

Supply Chain Optimization in the Digital Age: A Big Data Analytics Perspective on Resilience and Efficiency

Nguyen Van Anh

nguyen.vananh@hueagrii.edu.vn

Aw Yoke Cheng

awyokecheng@gmail.com

Abstract

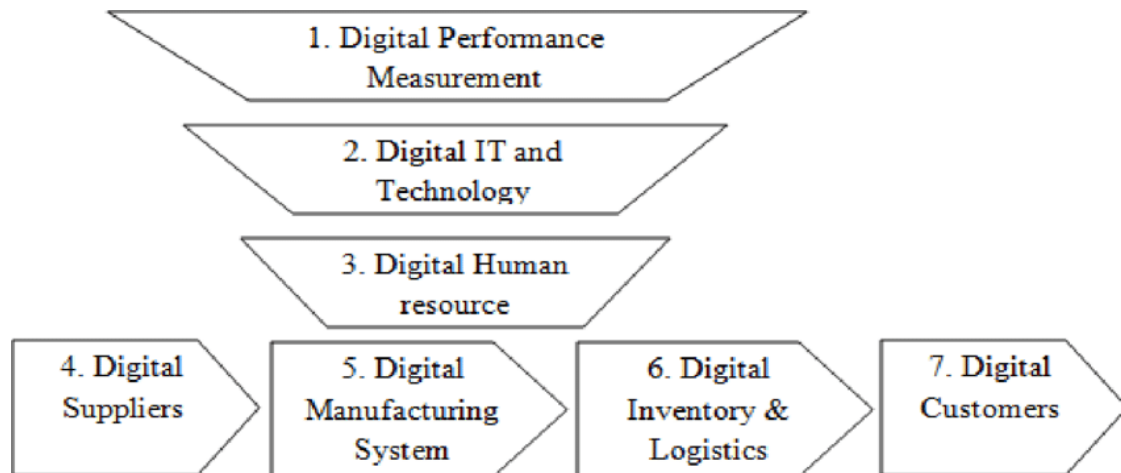
In the digital age, supply chain optimization has become imperative for businesses to remain competitive and adaptable in the face of dynamic market conditions. This paper explores the evolving concept of supply chain optimization in the digital age, emphasizing the pivotal significance of resilience and efficiency. Resilience, the ability to withstand disruptions and recover swiftly, is a core component in managing unforeseen adversities, which have become increasingly common in the global marketplace. Simultaneously, efficiency remains a foundational principle, facilitating cost control and enhancing customer satisfaction. The paper examines the symbiotic relationship between resilience and efficiency, illustrating how these two components can be harmoniously integrated into a comprehensive supply chain optimization strategy. We delve into the technological enablers of this transformation, including big data analytics, the Internet of Things, artificial intelligence, and blockchain, which provide essential tools for decision-making, transparency, and automation. The key to navigating the challenges and opportunities of modern supply chain management lies in understanding how organizations can leverage resilience and efficiency. By fostering a resilient and efficient supply chain, organizations can ensure agility and responsiveness to adversities and market dynamics. This paper provides valuable insights and strategies for organizations seeking to thrive in the digital age's transformative landscape.

Keywords: Supply Chain Optimization, Digital Age, Resilience, Efficiency, Disruptions, Big Data Analytics, Internet of Things, Artificial Intelligence, Blockchain.

Introduction

In the contemporary landscape of global commerce, supply chain management has emerged as a pivotal domain, one that plays a transformative role in the efficient functioning of businesses across industries. The convergence of globalization and technological advancements has ushered in the digital age, revolutionizing traditional supply chain practices. This introduction seeks to elucidate the evolving concept of supply chain optimization in the digital age, underscored by the paramount importance of resilience and efficiency. It aims to set the stage for the subsequent discussion within this paper by shedding light on the shifting paradigms of supply chain management, their relevance, and the broader context within which they operate [1].

Figure 1.



Supply chain optimization in the digital age represents the amalgamation of time-tested supply chain principles with cutting-edge digital technologies. It signifies the systematic and strategic use of these technologies to streamline, enhance, and adapt supply chain operations in the face of ever-evolving market dynamics and customer demands [2]. This evolution is driven by factors such as big data analytics, the Internet of Things (IoT), artificial intelligence, and blockchain, which provide a robust foundation for decision-making, transparency, and automation. Consequently, organizations are now tasked with the imperative to not only meet customer expectations but also to anticipate and exceed them in an environment that demands precision, speed, and adaptability. Resilience and efficiency have emerged as twin pillars that underpin supply chain management in this digital era. Resilience, characterized by the ability to withstand disruptions and swiftly recover, has gained prominence due to the increasing frequency and severity of unexpected events, such as natural disasters, economic downturns, and supply chain disruptions caused by unforeseen global crises. Efficiency, on the other hand, remains the bedrock of supply chain operations, with its continued significance in controlling costs and improving customer satisfaction. In the context of this discussion, resilience ensures the supply chain's robustness, while efficiency guarantees cost-effectiveness and customer satisfaction, collectively forming a dynamic equilibrium [3].

The purpose of this paper is to delve deeper into the intricate interplay between resilience and efficiency in the context of supply chain optimization within the digital age. By doing so, this paper aims to provide an insightful understanding of how organizations can leverage these two facets to navigate the challenges and opportunities of modern supply chain management [4]. It explores the strategies, technologies, and best practices that organizations can adopt to foster a resilient and efficient supply chain, ensuring it remains agile in the face of adversities and responsive to ever-changing market dynamics. To accomplish this objective, the paper is structured as follows: The subsequent section provides an in-depth examination of the significance of resilience in supply chain management, elucidating its relevance in the face of disruptions and uncertainties [5]. The subsequent section dissects the pivotal role of efficiency and its contribution to cost control and customer satisfaction within the supply chain. Afterward, the paper will explore the symbiotic relationship between resilience and efficiency, highlighting how these two elements can be integrated into a comprehensive supply chain optimization strategy. Finally, the paper will conclude with a summarization of key insights and future prospects in the realm of supply chain optimization in the digital age, serving as a valuable reference for organizations seeking to thrive in this transformative landscape. In essence, the paper aims to equip readers with a comprehensive understanding of the evolving dynamics of supply chain management, emphasizing the critical roles that resilience and efficiency play in ensuring a competitive advantage in the digital age [6].

The Digital Transformation of Supply Chains

The digital transformation of supply chains has emerged as a pivotal facet of modern business operations, catalyzed by the rapid integration of advanced technologies. This transformation represents a paradigm shift, revolutionizing the way goods and services move from producers to consumers. The impact of digital technologies on modern supply chains is multifaceted, redefining

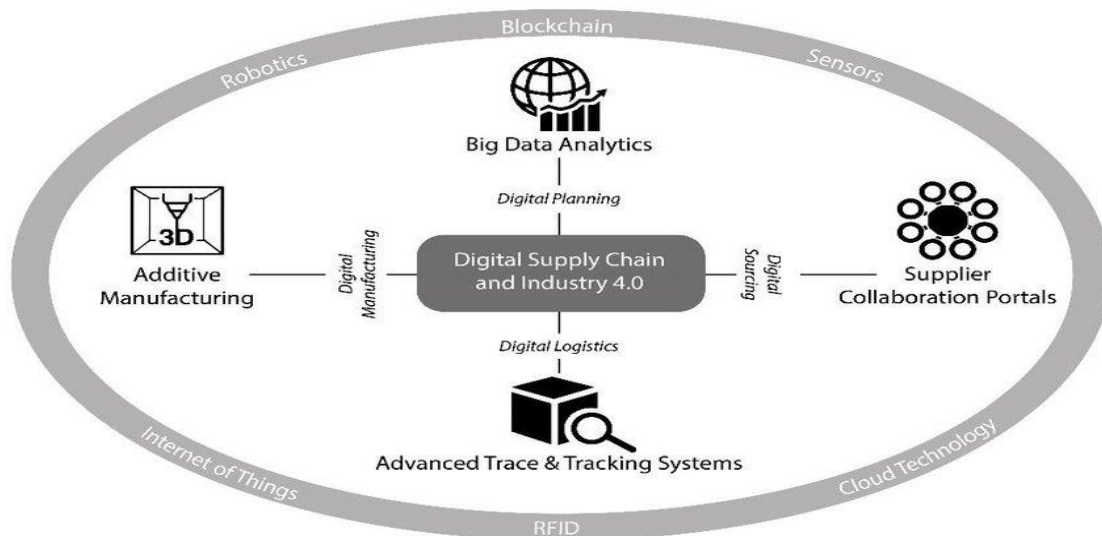
logistics, improving efficiency, and enhancing overall competitiveness. Digital technologies have streamlined supply chain processes, from procurement to distribution, and have enabled real-time data analysis, resulting in greater operational efficiency. Automation, the Internet of Things (IoT), and artificial intelligence (AI) have enabled predictive analytics, allowing companies to anticipate demand fluctuations and optimize inventory management. As a result, lead times have been reduced, and the risk of stockouts minimized, leading to improved customer satisfaction [7].

Key drivers behind the adoption of digital tools in supply chains include the imperative to enhance agility and responsiveness in an increasingly dynamic market. Market globalization and heightened customer expectations have necessitated a more adaptable supply chain. Digital tools provide the means to swiftly adapt to changing market conditions, whether it's sudden surges in demand or disruptions in the supply chain, such as the challenges posed by the COVID-19 pandemic. Additionally, sustainability concerns and the drive to reduce the environmental footprint have led to the adoption of digital technologies for optimizing transportation routes and minimizing waste. Numerous companies have reaped the benefits of digital transformation in their supply chains. Amazon, the e-commerce giant, exemplifies how digital technology enables efficient fulfillment and delivery [8]. Through its extensive use of automation, machine learning algorithms, and sophisticated logistics networks, Amazon has set new standards for rapid and reliable order fulfillment. The pharmaceutical industry also illustrates the advantages of digitalization. Companies like Pfizer have utilized blockchain technology for secure and transparent tracking of their products, ensuring authenticity and compliance with regulatory standards. Another noteworthy example is Walmart, which employs data analytics to optimize its inventory and distribution systems, resulting in substantial cost savings and streamlined operations [9].

Big Data Analytics in Supply Chain Management

Big data analytics is a technical approach that leverages advanced data processing techniques and tools to extract valuable insights and make informed decisions from vast and complex datasets. In the context of supply chain management, big data analytics plays a pivotal role in optimizing various aspects of the supply chain. It involves the collection, processing, and analysis of a wide range of data types, from structured to unstructured, to improve operational efficiency, enhance decision-making processes, and increase visibility throughout the supply chain.

Figure 2.



One of the key elements in understanding the role of big data analytics in supply chain optimization is its ability to harness data from various sources. Supply chains generate a plethora of data at every stage, including production, transportation, warehousing, and customer feedback. Data sources in the supply chain encompass structured data like order records, inventory levels, and transportation logs, as well as unstructured data such as social media sentiment, customer reviews, and weather data. Moreover, data can be sourced from Internet of Things (IoT) devices, sensors, and even external databases. The integration and analysis of these diverse data sources offer profound

benefits in supply chain management. Big data analytics can enhance decision-making by providing real-time insights into inventory levels, demand forecasting, and supplier performance. With the ability to process and interpret data rapidly, supply chain professionals can make informed decisions, reducing stockouts, overstocking, and other inefficiencies. Furthermore, big data analytics contributes to improved visibility by enabling end-to-end tracking and monitoring of goods throughout the supply chain [10]. This transparency helps in identifying bottlenecks, inefficiencies, and potential disruptions, allowing for timely adjustments and reducing operational risks [11].

Resilience in Supply Chains

In the realm of supply chain management, resilience pertains to the capacity of a supply chain to withstand and recover from disruptions while maintaining the flow of goods and services. In essence, it is the ability to adapt and rebound in the face of unforeseen challenges and adverse events. Resilience encompasses a broader spectrum of aspects such as flexibility, redundancy, and risk management, which collectively enable a supply chain to continue its operations efficiently. Supply chains today confront a multitude of challenges and risks, making resilience an imperative consideration. Firstly, globalization has led to an interconnected web of suppliers and manufacturers spread across the globe. This interdependence makes supply chains susceptible to disruptions due to factors like political instability, natural disasters, and economic downturns in different parts of the world [12]. Moreover, the rapid advancement in technology and increasing customer expectations have given rise to shorter product life cycles, which, in turn, can intensify supply chain vulnerability. Additionally, supply chains encounter risks related to regulatory changes, cyber threats, and resource scarcity, all of which can have far-reaching consequences. The significance of resilience in supply chains cannot be overstated. The ability to bounce back swiftly from disruptions ensures business continuity. In today's competitive market landscape, where customer expectations are high, even minor disruptions can have a detrimental impact on a company's reputation and profitability. Resilience in supply chains translates into uninterrupted delivery of products or services, which bolsters customer trust and brand integrity. Furthermore, a resilient supply chain aids in cost reduction through efficient risk management and optimized resource allocation, ultimately leading to enhanced profitability. It also allows businesses to stay ahead of the competition by adapting to changes and seizing opportunities, thereby fostering long-term sustainability [13].

Efficiency in Supply Chains

Efficiency in supply chain operations is a critical element in today's complex global business landscape. It refers to the ability to deliver goods or services to end-users in a cost-effective manner while minimizing waste and maximizing productivity. Achieving efficiency in supply chains is essential for organizations to remain competitive, enhance customer satisfaction, and sustain profitability. This efficiency is measured through various key performance indicators, such as cost per unit, on-time delivery, and inventory turnover. Common bottlenecks and inefficiencies in supply chains can arise at various stages of the process. One common bottleneck occurs in the procurement phase, where delays in sourcing materials or components can disrupt the entire chain. Inventory mismanagement is another issue, as excessive stock can tie up capital, while insufficient stock can result in production delays. Transportation is a significant source of inefficiency due to issues like delays, damages, and suboptimal routing. Inaccurate demand forecasting can lead to overproduction or underproduction, adding to inefficiencies. Poor communication between supply chain partners, lack of visibility, and the use of outdated technologies can also contribute to inefficiencies [14].

Data analytics plays a crucial role in driving efficiency improvements in supply chain operations. By leveraging data from various sources, organizations can gain insights into their operations and make informed decisions. This includes using historical data to improve demand forecasting accuracy, allowing for more efficient inventory management and reducing overstock or stockouts. Predictive analytics can help identify potential disruptions, enabling proactive measures to mitigate them. Real-time tracking and monitoring of shipments through IoT devices and GPS technology enhance visibility and reduce transportation-related inefficiencies. Furthermore, analytics can be

used to optimize routing, scheduling, and resource allocation. Advanced analytics techniques, such as machine learning and artificial intelligence, can provide even deeper insights into supply chain efficiency. These technologies can analyze vast datasets to identify patterns, detect anomalies, and predict future trends, thus allowing for more precise decision-making. They can also optimize production schedules and warehouse operations, reducing lead times and improving overall efficiency. Moreover, data analytics can enable the identification of underperforming suppliers or partners, leading to better collaboration and performance improvements [15].

The Intersection of Resilience and Efficiency

Resilience and efficiency represent two pivotal facets in the realm of supply chain management, each having its unique set of advantages and trade-offs. The interconnection between these two factors, when approached with a strategic perspective, offers a compelling framework to navigate the complex landscape of modern supply chains. Resilience in the supply chain denotes the ability to adapt and recover swiftly from disruptions, whereas efficiency seeks to optimize processes to reduce costs and enhance productivity. The intersection of these two concepts necessitates a judicious equilibrium to achieve optimal performance, as focusing solely on one at the expense of the other can expose vulnerabilities. Resilience, in the context of supply chain management, is exemplified by the capacity to mitigate and manage risks [16]. A resilient supply chain can weather unexpected disruptions such as natural disasters, geopolitical tensions, or pandemics. An instance of this is the Japanese automotive manufacturer Toyota, which introduced the concept of "Just in Time" production. Toyota developed a highly efficient supply chain that reduced inventory costs significantly. However, the 2011 Tohoku earthquake exposed a fragility in their supply chain, causing widespread disruptions. In response, Toyota recalibrated its approach to strike a balance between resilience and efficiency by incorporating redundancies in the supply chain and diversifying suppliers to ensure a more robust system.

Efficiency, on the other hand, focuses on streamlining processes and cost-effectiveness. Amazon, a global e-commerce giant, is a notable illustration of how a focus on efficiency can lead to supply chain dominance. Through the implementation of advanced technologies and data-driven analytics, Amazon optimized its distribution network, allowing for rapid delivery and lower operational costs. However, it is imperative to acknowledge that this extreme efficiency sometimes results in limited flexibility and vulnerability to disruptions, as seen during the COVID-19 pandemic, when the demand surged exponentially, challenging the robustness of the supply chain [17].

The synergy between resilience and efficiency is not about choosing one over the other but rather about leveraging each aspect in harmony. An exemplary case is the response of pharmaceutical companies in the face of the COVID-19 pandemic. While the urgency necessitated a rapid vaccine development, supply chains had to balance efficiency to ensure swift production with the need for resilience to mitigate unforeseen challenges. Collaborative efforts and diversified supply chain networks were employed to ensure efficient distribution and quick adaptation to unexpected supply disruptions [18].

Case Studies

In the realm of contemporary business operations, the utilization of big data analytics to enhance the resilience and efficiency of supply chains has become an imperative strategic approach. This section delves into a collection of case studies, shedding light on how various organizations have adeptly harnessed big data analytics to fortify their supply chains while concurrently boosting operational efficiency.

Amazon, the e-commerce giant, stands as an exemplar of successful implementation of big data analytics in its supply chain management. The company leverages massive volumes of data from customer orders, inventory levels, and logistical operations to forecast demand accurately. These predictions are used to optimize inventory positioning across its vast network of warehouses, which in turn minimizes shipping times and costs. Amazon's data-driven approach has significantly enhanced its resilience by enabling quick adjustments in response to fluctuations in demand and unforeseen disruptions. This case showcases the pivotal role of data analytics in creating a highly agile and efficient supply chain.

Walmart, a global retail leader, has achieved supply chain excellence through the application of big data analytics. The company employs advanced analytics to track consumer buying patterns and align inventory levels accordingly. By integrating point-of-sale data, weather information, and social media trends, Walmart can prepare for sudden surges in demand or weather-related disruptions. Moreover, their data analytics-driven system enables the minimization of excess stock, reducing holding costs and minimizing waste. As a result, Walmart maintains a responsive, cost-effective, and resilient supply chain that adapts swiftly to market changes.

In the realm of maritime logistics, Maersk, the world's largest container shipping company, has harnessed big data analytics to enhance supply chain resilience and efficiency. Maersk uses data analytics to optimize vessel routes, cargo loading, and port operations. By analyzing historical weather patterns, traffic at ports, and real-time data on ships, Maersk can navigate its vessels more efficiently and anticipate potential delays. This data-driven approach has allowed Maersk to reduce fuel consumption, lower shipping costs, and maintain reliable schedules, even in the face of unpredictable events like severe weather or geopolitical disruptions [5], [19].

Zara, a prominent fast-fashion retailer, has revolutionized its supply chain using big data analytics. The company utilizes data from in-store sensors, online sales, and social media feedback to respond swiftly to consumer preferences and market trends. Zara can quickly adjust its production schedules, reducing lead times, and ensuring that its stores are stocked with the latest fashion trends. This data-driven agility has bolstered the company's supply chain resilience by minimizing excess inventory and maximizing customer satisfaction [20].

Challenges and Future Trends

The implementation of big data analytics for supply chain optimization presents several significant challenges and obstacles that organizations need to address. Firstly, one of the foremost challenges is the integration of data from various sources and systems. Supply chain operations generate vast amounts of data from different touchpoints, such as manufacturing, logistics, and sales, making it imperative to harmonize and consolidate this data for meaningful analytics. This requires a robust data integration strategy and infrastructure, which can be resource-intensive. Secondly, data quality and accuracy are paramount in big data analytics. Inaccurate or incomplete data can lead to erroneous insights, impacting decision-making. Maintaining data integrity and ensuring the consistency of data across the supply chain is a persistent challenge. Data cleansing and validation processes are essential to mitigate this issue. Another challenge is the selection of appropriate analytical models and algorithms. Supply chains are inherently complex, and choosing the right analytics techniques to optimize operations can be daunting. Furthermore, organizations often struggle to find or develop talent with the requisite expertise in data science and analytics. A shortage of skilled professionals in this field remains a challenge [21].

Privacy and security concerns are also a significant hurdle. Supply chain data often includes sensitive information about partners, customers, and proprietary processes. Ensuring data privacy and safeguarding against cyber threats is an ongoing challenge in the era of big data analytics. Compliance with data protection regulations, such as GDPR or CCPA, adds complexity. In the realm of future trends, several factors are poised to shape the future of supply chain management. One notable trend is the growing influence of artificial intelligence (AI) and machine learning. AI-driven predictive analytics can enhance demand forecasting, route optimization, and inventory management, leading to more agile and efficient supply chains.

Blockchain technology is another emerging trend with the potential to transform supply chain management. It offers an immutable and transparent ledger for tracking products and transactions, reducing fraud and enhancing traceability. This can be particularly crucial in industries where product authenticity and origin are vital, such as food and pharmaceuticals. The Internet of Things (IoT) is expected to play a significant role as well. IoT devices can provide real-time data on the condition and location of goods in transit, enabling proactive decision-making and improving supply chain visibility. This, in turn, can lead to quicker responses to disruptions and improved customer service. Sustainability and environmental concerns are becoming central in supply chain management. Companies are increasingly focusing on reducing carbon footprints and ensuring ethical sourcing practices. Eco-friendly supply chain strategies, such as sustainable sourcing and

green logistics, are expected to gain traction in the coming years, driven by both consumer demand and regulatory pressures [22].

Conclusion

This paper has shed light on several crucial aspects of supply chain optimization, focusing on the significant role of adopting a big data analytics perspective. The key takeaways from this paper can be summarized into three major points: the transformative potential of big data analytics in supply chain management, the critical factors for building resilient and efficient supply chains, and the imperative for businesses to adapt to the digital age. These insights underscore the necessity of embracing data-driven strategies and technological advancements to meet the challenges and opportunities that modern supply chains face. First and foremost, the utilization of big data analytics in supply chain management has demonstrated its transformative potential. By harnessing the power of data, organizations can gain deeper insights into their operations, allowing for improved decision-making and risk management. Data analytics enables companies to optimize their inventory management, enhance demand forecasting, and streamline distribution networks [23], [24]. It also aids in monitoring the performance of suppliers and logistics partners, ultimately contributing to the reduction of operational costs and enhancing overall efficiency. The case studies and research findings discussed in this paper have substantiated the tangible benefits of adopting data-driven approaches, which are instrumental in mitigating the adverse effects of supply chain disruptions and fostering resilience [25], [26].

The emphasis on resilience and efficiency in supply chains is another pivotal takeaway from this research. Resilience is no longer an optional consideration but a fundamental requirement in today's globalized and interconnected business environment. The importance of diversifying sourcing strategies, establishing redundancy in critical components, and maintaining a robust risk management system has been underscored. Resilient supply chains can swiftly adapt to unforeseen disruptions, such as natural disasters, geopolitical conflicts, or global pandemics. By minimizing the impact of these disruptions, businesses can ensure a continuous and uninterrupted supply of goods and services to their customers, ultimately safeguarding their reputation and bottom line. Efficiency, on the other hand, remains a core principle in supply chain management [27]. Through data analytics, businesses can optimize their operations, reducing lead times, eliminating wastage, and enhancing overall resource utilization. As we conclude, it is imperative to acknowledge that the digital age has irrevocably altered the landscape of supply chain management. The integration of cutting-edge technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain, has revolutionized the way supply chains operate. These technologies enable real-time tracking, improved visibility, and enhanced decision-making capabilities. The interconnectedness of systems and devices has ushered in an era of unprecedented data availability, allowing for more accurate predictions and responsive supply chain strategies. Therefore, the future of supply chain optimization lies in harnessing these digital tools, incorporating them into existing processes, and continuously adapting to the ever-evolving technological landscape [28].

References

- [1] J. Valacich and C. Schneider, *Information systems today: Managing the digital world [RENTAL EDITION]*, 8th ed. Upper Saddle River, NJ: Pearson, 2017.
- [2] S. J. Berman, "Digital transformation: opportunities to create new business models," *Strategy & Leadership*, vol. 40, no. 2, pp. 16–24, Jan. 2012.
- [3] D. S. Alberts, R. E. Hayes, and J. Stenbit, "Power to the edge: Command, control in the information age," 2003.
- [4] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Approximate query processing for big data in heterogeneous databases," in *2020 IEEE International Conference on Big Data (Big Data)*, 2020, pp. 5765–5767.
- [5] D. Power, "Supply chain management integration and implementation: a literature review," *Supply Chain Manage.: Int. J.*, vol. 10, no. 4, pp. 252–263, Jan. 2005.
- [6] A. Gunasekaran and E. W. T. Ngai, "Information systems in supply chain integration and management," *Eur. J. Oper. Res.*, vol. 159, no. 2, pp. 269–295, Dec. 2004.

- [7] N. Hopkinson, R. Hague, and P. Dickens, *Rapid Manufacturing: An Industrial Revolution for the Digital Age*. John Wiley & Sons, 2006.
- [8] M. Muniswamaiah, T. Agerwala, and C. Tappert, "Data virtualization for analytics and business intelligence in big data," in *CS & IT Conference Proceedings*, 2019, vol. 9.
- [9] C. Zott and R. Amit, "Business model innovation: How to create value in a digital world," *NIM Marketing Intelligence Review*, vol. 9, no. 1, pp. 18–23, May 2017.
- [10] H. L. Lee, "The triple-A supply chain," *Harv. Bus. Rev.*, vol. 82, no. 10, pp. 102–112, Oct. 2004.
- [11] M. C. Cooper, D. M. Lambert, and J. D. Pagh, "Supply Chain Management: More Than a New Name for Logistics," *The International Journal of Logistics Management*, vol. 8, no. 1, pp. 1–14, 1997.
- [12] R. B. Handfield and E. L. Nichols, *Supply Chain Redesign: Transforming Supply Chains Into Integrated Value Systems*. FT Press, 2002.
- [13] M. E. Porter and V. E. Millar, "How information gives you competitive advantage," 1985. [Online]. Available: <http://faculty.yu.edu.jo/iaad/Lists/Taught%20Courses/Attachments/5/Reading%205-How%20Information%20Gives%20You%20Comp-Fall2015.pdf>.
- [14] P. A. Strassmann, *Information Payoff: The Transformation of Work in the Electronic Age*. Strassmann, Inc., 1985.
- [15] P. Rao, "Greening the supply chain: a new initiative in South East Asia," *Int. J. Oper. Prod. Manage.*, vol. 22, no. 6, pp. 632–655, Jan. 2002.
- [16] M. Muniswamaiah, T. Agerwala, and C. Tappert, "Big data in cloud computing review and opportunities," *arXiv preprint arXiv:1912.10821*, 2019.
- [17] H. L. Lee and S. Whang, "Information sharing in a supply chain," *technology and management*, 2000.
- [18] H. Peck, "Drivers of supply chain vulnerability: an integrated framework," *International Journal of Physical Distribution & Logistics Management*, vol. 35, no. 4, pp. 210–232, Jan. 2005.
- [19] E. Frazelle, "Supply chain strategy: the logistics of supply chain management," 2002.
- [20] R. Heeks, *Reinventing Government in the Information Age: International Practice in IT-enabled Public Sector Reform*. Psychology Press, 2001.
- [21] W. B. Arthur, "Increasing returns and the new world of business," *Harv. Bus. Rev.*, vol. 74, no. 4, pp. 100–109, Jul-Aug 1996.
- [22] J. Wirtz *et al.*, "Brave new world: service robots in the frontline," *Journal of Service Management*, vol. 29, no. 5, pp. 907–931, Sep. 2018.
- [23] U. Sivarajah, M. M. Kamal, Z. Irani, and V. Weerakkody, "Critical analysis of Big Data challenges and analytical methods," *J. Bus. Res.*, vol. 70, pp. 263–286, Jan. 2017.
- [24] L. Wang and C. A. Alexander, "Machine learning in big data," *International Journal of Mathematical*, 2016.
- [25] A. L. Beam and I. S. Kohane, "Big Data and Machine Learning in Health Care," *JAMA*, vol. 319, no. 13, pp. 1317–1318, Apr. 2018.
- [26] M. M. Najafabadi and F. Villanustre, "Deep learning applications and challenges in big data analytics," *of big data*, 2015.
- [27] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Automatic Visual Recommendation for Data Science and Analytics," in *Advances in Information and Communication: Proceedings of the 2020 Future of Information and Communication Conference (FICC), Volume 2*, 2020, pp. 125–132.
- [28] R. Dubey *et al.*, "Can big data and predictive analytics improve social and environmental sustainability?," *Technol. Forecast. Soc. Change*, vol. 144, pp. 534–545, Jul. 2019.