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Emerging Technologies in the Supply Chain Industry

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Today's supply chains are shaped by technologies that revolutionize efficiency, transparency, and decision-making. The rapid evolution of technology in the supply chain industry has transformed how businesses operate. New technologies that turn raw data into information and knowledge are changing the way the firms operate. Emerging technologies in supply chain include artificial intelligence, robotic automation, drones, big data, 3D printing, the Internet of things (IoT), blockchain, and predictive analytics. These technologies are improving supply chain efficiency, reducing costs, and enhancing customer experience. The global supply chain is continually evolving to keep up with the current era's frenetic technical breakthroughs. This paper highlights the challenges and barriers in the adoption of emerging technologies in the supply chain industry.

KEYWORDS: *technology, emerging technologies, supply chain, supply chain management*

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INTRODUCTION

For supply chain companies, technology is a strategic requirement and key differentiator for being competitive. Technology can have a significant impact on supply chains. Advanced technologies are shaking up the supply chain world. Technology is increasingly regarded as a key source of competitive advantage for supply chain leaders.

There are several technologies that are transforming supply chains for the organizations that adopt them. The impact and the relevance of the emerging technologies on the supply chains have attracted researchers and practitioners worldwide. With quickly evolving capabilities across generative artificial intelligence (AI), robotic automation, machine learning, Internet of things (IoT), blockchain and more, the "smart" supply chain is well on its way to becoming the new normal. The right technology solutions allow supply chain operations to make data-driven decisions and provide a competitive advantage.

A supply chain is a dynamic and complex process that includes provisioning, raw material supply, warehousing and the distribution of manufactured products to consumers. The impact of technology on supply chain management can take shape in a number of ways, including improving operations by increasing visibility, marrying disparate data sources to detect historical patterns, and enabling companies to more proactively anticipate potential challenges. We now expect Amazon to deliver in a day. Groceries are to be delivered in minutes. Online shopping, e-commerce and customer expectations along with the competition are driving the supply chain to bring the best of the technology to use. Figure 1 shows different components of supply chain [1].

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as "emergent." It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a "must-have" [2]. An emerging technology is the one that holds the promise of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [3]:

- *Novelty:* Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption:* Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty:* Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change:* Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. As emerging technologies continue to evolve, engineering is poised for a transformative future. Emerging technologies have driven innovation and progress in today's rapidly evolving digital landscape. The collective impact of emerging technologies such as artificial intelligence, machine learning, big data, and the Internet of things is undeniably transformative. Some emerging technologies are shown in Figure 2 [4].

WHAT IS A SUPPLY CHAIN?

The term "supply chain" describes the flow of goods from the first process encountered in the production of a product right through to the final sale to the end consumer. It involves all the activities involved in delivering a product from raw material through to the customer including sourcing raw materials, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer. There are dependencies between levels in channels from the point of origin to the point of consumption. The point of origin usually refers to suppliers or manufacturers and customers or end-users in a supply chain usually refer to the point of consumption.

Traditional approaches to the needs of global marketplaces are not going to be good enough. The changing customer expectations are forcing a re-appraisal of basic technological approaches in manufacturing and organizational principles. Today's consumers are increasingly sophisticated, educated, confident, and informed. They have high expectations from the products and services they receive, particularly with the speed of response, breadth, and depth of communication, and customization of product/service offerings.

Today, organizations can no longer compete solely as individual entities. They must rely on effective supply chains, or networks, to successfully compete in the global market and networked economy. The supply chain has three perspectives: the internal supply chain, the conversion process between departments, and two external supply chains, i.e. the relationships with customers and suppliers. Supply chains can be possible in both manufacturing and service organizations, and they are principally concerned with the flow of products and information between supply chain partners i.e. supply chain member organizations and distribution of those products to end customers.

Supply chains today are complex, fragmented and work very differently from a few years ago. Advanced technology in supply chain processes is revolutionizing global logistics, from inventory management and warehousing to last-mile delivery. These innovations are not only making operations faster and more efficient; they are also helping companies adapt to evolving customer demands and market complexities.

Supply chain management (SCM) is an important tool for managing products or services from their raw state to the finished state and managing after-sales services. It is the strategic coordination and

management of all activities involved in procuring raw materials, manufacturing, warehousing, and distributing finished products to the end customer. It is a critical function for companies of all sizes and industries, as it involves the coordination of materials, production, and distribution processes to meet customer demand. It is principally concerned with the flow of products and information between supply chain partners, i.e. supply chain member organizations. In the world of supply chain management, the winds of technological change are blowing stronger than ever. Figure 3 shows various components of SCM [5].

EMERGING TECHNOLOGIES IN SUPPLY CHAIN

We will examine the technologies that are making the biggest impact on supply chains around the world and could transform the supply chain for the better. These emerging technologies be the answer to the needs of supply chain right now. There are many emerging supply chain technologies, but the following are the most popular [6,7]:

1.*Artificial Intelligence:* Artificial intelligence is set to be a game changer with several use cases across supply chain operations. It can transform supply chains in two broad ways. First, it can automate most of the routine, time-consuming functions that teams are currently engaged in. Second, by decoding large volumes of data, AI can provide the intelligence needed to make well-informed decisions, enhance efficiency, and mitigate risks. AI enhances decision-making, operational efficiency, and customer satisfaction, cementing its role as a transformative force in modern supply chain operations. AI applications have transformed the landscape of technology in supply chain management by optimizing inventory systems. For example, companies are adopting AI-powered demand forecasting to address inventory challenges, allowing for better stock level optimization and waste reduction. Generative AI (GenAI) is a subset of AI that has the potential to revolutionize supply chain management, logistics, and procurement. GenAI can and teach itself about the nuances of any given company's supply chain ecosystem, allowing it to refine and sharpen its analysis over time. GenAI can help ensure procurement and regulatory compliance, streamline, and enhance the efficiency of manufacturing production workflows, or enable virtual logistics communication by using virtual assistants to handle routine inquiries and provide quick responses. AI and ML are technologies that can be used to analyze data in the supply chain and identify patterns and trends. They can be used to predict demand, optimize inventory, and improve delivery times. AI symbol is shown in Figure 4 [8].

2.*Robotic Automation:* Robots are designed to assist human labor by automating some operations. The robotics approach helps enterprises reduce human intervention and cut overall operating costs. There are two main ways that robotics has the potential to transform the supply chain. The first is in the warehouse. The second is on the road.

Warehouse robotics are not yet the norm. They are expensive, tricky to integrate with existing systems, and perceived as a threat to job security. Extensively used in inventory and warehouse management, robotic process automation is likely to be increasingly deployed across several supply chain functions, particularly those that are low value, high risk or potentially dangerous. Implementation is quicker and less expensive than more standard automation methods such as conveyor sortation or automated guided vehicles. Robotics, driverless vehicles, and drones benefit the manufacturing and warehousing industries in several ways. Robotics enabled with AI and ML augment the work of humans in warehouses and distribution centers. There are many types of robots used in supply chain. Collaborative robots like Chuck are programmed to guide users through specific tasks, and they also have built-in quality control measures like barcode readers to help reduce human errors and improve accuracy. Collaborative robots work with a warehouse's existing infrastructure, eliminating costly infrastructure upgrades and lengthy wait times to achieve ROI common with traditional warehouse automation solutions. Warehouse operators can rent additional collaborative robots to meet demand during peak periods and return the additional units when demand returns to normal. Smart autonomous vehicles and drones we used to hear about are robots allowing supply chain companies to optimize the delivery process and make it efficient. For example, Amazon has already had 520,000 robotic drive units worldwide and continues to increase their amount to ensure core delivery benefits it provides, such as a 30-minute delivery. Figure 5 shows robots in supply chain inventory [8].

3.*Drones:* Used to streamline inventory management, drones can scan barcodes on pallets and record the location of every item in a warehouse, automating the tedious and error-prone process of manual inventory counts. Drones are a safer alternative to manual inventory processes, eliminating the need for reach trucks, scissor lifts, and forklifts to access hard-to-reach inventory during inventory counts. Autonomous vehicles and drones are transforming last-mile

delivery by reducing human intervention and expediting delivery times. Companies like Amazon have been developing drone delivery services, aiming to integrate drones into their delivery network to offer faster and more efficient services. Similarly, Zipline operates the world's largest autonomous delivery system, specializing in on-demand drone delivery and instant logistics. Figure 6 shows a drone used for delivery [8].

4.*Internet of Things*: IoT became the main lifebuoy for supply chain companies since this technology creates a basis for adopting other innovations, like AI and ML. IoT improves visibility and connectivity while lowering expenses. The Internet of things (IoT), comprised of physical devices equipped with remote sensors that capture and transmit large amounts of data, is already making a big impact in the supply chain industry. Forward-looking businesses are increasingly using IoT to transform their complex supply chains into fully connected networks. IoT allows business leaders to keep the supply chain under control and respond to challenges timely. For example, companies can track products throughout the entire lifecycle with RFID and GPS sensors. IoT sensors provide real-time visibility into inventory levels, making it possible to identify sales trends and make more accurate projections to plan for future manufacturing or replenishment. Thanks to the ability to track the location of items in real-time during shipping, companies can deliver excellent customer service by providing customers with accurate delivery estimates and real-time location information. Industrial IoT (IIoT) shows tremendous promise for providing the real-time information needed to make better decisions about whether you can meet demand and about how to allocate your resources quickly enough to meet that demand. Many experts cite IoT as the most promising emerging technology solution for the cold food chain, such as shown in Figure 7 [9].

5.*Cloud Computing:* Cloud computing is an important part of the thriving global digital logistics market. Increased investments in cloud-based solutions indicate the growing preference to move data and workflows to cloud-based systems. “Cloud-based” is now among the most important characteristics for evaluating supply chain solutions. Cloud technology allows organizations to combine all supply chain and logistics information into a single, central solution. This eliminates data silos and strengthens information sharing through real-time communication. The biggest benefit of cloud technology is that it allows organizations to leverage large pools of IT resources without the need to build and maintain data center infrastructure. In the cloud, companies can deploy resources on an as-needed basis, rather than invest in additional servers and storage capacity. Cloud technology allows organizations to combine all supply chain and logistics information into a single, central solution.

6.*3D Printing:* 3D printing impacts the supply chain by supporting on-demand manufacturing, which results in inventory cost savings. Because 3D printing relies on digital files or blueprints of a product, developers and companies can implement new iterations in less time and at a lower cost. More than one in five manufacturers (22%) say they believe the restructuring of the supply chain will be the most significant change resulting from widespread adoption of 3D printing.

7.*Blockchain:* With the rising popularity of blockchain, it makes sense to follow the need for more supply chain visibility. A digital, decentralized ledger, blockchain records transactions in a series of blocks. Blockchain technology is transforming supply chain management by enhancing transparency, security, and efficiency. Its decentralized and immutable ledger system allows for real-time tracking of goods and verification of transactions, addressing long-standing challenges in the industry. Blockchain could resolve much of the friction present in the supply chain today. This friction arises from the multiple entities involved in the supply chain and the need to share information freely with those entities. Blockchain enhances supply chain transparency by creating an immutable, decentralized ledger that records every transaction across the network. The distributed nature of blockchain makes tampering difficult, as hackers or those with malicious intent would need to update all copies of the blockchain at precisely the same moment. All partners, suppliers, and other entities involved in a supply chain would need to buy into blockchain to realize the full potential of this technology. By tracking products from the point of origin to the end consumer, blockchain has promise for use in industries requiring excellent traceability. Several companies have successfully integrated blockchain into their supply chains. For example, OpenSC, a platform launched by WWF Australia and BCG Digital Ventures, uses blockchain to track products throughout their supply chain,

8. *Big Data:* The modern world of business runs and operates on the premise of big data. From collecting customer information to understanding consumer trends and market indicators, big data helps the business understand its place in the current market. Big data does not only find problems, it also looks to create solutions that can help minimize costs and

reduce human-induced working hours. Big data analytics can enable businesses to derive meaningful insights from the vast amount of data generated from different systems, operations, and geographies. Data analytics has become a cornerstone of modern supply chain management, offering insights that drive efficiency and strategic decision-making. Analytics can also combine internal data sources such as spend and contract data with supplier databases and other external data sources. These days, big data is more than just numbers and statistics, it is a way for a fleet management team to understand how they can navigate the challenging market while being resilient.

9. *Predictive Analytics:* A thing crucial for the supply chain industry is predictive analytics created based on information collected from IoT devices. Predictive analytics uses AI to forecast future trends. Predictive modeling, or predictive analytics, is a form of analytics that evaluates a set of historical and current data to identify patterns and behaviors, predict the most likely outcomes, and estimate the probability of different outcomes based on the data. Predictive analytics in the supply chain helps solve issues before they arise. Predictive analytics, for example, enables businesses to anticipate market trends and consumer behavior as well as proactive adjustments in procurement and production. It has many use cases in the supply chain. In manufacturing, predictive analytics supports predictive maintenance. Logistics managers leverage predictive analytics to determine the shortest and fastest route to a destination considering factors such as weather conditions, traffic delays, and vehicle data such as mileage. Predictive analytics can help warehouses and distribution centers optimize inventory, ensuring that there is enough stock on-hand to meet anticipated demand. Coupled with demand forecasting, predictive analytics enables warehouses to optimize inventory levels. By using predictive analytics to evaluate vendors on factors such as reliability, cost, and quality, companies can make data-driven procurement decisions and implement contingency plans to mitigate risk. AI-associated technologies can be used together with predictive analytics to streamline critical functions such as demand forecasting and planning. Technology that focuses on predictive analytics and historical sales analysis will be very important in the coming years.

10.*5G Network:* With IoT-enabled gadgets flooding the market, networks capable of handling massive numbers of devices are required. 5G enables a much larger number of devices to be connected to the Internet. The advent of 5G technology is set to revolutionize supply chain communications by providing faster data transmission, lower latency, and enhanced connectivity. For example, 5G networks facilitate enhanced asset tracking, allowing teams to monitor the movement of goods and materials in real time with unprecedented accuracy and efficiency. 5G's high-speed connectivity supports the deployment of autonomous vehicles and drones, further streamlining logistics operations. Figure 8 shows some 5G devices [10]. The transformation of networking from 4G to 5G is impressive as it is resulting in fruitful impacts across industries. 4G networks can accommodate 10,000 devices per square mile, whereas 5G networks can support 100 times that number.

Among these innovations, the Internet of things (IoT) and artificial intelligence (AI), including machine learning (ML), are particularly transformative. Other technologies used in supply chain include digital twins, weighing technologies, driverless vehicles, electronic data interchange (EDI), cybersecurity, fleet electrification, green supply chain, augmented reality, wearables, data fabric, and demand forecasting.

APPLICATIONS OF EMERGING TECHNOLOGIES

The number of supply chain technologies keeps proliferating. Emerging technologies accelerate innovation because it allows companies to move faster with more data. They will disrupt or alter industries and "established ways of doing things." Companies cite multiple reasons for investing in emerging technologies, including supporting new business, improving process efficiency and productivity, enhancing decision-making, and improving supply chain resiliency and agility. It is expedient to first clearly identify the needs of supply chain network partners in terms of competitive direction and customer satisfaction, and then try to find the solutions or emerging technologies that support those needs. Common applications of emerging technologies in supply chain include the following:

- *Pharma Supply Chain:* Pharmaceutical sector, being an integral part of the healthcare system, plays an important role in any modern economy. It is always associated with supply chain risks as a result of which it is more prone to disruptions The pharmaceutical supply chain processes are considered as the mediators and the emerging technology adoption barriers are proposed as the moderators. In the recent past, Industry 4.0 is a topic that is attracting researchers and practitioners in the pharmaceutical sector, particularly pharmaceutical supply chain management. Pharma 4.0 is regarded as the

pharmaceutical version of Industry 4.0. Pharma 4.0 adoption improves pharmaceutical supply chain processes and performance [11].

- *Construction Supply Chain:* Construction supply chain and procurement is a core artery in a project's lifecycle. It ranges across the planning, construction, delivery, and maintenance of projects in the built environment. Due to these benefits and opportunities, new technologies have increasingly attracted great attention from several industries including the AEC. With rapid advances in digitalization, the application of digital technologies for supply chain and procurement processes have been advocated to facilitate revolutionary innovations in the built environment. Themes such as digital construction, digital integration concepts, and security are identified, with blockchain-smart contracts being the most recent trend in construction supply chains [12].
- *Intelligent Systems:* The days of siloed supply chain systems are numbered as the industry enters the era of purpose-built intelligent applications. It is becoming more evident that purpose-built intelligent applications are increasingly shaping the future of supply chain technology. This represents a wholesale departure from the monolithic and project approaches of the past. In the supply chain model, the purpose-built intelligent AI applications can read descriptions, identify items, and confirm quantities. With multiple lessons learned over the past few years, purpose-built intelligent applications are creating the connective tissue that solves specific problems by weaving together disparate systems of records and transactions [13].
- *Supply Chain as a Service* (SCaaS): Most of the SCM operations are still under the vision of in-house staff people. However, we may see more organizations embrace "supply chain as a service" (SCaaS) business models and outsource tasks such as manufacturing, shipping, and inventory management. Figure 9 shows SCaaS distribution [10].
- *Real-time Visibility*: Real-time visibility in the supply chain means being able to track and watch products at every point in the supply chain as it happens. This gives companies an up-to-date picture of where their goods are and in what condition. Real-time visibility is important at every stage to maintain a competitive edge. It is the ability to track goods and products as they move through the supply chain network in real-time. This is important because it helps companies identify and address bottlenecks and inefficiencies, improve operational efficiency, and enhance customer satisfaction. The time has come that we explore and use emerging technologies extensively for real-time visibility in the supply chain. Emerging technologies such as the Internet of things (IoT), artificial intelligence (AI), machine learning (ML), and cloud computing are transforming how we track products and shipments in real time. Blockchain technology is another technology that can enable real-time visibility in the supply chain. Real-time visibility means monitoring the exact location and conditions of goods at any moment, allowing for instant problem-solving and cost-saving. This is really helpful because if something goes wrong or gets delayed, businesses can see that instantly and do something about it. Companies can use blockchain to create a tamper-proof record of transactions in the supply chain, from the origin of the product to the final destination. This real-time visibility can help to reduce fraud, errors, and delays in the supply chain, leading to improved efficiency and reduced costs. By using supply chain visibility software, companies get a much better handle on where their current goods in transit are and when they are expected to arrive. Figure 10 shows the role of technology on real-time visibility in supply chain [14].

BENEFITS

Deploying emerging technologies allows manufacturers to gain real-time insights that can help them avoid waste that comes from machine malfunctions or process errors, which in turn helps reduce carbon emissions and improve worker safety. By leveraging these technologies, companies can differentiate their products, ensure superior quality and elevate the customer experience, ultimately staying ahead of the curve. The integration of technology in supply chain has driven significant advancements in operational efficiency. It is revolutionizing supply chain management, enhancing efficiency, accuracy, and responsiveness. Emerging technologies are transforming how we track products and shipments in real time. The biggest benefits of technology in supply chains management come from reducing costs, improving customer service, and increasing operational efficiency. Other benefits include the following [15,16]:

- *Automation:* Most supply chain tasks can be fully or partly automated through low-code platforms, which use a wide range of application programming interfaces (APIs) and pre-packaged integrations to link previously separate systems.

AI automates tasks like reordering supplies and adjusting stock based on real-time market conditions, saving time and resources. Robotics, AI, and machine learning streamline and optimize supply chain processes. Organizations will continue to accelerate the automation of the logistics transport value chain, especially those that remain costly or manual, such as processing of air freight and last mile delivery.

- *Intralogistics Robots:* Intralogistics robots are devices that can be operated autonomously, reprogrammed, multi-purposed (capable of being converted to a new use with physical modification), and programmable in three or more axes. Intralogistics robots greatly increase warehouse automation and efficiency, resulting in speedier operations and the capacity to handle demand surges considerably better.
- *Humanoid Working Robots:* Next-generation humanoid robots "combine sensory awareness with mobile manipulation and dynamic locomotion" to perform productive work that was previously carried out by humans. These robots will typically imitate the human body with a head that has sensors and cameras for sensing its environment; a body that houses the power and mechanicals; arms and hands for grasping, manipulating and carrying items; and legs for dynamic locomotion.
- *Customer Satisfaction:* In the competitive landscape of modern commerce, leveraging technology to enhance customer satisfaction is paramount. Innovations in big data analytics and delivery systems are enabling businesses to offer personalized experiences and improve service efficiency in order to meet and exceed customer expectations.
- *Delivery Speeds:* Advancements in logistics technology, such as autonomous delivery vehicles and drones, are substantially improving delivery speeds and accuracy. These technologies reduce the need for human intervention and allow for faster, more precise deliveries. The integration of GPS technology in logistics has become a game-changer, boosting delivery speed and customer satisfaction by providing real-time tracking and optimized routing.
- *Composite AI:* Composite AI is defined as the combined application of multiple AI techniques to improve the efficiency and accuracy of learning, broaden the level of knowledge representations and solve a variety of business problems that drive supply chain performance improvements.
- *Digitized Quality Check Process:* Enterprises use intelligent hardware to reduce manual work and the risk of human error. They entrust the quality check to machines capable of detecting any damages owing to the image recognition feature. Consequently, it helps companies to fulfill the delivery obligations under partners properly.
- *Fraud Prevention:* Based on real-time data and relevant algorithms, devices can analyze the supply chain process and notify managers in case of any deviation. ML helps to track goods movement, location, and storage. Such transparency helps businesses to prevent fraud and deliver items of needed quality and quantity.
- *Elimination of a Last-Mile Issue:* The last-mile delivery is always the most expensive for companies. Autonomous vehicles and drones streamline last-mile delivery. Machine learning can analyze delivery addresses and optimize routes to help enterprises kill two birds with one stone: achieve timely shipping and cut costs. Traffic congestion in city centers caused by the increase in last-mile delivery initiatives in logistics is an environmental issue that companies must deal with.
- *Shipment Tracking:* This tracking has improved dramatically with the increased availability of low-cost GPS devices giving shippers the ability to quickly and easily verify the location of their freight as well as check on delivery times and potential delays. With the current offerings of tracking apps and automated email notifications, shippers should strongly consider requiring the carriers they work with to have some sort of automated tracking alert system or an online web-based shipment tracking portal.
- *Transportation Management Systems* (TMS): TMS systems are a great way for shippers to better organize and consolidate their inventory levels. Freight moments are one-easy-to-use computer systems; there are many TMS systems that provide document management for shipment documents and shipment management tools as well.
- *Predictive Maintenance:* This is a preventative technique that uses machine learning technologies and sensors to track how machines and systems are functioning. Predictive maintenance is able to foresee when a machine is likely to develop issues in the near future so that maintenance can be done before any breakdowns. Supply chain operations become more resilient knowing that all machines and robotics are working efficiently.

CHALLENGES

In today's global market, supply chains face numerous challenges that can disrupt operations and impact business continuity. For many companies, stepping out into the wilderness of selecting the right solution for their business can be daunting. There are too many industrial tech providers to count and it may be hard to figure out which vendors can help your company and which vendors are just pushing marketing jargon. Supply chain failures could gave global ripple effects across industries when it comes to key components when it comes to our daily lives. Supply chains are complex and disruption is becoming the norm. Other challenges include the following [15,16]:

- *Cybersecurity:* The increasing digitization of supply chains has heightened vulnerability to cyberattacks, which can lead to considerable operational disruptions and financial losses. For example, the National Institute of Standards and Technology (NIST) emphasizes the importance of managing cybersecurity risks in supply chains to ensure the integrity and resilience of products and services. Cybersecurity technologies like encryption and automatic alerts help reduce risk without slowing supply chain efficiency.
- *Cyber Extortion:* Cyber criminals are highly successful when it comes to executing ransomware attacks to extort funds from supply chain organizations. It is highly likely they will harness the power of AI to generate advanced attack tools, making their attacks even more effective. Supply chain technology leaders should collaborate with IT leadership to confirm ransomware attack scenarios are included in the corporate risk management processes and develop a detailed ransomware incident response playbook.
- *Disruption:* Whether due to natural disasters, geopolitical tensions, or other unforeseen events, supply chain disruptions can have severe consequences on business operations. For example, implementing a multitier inventory system, where key parts are held in reserve at different supply chain levels, can help minimize the risk of a single point of failure.
- *Transparency*: The lack of visibility across the layered tiers of a supply chain has major implications for organizations across industries, particularly for meeting regulatory requirements, and for the identification and mitigation of supply chain risks. By utilizing blockchain, companies can create a tamper-proof record of each transaction within the supply chain. This transparency ensures that all parties have access to the same information, in turn reducing disputes and elevating trust. For example, blockchain's ability to interface with emerging technologies like the IoT and smart contracts further secures the supply chain by automating processes and providing real-time data.
- *Data:* Data is still one of the core challenges facing supply chain management. Each day millions and millions of records are generated across the supply chain from multiple systems. This wealth of data has given rise to greater silos of data within the organization which in turn has led to disconnected data sets. Duplication and misinterpretation will become increasingly problematic. Critically, the fragmentation of data impedes the creation of a holistic view of the organization's supply chain. Consequently, data availability, quality, cadence, and consistency are now critical considerations.
- *Data Governance:* The emergence of powerful tools for advanced analytics and AI techniques is massively scaling the capabilities for cross-functional visibility, scenario modelling, and decision automation. As those technologies are increasingly adopted, the importance of maintaining a high level of data quality and strict governance process is becoming business mission critical.
- *Sustainability:* Sustainability has become one of the most crucial factors for the success of supply chain management businesses. Previously, linear supply chains caused waste by discarding unused components after producing a product. Sustainability-related legislation is growing globally, driving a shift from voluntary to mandatory compliance. As a result, the accuracy of sustainability data must be uplifted from indicator to investment grade, thus meeting stakeholder requirements while also driving internal decision making.
- *Fuel Consumption:* For some companies with large fleets, fuel consumption and cost are perhaps one of the biggest burdens they may have. For smaller freight companies and courier businesses, the rampant cost of fuel is not only hurting them financially, but also impacting the routes they are able to take, and deliveries they can complete. With software integration, fleet teams can assess fuel consumption on various routes and trucks at the same time. Although it is possible to manually assess fuel consumption, software provides more real-time data and tracking for fuel management.

CONCLUSION

The increased use of emerging technologies such as artificial intelligence, machine learning, and Internet of things is reshaping and improving supply chains. Enabled with a raft of technology developments, a new paradigm is emerging in supply chain management. If emerging technologies like artificial intelligence, robotics, and drones reach fruition, we could be looking at a much smoother operation than the last few years have given us. With a future that promises autonomous, self-learning machines seamlessly managing the broader supply chain process, now is the time for organizations to overcome the inherent silos and enterprise systems that will restrict their progress.

Whether it is big data or artificial intelligence, technology plays a significant role in the overall well-being of any business. Future technology in supply chain can be exciting. Technology will continue to be more widely adopted and deployed within the supply chain sector. There is the need for supply chain leaders to leverage emerging technologies to control and protect their businesses. Though it might be challenging for supply chain managers and business leaders to keep up with the technological developments, it is critical to do so in order to preserve supply chain resilience and boost your company's performance. More information about emerging technologies in the transportation can be found in the books [17-23].

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Figure 1 Different components of supply chain [1].

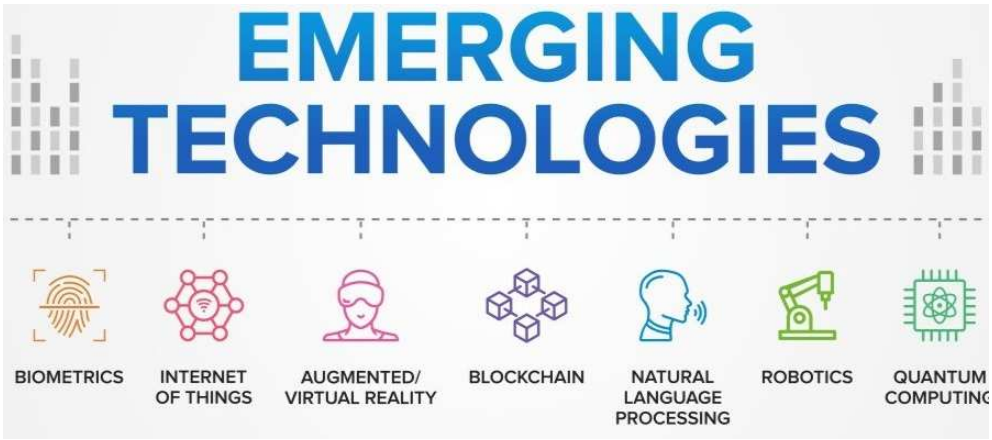

Figure 2 Some emerging technologies [4].

Figure 3 Various components of SCM [5].

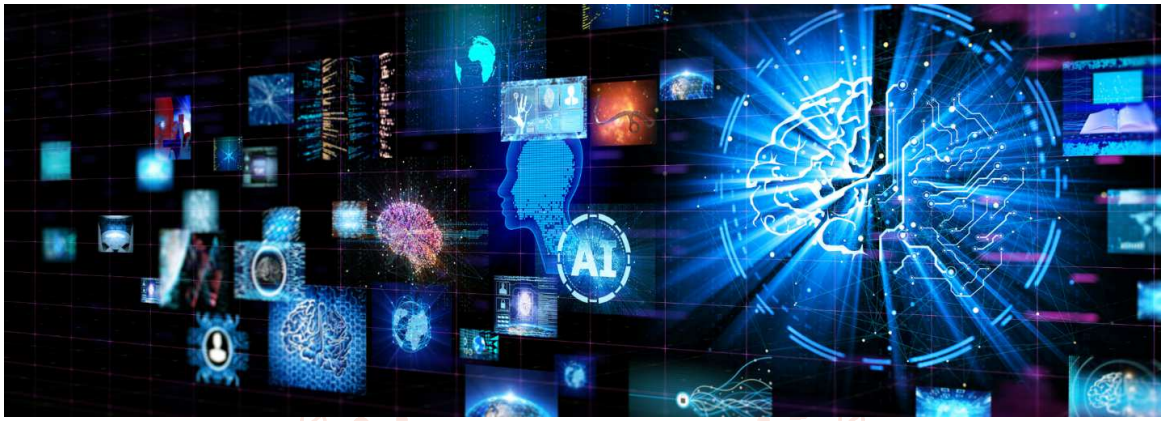

Figure 4 AI symbol [8].

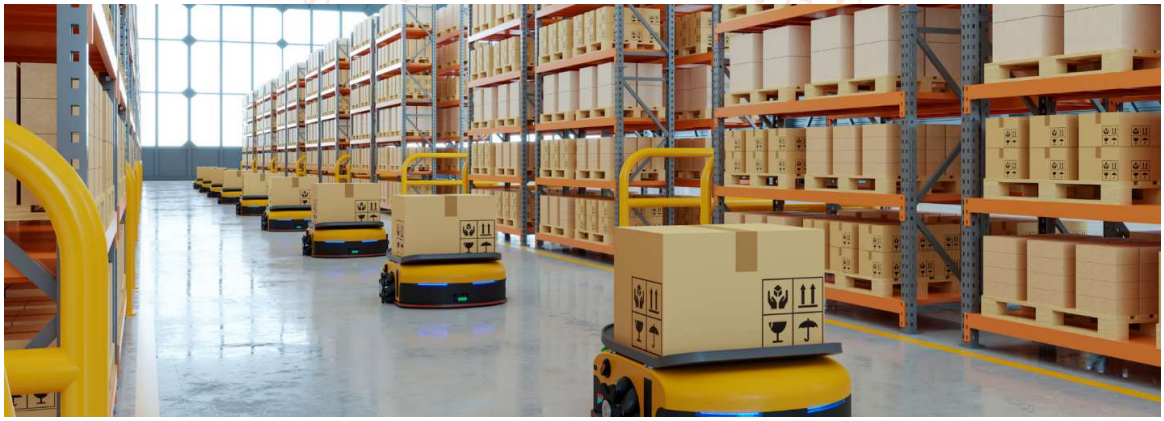

Figure 5 Robots in supply chain inventory [8].

Figure 6 A drone used for delivery [8].

Figure 7 IoT is the most promising technology solution for the cold food chain [9].

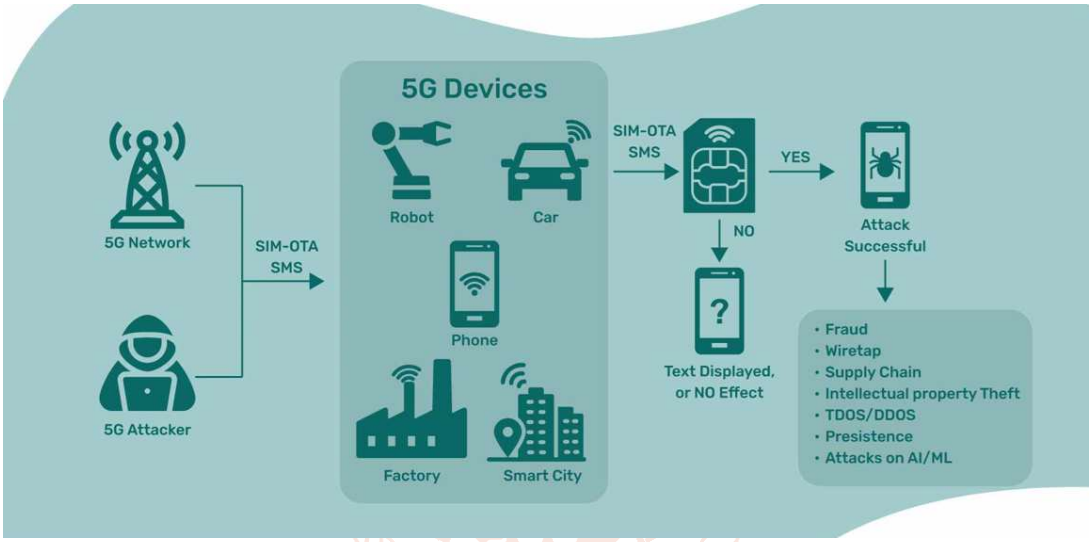

Figure 8 Some 5G devices [10].

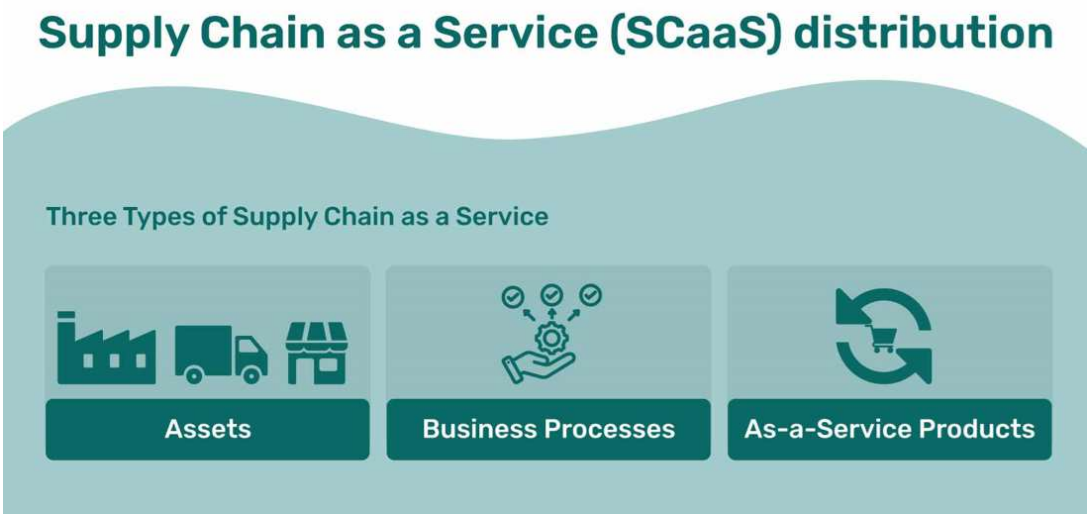

Figure 9 SCaaS distribution [10].

Figure 10 Role of technology on real-time visibility in supply chain [14].