain

The Supply web is the next generation of a supply chain that integrates valued chains horizontal, vertical, and diagonal dimensions through collaboration. Through Industry 4.0, supply web management (SWM).

Which Industry 4.0 strategy supports the tenets of the next generation of the supply chain into a supply web? The answer cannot fundamentally be linear, as the strategy would be dependent on the industry. Nonetheless, firms would want strategies that can integrate basic tenets of the supply web. In so doing, firms would need to employ a blend of technologies into their business operation. While not inclusive, such technology could range from cloud computing, big data, artificial intelligence (AI), machine learning (ML), commodity sensors, robotics to automation. For the clarity and organization of concepts into the figure, the collaborative dimensions are categorized into levels: One, Two, and Three.

Figure 3 illustrates how the supply web incorporates the three-dimensional (vertical, diagonal, and horizontal) collaborations into a framework. The vertical Dimension or Level one (L1) represents internal business activities between firms that impact the main production effort. The level 1 collaborative dimension concerns firms within the same product line as A-A, B-B, and C-C.

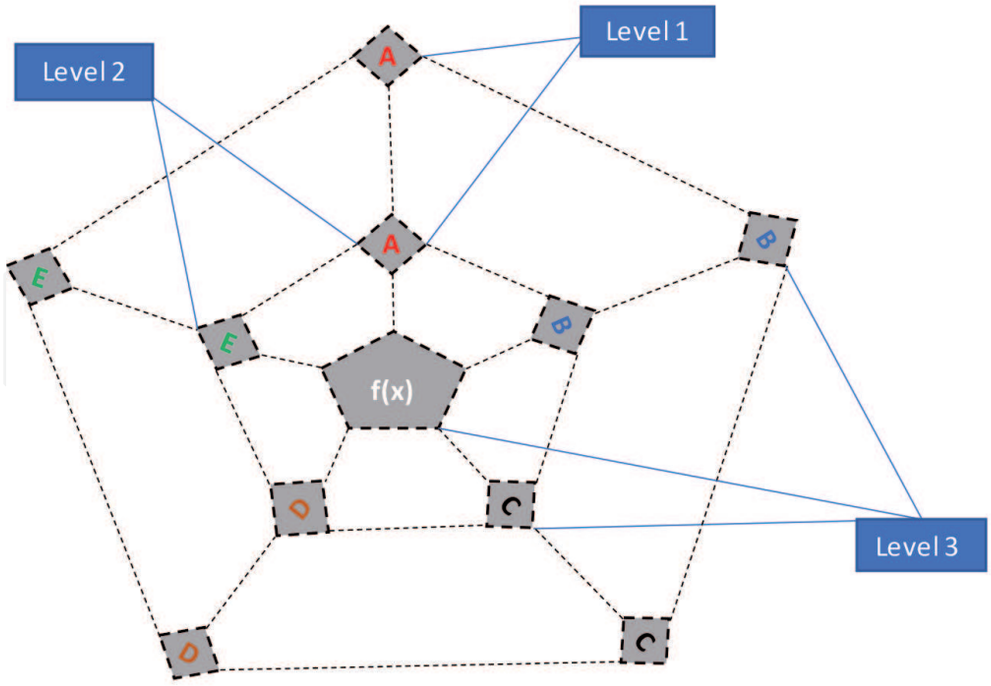

Figure 3.
Unit of supply web.

4.3 Tenets

The main production effort is the final service product can a single, or multiple firms produce conjointly. Meanwhile, a horizontal collaborative dimension or Level Two (L2) outside the primary production when as in A-B, C-D, A-E.... For instance, a transportation firm that delivers parts or final products participates in the collaboration under this category. Finally, firms maintain a diagonal collaborative dimension or Level Three (L3) collaboration when they have business transactions that impact the main production effort's internal and external activities. Level 3: A-A-B-B-C-C... The preponderance of Industry 4.0 elements that enable SW within and outside the main production effort would occur at this level. Firms that provide innovative technologies services from cloud computing, Big Data, ML, AI, RFID, IoT, and others add value to the supply web by enabling collaborative Dimension.

The tenets that enable tenets supply web include among others:

Big Data. Consumer and company data collection and storage paved the way for extensive data trends analysis. Data has become the most valued asset of any organization today, enabling analytics and market intelligence on customers' behavior, business practice, and decision-king [12]. Businesses and governments could use crowdsourcing technology to reinforce manufacturing standards. Many firms also offer to monitor and track production processes to support the supply industry, enhancing the efficacy of production control and decision making [11]. Comparatively, researchers from the Boston University School of Medicine applied big data analytics to realize early exposure to unsafe food products [14]. In so doing, they discovered that hazardous consumer products in the market could have been possible without the current state of technology [15].

Artificial Intelligence (AI). A survey found because of COVID, 55% of companies fast-tracked their way onto AI implementation in 2020, with more companies

expected to do the same in 2021 and beyond [16]. With the help of AI, it is possible to depict trends out of large amounts of data. Governments and corporations now employ AI technology in place of human intelligence to enhance decision-making capabilities in machines, which apply scientific models for swift trends analysis. AI technology proved to accurately forecast consumer behavior and business trends crucial to sustaining commodities' management.

Internet of Things (IoT) digitizes business and social activities. Intelligent factories, for instance, enable customers, companies, machines to communicate with workers, other technologies, and resources [12] to facilitate collaborative planning, goal setting, and sharing decision-making with stakeholders. The Just-In-Time or JIT model is an efficient inventory management concept used to lessen the need for warehousing and decrease warehousing-associated costs. Thought JIT model antedates Industry 4.0 when applied within IoT, strengthening collaboration. "Much of what people say about the New Economy is not all that new. A series of discontinuous technological changes before the industrial age sparked technological innovations in the 18th Century. The inventions that the steam engine, railroads, steel, electrification, and telecommunications characterized improved internal and external collaboration with various industries [5]. For instance, a home device equipped with intelligent technology could detect and place an order when certain goods reach a set limit. The sensor submits an order processed through the web and informs what follows. The customer and all other statehooders could monitor the order fulfillment and address any issues accordingly.

Throughout humankind, societies implemented innovative technologies to fix the crisis of their time. The massive backlog of cargo ships in Los Angeles ports and across the globe in October 2021 illustrates some of the issues of the state of the early supply chain models. During an interview on CNN, the Executive Director of Port of Los Angeles noted that the orchestra of players needs to get on the same schedule. COVID-19 pandemic reaffirmed that efficient inventory management continued to be a common business challenge for many firms [12]. COVID-19 induced lockdowns disrupted medical and other supply chains creating impacting commodities supply chain [6]. There is evidence that there is a need for greater collaboration between industries and governments to minimize supply disruption at the national and global scales. Firms that collaborate with multiple stakeholders have better business strategies [6].

5. Discussions

This chapter provides a synopsis of 4IR innovative technologies and related concepts for the next generation of the supply chain. Industry 4.0 is setting the next generation of the supply chain by making it more agile and efficient than the traditional supply chain [17]. The next generation of supply chain management ought to integrate processes that share data among partners through collaborative efforts and automation enabled by the Internet of Things, machine learning to artificial intelligence.

The current global environment enables businesses to expand and connect internal processes with customers and suppliers [18]. The expansion and connections require collaboration, flexibility, redundancy, and integration impact supply chain resilience [19]. The collaboration empowers customized configuration processes and is an essential element in tracking products from suppliers to customers with customized configuration [20] I4.0 offers a set of tools to support decision making through collaboration [21].

The impact of the COVID-19 pandemic and other recent supply chain crises offered the supply industry compelling arguments for implementing4.0 [22]. The adoption of I4.0 has grown in the manufacturing and supply chain sector [23].

Several barriers and drivers exist to Industry 4.0 implementation in the supply chain, including economic, technological, social, organizational, environmental, and inter-relationships [24]. A study found the reduction in supply–demand misalignment, changing consumer needs, legal penalties, and cost optimization as drivers of I4.0. At the same time, a lack of collaboration, organizational inertia, and lack of awareness are designated as barriers [5, 25]. Despite its advantages, firms still face challenges in implementing the I4.0 and in sustaining the security requirements. The cyber community continues to register attacks on secure systems that include attacks in web applications using TLS to secure HTTP communications [17, 26].

Not enough knowledge exists on the implementation strategies of Industry 4.0 concepts for small and medium-sized enterprises [27]. Additionally, no evidence of a conceptual SCM integrates the fundamentals of Industry 4.0, henceforth suggesting the development of business models that tolerate integrative and collaborative connectivity [28].

6. Conclusion

The next generation of supply chain management needs to integrate automation of processes from manufacturing, distribution, retailing to customers through Industry 4.0. The capability gives the supply industry compelling arguments to shift from traditional supply chain models to a supply web for enhanced collaboration and efficiency. The supply web paradigm offers the supply industry to generate and transfer business data internally, externally, and between PBPP. The chapter presented and defined *Supply Web* (SW) and suggested the basic tenets. Firms need to have their business operation participate in the three collaborative levels to integrate SW. Primarily, firms need to maintain an internal Collaborative Dimension with other firms that add value to the primary product or service. Next, a firm must maintain another level with firms external to the main product or service. Lastly, firms will equally require a collaborative dimension that impacts internal and external operations.

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Conflict of interest

None.

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