



2024

Article
Page 2

References
Page 11

Mohammed Ali
The University of Texas at Tyler

Big Data Driven Innovations Thrive Supply Chain

Keywords:

COVID; Supply chain management; Data lake; Industry 4.0; ERP; SWAT; Internet of things; Omnichannel fulfilment

APPLIED RESEARCH

Ali, M. Big Data Driven Innovations Thrive Supply Chain. The Journal of Technology, Management, and Applied Engineering, xx (xx), 2024, 1–13. <https://doi.org/10.31274/jtmae.16138>

Submitted: March 1, 2023; Accepted: May 16, 2024

© 2024 The Author(s). This is an open access article published under a Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0>).

Big Data Driven Innovations Thrive Supply Chain

ABSTRACT

The worldwide events like corona virus disease (COVID) pandemic, war, natural disasters, and nontariff barrier enforcements have tested humanity like never before. The supply chain industry (SCI) endured the hardest hit by these events and changed the way it has been conducting businesses. This paper aims to determine the strengths, weaknesses, opportunities, and threats that have evolved from the lessons learned through unexpected events. It portrays the approaches of adopting opportunities with the SCI's strengths while mitigating weaknesses to address threats timely and precisely. Additionally, it elaborates on how to collect, synthesize, universalize, and harness Big Data towards improvements in cost reduction and effective logistics revitalization. Furthermore, a four-step strategy to build a shockproof supply chain organization is proposed to minimize supply chain disruptions in the era of Industry 4.0.

Introduction

The worldwide coronavirus disease 2019 (COVID-19) pandemic unexpectedly started by the end of 2019 and lasted until almost 2022 before subduing. During this crisis, things suddenly had to be made differently and fast, from Pillsbury dough to semiconductors, while adopting Centers for Disease Control and Prevention (CDC) orders, like temperature checks, mask use, and social distancing. Governments were locking their people in, businesses were being closed, and employees worldwide were working from home. That ends up drawing such an incredible demand shift that it is something the supply chain industry (SCI) cannot plan for. Moreover, it revealed grave and systematic weaknesses in supply chains, a realization that has made supply chain flexibility a top priority for multinational corporations that source raw materials and principal parts globally (Manders et al., 2017). Successively, after the pandemic, SCI leaders were looking for strategic solutions to prepare for the next significant disruption.

Boll and Branch is a direct-to-consumer bedding company; all its products are sources (Boll and Branch, 2022). COVID-19 has made consumers think about their homes a lot more, so the demand for Boll and Branch products has remained strong and increased. The company used to source from developing countries in Asia, where thousands of workers depend on it for their living, from areas that have challenges from human health and safety standpoints. Since the demand for their product has increased during COVID-19, it started paying for goods early before shutdown orders came from the governments of those countries. It had to consider the timing of shutdowns and restrictions in various countries. Boll and Branch brought on board manufacturing in Portugal, Turkey, Pakistan, and other countries to promptly reroute overseas supply chains (MHI, 2022). This is one of the many examples in the SCI. Now, post COVID-19 is the time to take these learnings and use them to invest in the right technology to mitigate future disruption and respond to future speed and transparency demands—in short, to revolutionize every industry specific to the supply chain.

As the COVID-19 pandemic, natural disasters, and other recent crises (e.g., ripple effects from microchip shortage) disrupted worldwide supply chains, manufacturing industry leaders were forced to rethink standard sourcing practices, such as low-cost sourcing and just-in-time (JIT) manufacturing. Today's supply chain challenges demand resiliency through new approaches in (1) supplier network optimization, (2) cost control, (3) accurate demand forecast, (4) holistic view of supply chains, and (5) effective management of inventory, supplier relationships, and risks (RSM, 2023).

Purpose and Methodology

This study has aimed to determine evolving post-pandemic strengths, weaknesses, opportunities, and threats (SWOT) in the SCI. After that, a consequent analysis is done to understand the possible application of big data toward improvements in cost reduction and effective logistics revitalization.

Subsequently, a four-step strategy to build a shockproof supply chain organization is proposed to minimize supply chain disruptions in the era of Industry 4.0.

BIG DATA STRENGTHS SUPPLY CHAIN

When raw and unorganized facts are processed and organized into an analyzable form, they turn into data. "The data" is valuable because it tells a story about the past and possible future. Data from suitable sources helps predict anything. Unlike crude oil, data has no intrinsic value. For example, a billion terabytes of random data is worthless unless adequately harnessed. Data from the supply chain can be just as accurate and valuable as any company asset because it allows insights gained about suppliers, customers, and markets, which can lead to dramatic improvements in supply chain planning and execution (Howson, 2021).

Thanks to computing technology for analyzing massive amounts of data that supply chain operators may uncover from a treasure trove of trivial sources, advanced analytics is an essential tool here because it can store and process data that the SCI produces every minute at an incredible rate and variation. In this paper, this concept will be referred to as big data. Such an enormous amount of data is impossible for the human mind to fully comprehend, examine, and make a thoughtful decision on.

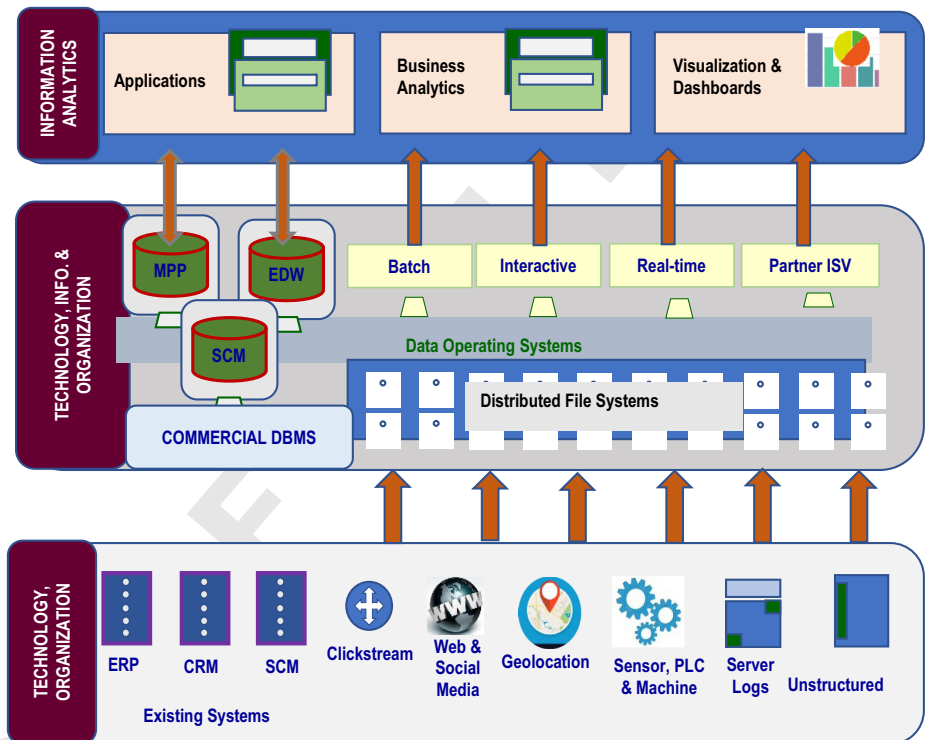
Additionally, the users of these analytics must learn not only how to make a decision but also how to make the best decision. The supply chains' performance optimization data can be combined into a few categories to predict and act on organization-specific requirements. Internal data is generated from transactions in marketing, production hardware, software interface, machine-produced, movement of goods, and underneath all these categories. External data sources include but are not limited to weather news, trade organizations such as the North American Free Trade Agreement (NAFTA), the Organization of Petroleum Exporting Countries (OPEC), and economic reports. These entities, which are outside of the supply chain, also influence in both positive and negative ways. These are a multitude of data assets. Enterprise resource planning (ERP) systems are business-critical software applications that manage essential business processes across the enterprise, from accounting and manufacturing to sales and purchasing; such useful business process automation technology has been developed since the 1990s. ERP systems' integrity and data integrity are vital to an organization's function. ERP systems contain an organization's crown jewels, like the sensitive information enterprises need to function daily. If that data were hacked, the impact would be devastating. Critical vulnerabilities, potential internal misuse, external attacks, and compliance violations may go undetected. Therefore, robust ERPs offer a strong defense against insider and outsider threats.

A manufacturer's supply chain management (SCM) module is a critical organizational component of ERP systems. It maintains vital relationships with customers and suppliers, streamlines manufacturing processes (like planning, distribution, inventory, and transportation), and effectively manages the entire supply chain to meet customer expectations and achieve optimal business performance. Many companies have invested in powerful cloud ERP systems but have not taken advantage of all these tools offered for the SCM. In the Industry 4.0 era, they need to investigate how it is possible to integrate ERP with SCM solutions, which will eventually deliver incredible speed and efficiency.

Daily business operations depend on the integrity and security of the SCM system. Unauthorized access to the SCM system could sabotage a company's entire supply chain, resulting in the theft of goods and funds. In addition, a company's SCM system data is required to comply with many important regulatory mandates, such as the General Data Protection Regulation (GDPR), Sarbanes-Oxley Act (SOX), Payment Card Industry Data Security Standard (PCI DSS), and National Institute of Standards and Technology (NIST). Figure 1 shows an example of how modern data architecture works with technology or technoware (T), talent workforce or humanware (H), information systems or infoware (I), and organizational or organizational (O) components. Although many THIO components were developed over the decades and incorporated to form modern big data architecture, the COVID-19 pandemic revealed serious and systematic weaknesses in supply chains. This realization has made supply chain resilience a top priority for organizations that source globally (RSM, 2023).

Figure 1.

Modern big data architecture embodies organization's technology (technoware), talent workforce (humanware), information (infoware), and organizational (orgaware) components into enterprise resource planning, supply chain management, and business competitiveness. Note. MRP - Material Requirements Planning, EDW - Enterprise Data Warehouse, SCM - Supply Chain Management, Partner ISV - Partner Independent Software Vendor, DBMS - Database Management System, ERP - Enterprise Resource Planning, CRM - Customer Relationship Management, SCM - Supply Chain Management, PLC - Programmable Logic Controller, ERP - Enterprise Resource Planning.



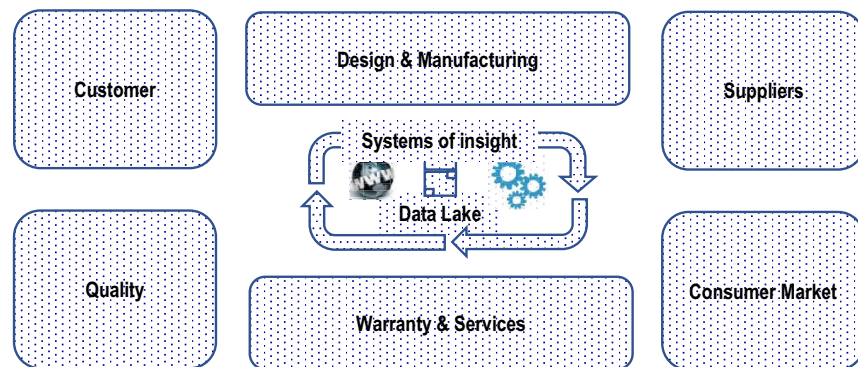
Operational data encompasses the systems, structures, and processes to plan and execute the flow of goods and services from supplier to customer. Machine-generated data is collected from connected Internet of Things (IoT), like robots and sensors. The IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Transactional data is collected when an item is bought or sold. It is necessary to view that data as a buffet and then carefully pick, process, and use it for any given circumstances.

Let us see an example of an ice cream treat and how many data points are engaged in making and selling it. When weather data of heat waves is floating around, more people are looking for a sweet cold snap. If ice cream is selling out fast, it might make sense to store it in an easily accessible warehouse or distribution center area during that hot flash. That way, ice cream will sail smoothly through the facility, which would be a thoughtful decision. Once the delivery truck is en route to its destination, sensing devices can determine whether the snacks have been exposed to temperature fluctuations. The exact location of the delivery truck can be tracked so its arrival can be anticipated. Once it shows up, the proof of delivery can be generated. As the ice cream is sold, information can be collected to determine what and when other similar seasonal products might be popular.

Big data has become more critical than ever and evolved as good data. Supply chain companies are looking closer at internal corporate and customer data. They are also shifting focus on what and

Figure 2.

A data lake enables all data from suppliers, external consumer market environment, manufacturing, and quality controls to the customers to be searchable.



why to collect and analyze data. However, these traditional internal data sources must be revised to optimize supply chain operations. The complexities emphasized by the pandemic have shown that supply chains need to harness a more extensive array of data lakes and integrate them into their analytics to boost performance and mitigate disruption, especially as consumer patterns and the talent workforce continue to evolve rapidly (MHI, 2022).

A data lake is a centralized computing architecture with multiple applications on a shared dataset with consistent service levels with any application. It allows for multiple applications to access data from anywhere. A data lake unlocks “systems of insight” using advanced algorithms and applications to derive new value and optimize the existing value of a query. Massive datasets are generated from deployed IoT applications, such as clickstream, sensor, social, mobile, geo-location, server log, and other new paradigm datasets within existing datasets. Access to these data types from anywhere by any application requires deep integration with ecosystem partners to extend existing investments and skills.

Advanced analytics, machine learning, predictive analytics, and recommendation engines are promising big data technoware that can aid modern-day industries in overcoming various challenges. Technoware is hardware. It is the tangible machines and tools that produce consumable goods and supplies. They are already changing human lives, with applications ranging from self-driving cars to improved voice and visual recognition technologies. Furthermore, it provides methods to look for disease signals in genetic codes and to read IoT signals for predictive maintenance. All of these applications run on data, which is provided by the enterprise data lake (EDL) (Gorelik, 2019). The EDL offers predictive analytics for optimized manufacturing of the auto industry’s original equipment manufacturers (OEMs). Many manufacturers have disparate data and processes, and the data lake makes data searchable, as shown in Figure 2.

Findings and Implications

INNOVATIONS AND THE FUTURE OF SUPPLY CHAIN

Innovation has shaped the way humans live, work, and play. In the digital age that modern humans live in, technology acceleration means differentiating. A thriving supply chain must have innovation as the key to acceleration; otherwise, it risks becoming irrelevant (McDowell et al., 2020). If it is not differentiating through innovation, it is on the path of dying because changes are happening faster outside than inside its ecosystem, irrespective of its strategic planning. That puts it in a disadvantaged situation. Supply chain experts refer to it as an undesirable catalyst, advising the thriving supply chain organization to adopt the pace of change to happen faster internally, not externally (Palmer, 2019).

Solaimani and van der Veen (2022) proposed an open innovation approach in a supply chain framing three ambidextrous capabilities.

1. Purpose: The organization will pursue the leadership of steady cooperation between employees and management in their mutual pursuit of perfection, focusing on long-term benefits, with customers at the center. Empowering leadership creates a permissive environment based on mutual respect, reciprocity, and trust.
2. Span: A horizontal collaboration with indirectly related firms, such as joint distribution centers between two retailers, and a vertical collaboration among supply chain partners, such as between suppliers and customers.
3. Orientation: Continuous incremental improvements and radical shifts in products, processes, markets, and business models (Poot et al., 2014; Soosay & Hyland, 2015).

Every innovation demands adaptability. To avoid the potential extinction of a good, thriving company, it is incumbent on today's business managers not just to understand the pitfalls and disruptors that can threaten their futures but to actively pursue new solutions and strategies that will enable them to adapt to changing technology and market conditions and to innovate so that they continue thriving while their competitors cannot.

Without creative problem-solving, most industries will slow down and grind to a halt, as seen when the recent worldwide COVID-19 pandemic halted conventional supply chain methods. Such an unexpected catastrophe drove us to a point where the need for innovation has never been higher. The culture of encouraging innovation is an integral part of the supply chain meeting challenges with the support of big data; thus, many SCM employers hire people with creativity, problem-solving, and eagerness to learn. Nevertheless, to encourage new hires in the path of innovation, employers need a culture that provides room to experiment with new methods, some of which may not bring successful results. However, people who enjoy the freedom of creation should not be penalized for lack of failure at their annual performance evaluation (MHI, 2022).

Where once supply chain leaders used to say evolve or die, now they are saying either transform or die. Supply chains are becoming more and more a technology-ridden industry. During the mid-2010s, while transportation and logistics firms did not adopt some technologies as quickly as they thought, there was a big jump in these investments in the post-COVID-19 era (Deloitte Consulting, 2019). Emerging technology is transforming present supply chains at such a rate that equipment that was once a competitive advantage is rapidly becoming a requirement to stay in the game. So how does a company know where to invest to ensure it gets the return on investment it needs when technology adoption and innovation are all-time high challenges?

SUPPLY CHAIN SWOT ANALYSIS

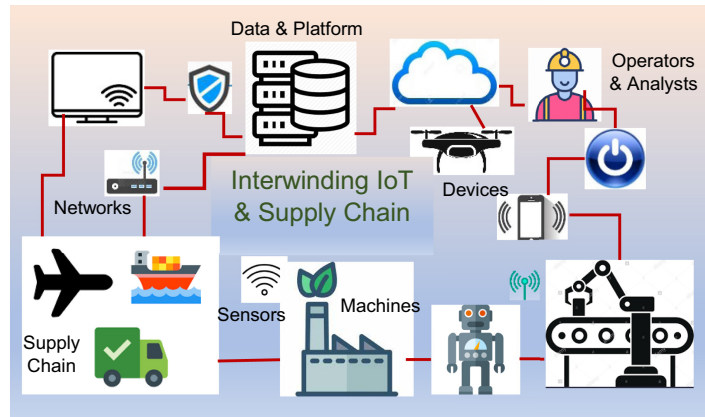
The fourth industrial revolution, or Industry 4.0, focuses heavily on IoT interconnectivity, intelligent automation, AI machine learning, and real-time data (Epicor, 2022). More precisely, it represents the fourth revolution that has occurred in manufacturing. From the first industrial revolution (steam-powered mechanization) to the mass production and assembly lines using electricity in the second, the fourth industrial revolution will take what was started in the third revolution with the adoption of computers and automation and enhance it with intelligent and autonomous systems fueled by data and machine learning (Marr, 2018).

Many economists recently suggested that the world's most valuable resource is not gas and oil but data (Vavra, 2019). Data is undeniably the new currency for supply chains. However, this currency differs from the gold rush as it moves like money and transfers between entities millions of times each second for the cause of digital supply chains (Tkatchuk, 2017). Because they are in infinite supply, the key is to use technology and analytics to find insights into that data to implement operational improvements of agility performance visibility and customer service.

As mentioned earlier, raw data has no inherent value, unlike oil, but properly analyzed insights can be gained from that raw data about customers, suppliers, and markets. Such information can transform a supply chain into a point of competitive advantage. Catching these "opportunities" at the right time and in the correct instant becomes the "strength" of the organization. One of the most significant

Figure 3.

Internet of Things (IoT)—device and sensor networks feed data to the repository from every node of manufacturing and convoluted with supply chain.



technological advancements today is the IoT, which is foundational to capturing value from the data. For example, emerging sensor technology at every supply chain node can generate data and become a digital informant (Fan, 2021). The network of these connected intelligent devices is called the IoT, an “opportunity.” Figure 3 illustrates how the IoT components feed data repositories that can be analyzed to reveal hidden insights that inform decisions and actions.

Many supply chain companies indicated they need help capturing data from multiple sources and their integration. Overcoming these “weaknesses” is a critical success factor for these organizations. The IoT amplifies the technology of vastness in terms of sensors and the ability to capture data across the supply chain. To make the best use of data resources, it must not be confined to the distribution centers but rather be transmitted to the analysts who will be mining that data.

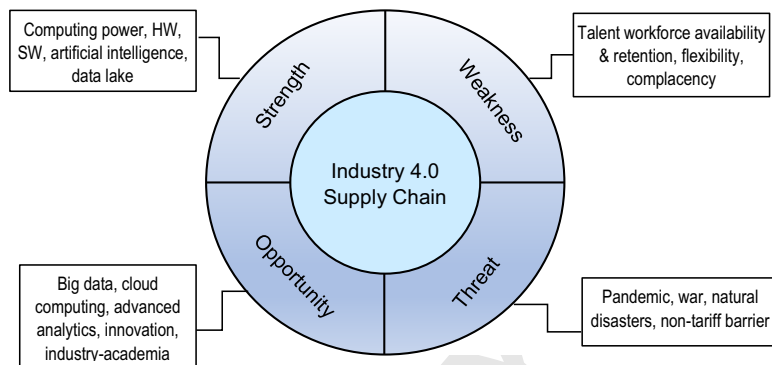
The talent shortage has long been a top concern in the material handling and SCI. The material handling industry (2020) survey shows that there will be about four million manufacturing and supply chain jobs available from 2023 to 2030, and the industry will have a hard time filling beyond 53% due to the lack of qualified talent and skills. To address this limitation, industry leaders discovered that companies can improve performance, retention, and workforce productivity by (a) optimizing shift patterns, (b) planning for resource demand, and (c) identifying and analyzing indicators of high performers (MHI, 2020). Since skill, talent, and technology are linked, workforce challenges cannot be solved without building and maintaining a culture of innovation and technology within the manufacturing and supply chain organization.

An organization’s challenge is capturing corral and integrating this data from multiple sources. Moreover, data about pandemics, like COVID-19, weather, public health, political trends, tariffs, consumer behavior, traffic, and geopolitical conflicts, are “threats” of which humans have no pre-knowledge about the event’s time, location, and consequences. Nevertheless, it is adopting opportunities with the organization’s strengths while mitigating weaknesses that make it possible to shoot down the threats promptly and precisely. Figure 4 illustrates the SCI’s SWOT in the era of Industry 4.0 for an agile supply chain.

In the future, real-life data tools and predictive analytics will create visibility and transparency throughout the supply chain. From the manufacturer to the customer, information about the company’s suppliers and sourcing locations must be available to all stakeholders. When these users can access the data, preventing supply chain disruption and product shortage and limiting counterfeits will boost customer trust. For example, about three years ago, there was an E. coli outbreak with lettuce in the US, and it took ten days to trace the source location (CDC, 2022). Thanks to data analytics or blockchain technologies, they could track the origin of the contamination source in less than two minutes to address similar incidents in fall 2022 (Salisbury, 2022).

Figure 4.

Illustration of supply chain industry's strengths, weaknesses, opportunities, and threats (SWOT) in the era of Industry 4.0. Note: HW – hardware, SW – software.



IoT-generated big data analytic tools will give customers real-time status updates and opportunities to change their order or delivery window. Likewise, the companies will have access to more customer data, allowing them to expand their relationships and marketing mix. However, none of these would ever be possible without the latest advancements in computing analytical capacity tools, like cloud computing (CC). Open-source data analysis and industry-wide standards are critical components of this movement (Kumar et al., 2014). The development of data science with AI capability will significantly impact learning how to utilize that data because machines are quicker analyzers than humans.

Once the SCM can collect, synthesize, universalize, and share data among the supply chain partners, it will enable them to figure out areas of improvement for cost reduction, determine how logistics can be organized effectively, and build agility to minimize supply chain disruptions (MHI, 2022). Additionally, it will detect process inefficiencies that create the most impact, monitor equipment for vital signs, schedule maintenance, track customer relationships, and explore how to extend service. These insights can also apply to workforce goals, performance retention, and productivity by allowing shift patterns and automating tasks where it makes sense to plan for resource demand and analyze key performance indicators.

SHOCKPROOF FUTURE SUPPLY CHAIN STRATEGY

The worldwide SCM organizations are experiencing global disruptions in supply availability, cyberattacks with ransomware, manufacturing capacity, lead times, and transport of goods. Even though most industries only started remote work during the pandemic, it is not a new concept. Contractors, freelancers, and even consultants often work remotely for companies but need actual office space. However, remote work to meet stringent pandemic requirements is challenging to implement in the SCI. The main reason is that many organizations must have their employees physically present to operate and solve unexpected troubleshooting and maintenance at the warehouse, distribution center, logistics, and transportation. According to a survey conducted by the Institute for Supply Management, among supply chain companies that reported COVID-19 pandemic-related disruptions were China 72%, Europe 58%, South Korea/Japan 41%, US 36%, and Mexico/Canada 20% (ISM, 2021). These global disruptions are impacting revenues, demand for goods, and operations.

Considering all the hurdles discussed, future supply chains need to instill more resilient, faster, and sustainable shockproof operations. Cybersecurity and ransomware threats are constantly evolving, and hackers have continued focusing on the middle market as the pandemic has persisted.

The RSM and the US Chamber of Commerce surveyed from January 9, 2022, to January 30, 2022, among 406 senior executives at middle market firms across manufacturing, food, supply chain, and information technology industries. Many vital findings came out of that study. For example, about 72% of businesses reported unauthorized users deliberately and illegally attempting to access their data or systems in 2022.

Given the level of fear about potential cyberattacks, cyber insurance policies have grown in importance. Sixty-one percent of survey respondents reported they carry a cyber insurance policy, and two-thirds said their policy premiums had significantly increased (RSM & USCC, 2022).

The most expensive part of a supply chain is the last mile. The SCM industry reports that the last-mile delivery costs can contribute up to 41% of the total supply chain costs and account for almost half, i.e., 53% of the total shipping cost (Puri, 2022). Omnichannel fulfillment (OF) is an interesting new concept that uses greater computing power and storage in everyday life (Pham, 2022). Figure 5 illustrates the OF method to bring customers a great and seamless shopping experience, making the purchase process convenient. It works on store networks to position inventory to compete on the concept of time. In an OF, merchandise is shipped from one store and collected at another store, which becomes an in-store purchase. In-store purchase is one of four major fulfillment types of the supply chain. When customers do not want to wait weeks for a product to be received, they can order from their computer and cellphone app or visit a nearby retail outlet to place the order. That is when the order management system (OMS) comes into play. It looks at which nearby distribution centers or warehouses could have the product in stock, and that is where CC comes into action. The OF occurs seamlessly if all products are listed in a central database and connected to the distributor via a network. So a good OMS will work in tandem with an on-demand I/O platform forecasting imagery optimization written by AI and machine learning combined to help delight the customer (Dash et al., 2019). However, the supply chain organization must have a consistent data system among the channels and a reliable OMS fulfillment module to make all the processes operate smoothly. Hence, OF is a key to achieving the target.

From natural disasters to cybercrime and political turmoil, uncontrollable risks will continue to threaten supply chain companies worldwide, irrespective of their locations, in the era of Industry 4.0. Therefore, their agile SCM operations require them to be prepared for the next supply chain disruption. SCI leaders have identified four steps an organization can take to overcome supply chain challenges (RSM & USCC, 2022; RSM, 2023). They are (1) optimization of the supplier network, (2) upgrade of IoT technologies, (3) creating a rigorous demand forecasting process, and (4) networking with trusted and reliable partners. RSM is a multinational network of accounting firms forming the world's sixth-largest accountancy professional services network by revenue (RSM, 2023). Figure 6 illustrates the implementable framework of the four-step reinforced shockproof Industry 4.0 supply chain.

The pre-COVID-19 SCI used many legacy systems in individual organizations' supply chains to meet their customer mix. The unexpected arrival of COVID-19 exposed systematic weaknesses in the supply chain concerning the organization's industry it serves. So strategic solutions are sought to fit pandemic requirements in purchasing, warehouse management, transport management systems, etc. The four-

Figure 5.

Illustration of omnichannel fulfillment (OF) method to bring a great and seamless shopping experience to the customers—making the convenience of the purchase process (adapted from Pham, 2022).

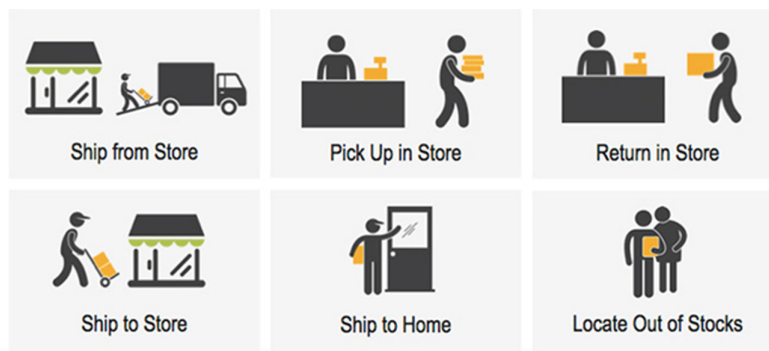
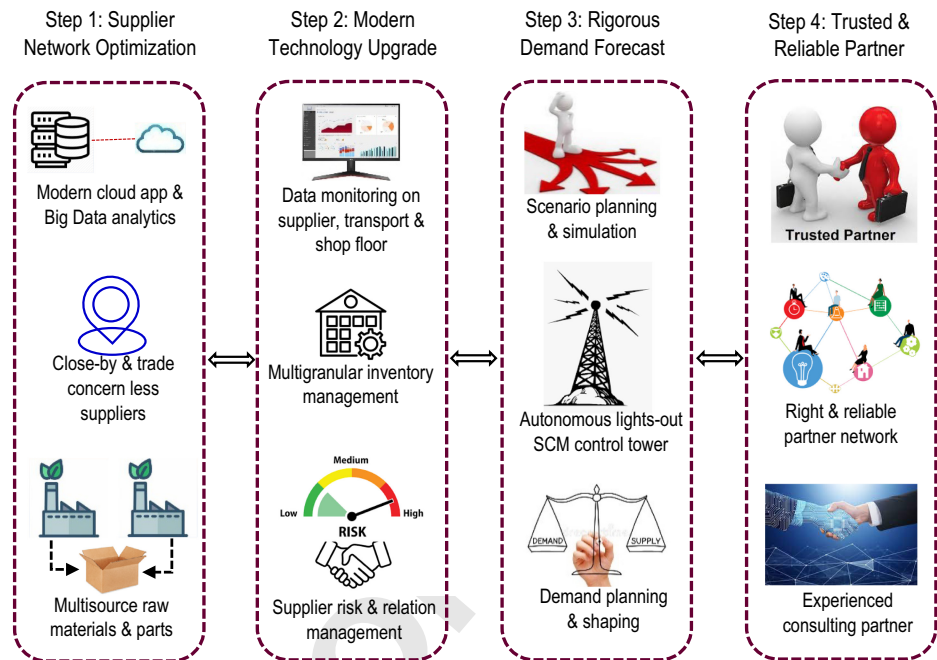


Figure 6.

Illustration of the proposed four-step reinforced shockproof Industry 4.0 supply chain.



step shockproof supply chain is a possible solution. Furthermore, Industry 4.0 heavily focuses on automation, machine learning, interconnectivity, and real-time data. The shockproof SCM will be more holistic and better connected to IoT with the blessing of AI-enhanced Industry 4.0, which will tie physical production and operations with intelligent digital technology.

OPTIMIZATION OF THE SUPPLIER NETWORK

The JIT manufacturing model of the late twentieth century brought companies greater efficiency and cost savings (Wrike Team, 2023). Unfortunately, COVID-19 pandemic-induced disruptions showed that these advantages came at the cost of supply chain resiliency. Therefore, this industry needs to optimize its supplier network. Additionally, OF takes the ultimate goal of managing the order process effectively and satisfying the consumer.

UPGRADE TO MODERN TECHNOLOGY

Cloud SCM solutions can spotlight the entire supply chain by connecting partners and enabling mobility, accountability, and proactive response to potential problems.

CREATE A RIGOROUS DEMAND FORECASTING PROCESS

While there are several actions a middle market company can take to insulate its supply chain from disruption, the most efficient—and promising—approach is to improve its ability to predict demand. This requires the business analytics power to pull in data from multiple sources and leverage AI and machine learning to make intelligent predictions.

FIND A TRUSTED AND RELIABLE PARTNER

Working with an experienced consulting partner can help the organization “X” develop a unique SCM strategy for its business and goals. The usefulness of a consulting partner lies in its capabilities, including the following: (a) it understands and possesses data about the SCI where the organization is doing business; and (b) it has the breadth of knowledge to bring best practices, knowledgeable people, and right-sized technology to address the problems faced by “X.”

Conclusions

The COVID-19 pandemic has resulted in exceptional supply chain disruptions and product shortages. This industry's analysts, operators, and leaders learned many lessons. It also brought this business into the headlines of every news organization worldwide as the strategic importance of supply chains gained clarity. Now is the time to take these learnings, data, and information to invest in the right technology to mitigate future disruption and respond to future speed and transparency demands—in short, to revolutionize the entire supply chain.

Good and valuable data is the lifeblood of the innovation-trusted digital supply chain. Companies that recognize the value of this data and analysts' approach to collecting, filtering, and synthesizing it into customer demand and market insights will be successful. Those who do not will drown in the wave of exponential data proliferation.

Every global disaster uncovers many supply chain vulnerabilities and the resilience that innovation adoption can provide. This industry would benefit from those insights by embracing groundbreaking innovations that can revolutionize how supply chains operate—enabling future supply chains to thrive in the face of inevitable disruptions.

References

- Boll and Branch. (2022). *The most loved 100% organic bedding*. Retrieved January 9, 2023, from <https://www.bollandbranch.com/collections/sale/>
- CDC (Centers for Disease Control and Prevention). (2022 March 3). *E. coli outbreak linked to packaged salads*. https://archive.cdc.gov/www_cdc_gov/ecoli/2021/o157h7-12-21/details.html
- Dash, R., McMurtrey, M., Rebman, C., & Kar, U. K. (2019). Application of artificial intelligence in automation of supply chain management. *Journal of Strategic Innovation and Sustainability*, 14(3), 43–53. <https://doi.org/10.33423/jsis.v14i3.2105>
- Deloitte Consulting. (2019). *Deloitte perspectives: Generating value from data capture*. Deloitte Consulting LLP. <https://www2.deloitte.com/ie/en/pages/deloitte-private/articles/generating-value-data-capture.html>
- Epicor. (2022). *What is industry 4.0—the industrial internet of things (IIoT)?* Retrieved December 12, 2022, from <https://www.epicor.com/en-us/blog/what-is-industry-4-0/>
- Fan, Y. C. (2021). Emerging sensing technologies in consumer electronics. *Sensors*, 21(22), 7689. <https://doi.org/10.3390/s21227689>
- Gorelik, A. (2019). *The enterprise big data lake: Delivering the promise of big data and data science*. O'Reilly.
- Howson, C. (2021). *Six top trends and predictions for data, analytics, and AI in 2021: And what to do about them*. ThoughtSpot. Retrieved January 8, 2023, from <https://go.thoughtspot.com/ebook-6-top-trends-predictions-data-analytics-ai-2021.html>
- ISM (Institute for Supply Management). (2021 March 30). *COVID-19 and supply chains: Increasing impacts, decreasing revenues*. ISM, Tempe, Arizona. <https://weareism.org/docs/White-Paper-Corona-V2.pdf>
- Kumar, R., Gupta, N., Charu, S., Jain, K., & Jangir, S. K. (2014). Open source solution for cloud computing platform using OpenStack. *International Journal of Computer Science and Mobile Computing*, 3(5), 89–98.
- Manders, J. H. M., Caniels, M. C. J., & Ghijsen, P. W. T. (2017). Supply chain flexibility: A systematic literature review and identification of directions for future research. *The International Journal of Logistics Management*, (4), 964–1026. <https://doi.org/10.1108/IJLM-07-2016-0176>

- Marr, B. (2018 September 2). *What is Industry 4.0? Here is a super easy explanation for anyone*. Forbes. ~<https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#:~:text=Industry%20optimizes%20the%20computerization%20of%20Industry%20.0&text=A%20combination%20of%20cyber%2Dphysical,the%20smart%20factory%20a%20reality>.
- McDowell, T., Mesaros, N., Sorkin, J., & Rooney, C. (2020). *The evaluation of business innovation*. Deloitte Insights. Retrieved December 15, 2022, from <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/human-capital/us-human-capital-organizing-for-innovation-081920.pdf> (2020 October 28).
- Embracing the digital mindset*. Material Handling Institute (MHI) Industry Report 2020. <http://2020.modexshow.com/seminars/assets-2020/100014.pdf>
- MHI. (2022 November 1). *Evaluation to revolution*. Material Handling Institute (MHI) Industry Report 2022. <https://www.six-15.com/wp-content/uploads/2022/10/mhi-industry-report-2022.pdf>
- Palmer, D. (2019). *Accelerating digital innovation inside and out*. *Deloitte Insights*, 6(4). Retrieved December 14, 2022, from https://www2.deloitte.com/content/dam/insights/us/articles/4930_MIT-SMR/Accelerating%20Digital%20Innovation%20Inside%20and%20Out.pdf
- Pham, K. (2022 November 24). *Omnichannel fulfillment: Retailer's success guide*. Magestore. <https://www.magestore.com/blog/omnichannel-fulfillment-the-key-of-growth/>
- Poot, T., Faems, D., & Vanhaverbeke, W. (2014). Toward a dynamic perspective on open innovation: A longitudinal assessment of the adoption of internal and external innovation strategies in The Netherlands. *International Journal of Innovation Management*, 13(20), 177–200. <https://doi.org/10.1142/S136391960900225X>
- Puri, K. (2022 October 13). *What are last-mile delivery costs? 7 ways to reduce them and boost last-mile delivery profits*. FarEye. Retrieved December 12, 2023, from <https://fareye.com/resources/blogs/last-mile-delivery-costs#>
- RSM. (2023 March 30). *Supply chain challenges guide: 4 ways to build resiliency*. Retrieved January 13, 2024 from <https://rsmus.com/insights/services/business-strategy-operations/supply-chain-challenges-guide.html>
- RSM & USCC. (2022 April 25). *U.S. middle market business index Q1-2022*. RSM and United States Chamber of Commerce (USCC). <https://rsmus.com/middle-market/mmbi.html>
- RSM. (2023). *Enhance your company's cash flow through an accounting methods study*. Retrieved January 5, 2023 from <https://rsmus.com/services.html>
- Salisbury, D. (2022 November 7). *16 days hospitalized: Summer E. coli outbreak linked to Wendy's takes toll on Michiganders*. MLive. Advance Local Media. <https://www.mlive.com/public-interest>
- Solaimani, S., & van der Veen, J. (2022). Open supply chain innovation: An extended view on supply chain collaboration. *Supply Chain Management*, 27(5), 59–7610. <https://doi.org/10.1108/SCM-09-2020-0433>
- Soosay, C. A., & Hyland, P. (2015). A decade of supply chain collaboration and directions for future research. *Supply Chain Management: An International Journal*, 20(6), 613–630. <https://doi.org/10.1108/SCM-06-2015-0217>
- Tkatchuk, R. (2017 September 13). *Is data the currency of the future?* CIO. <https://www.cio.com/article/230679/is-data-the-currency-of-the-future.html>

Vavra, B. (2019 February 5). *Data is the currency of the future: embrace digital manufacturing and use data to provide customer value*. <https://www.plantengineering.com/articles/data-is-the-currency-of-the-future>

Wrike Team. (2023 July 23). *Just in time production: A strategy for efficiency*. Wrike. Retrieved October 18, 2023, from <https://www.wrike.com/blog/just-in-time-production/>

PROOF ONLY