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Big Data Driven Supply Chain Optimization

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Abstract: With the digital transformation of the global economy and the rapid development of information technology, big data has become a key driving force in supply chain optimization. The introduction of big data technology provides new perspectives and solutions for traditional supply chain management, especially in improving decision-making efficiency, reducing operating costs, and enhancing supply chain agility. This article reviews the application of big data in supply chain optimization based on existing research literature, and analyzes its practices in different fields, including demand forecasting, inventory management, transportation optimization, supplier management, and more. Meanwhile, this article summarizes the challenges that currently exist in the application of big data in supply chain optimization, such as data privacy, security issues, and the complexity of real-time data processing. In addition, this paper also puts forward the development direction of future big data research in the field of supply chain, focusing on the application prospects of cutting-edge technologies such as intelligent supply chain, edge computing and cross enterprise data sharing. This study provides valuable theoretical basis for further understanding the application and future trends of big data in supply chain optimization, and provides reference for academia and business practice.

Keywords: Big data, Supply chain optimization, Demand forecasting, Inventory management, Transportation optimization.

1. Introduction

In the context of a globalized economy and rapidly changing market landscape, Supply Chain Management (SCM) has emerged as one of the critical factors for enterprises to gain competitive advantages and improve operational efficiency.

Big Data refers to the process of extracting valuable information from large and complex datasets by means of advanced technical tools. Such data come from diverse sources, including transaction records, social-media interactions, sensor readings, and Internet of Things (IoT) data. The core strength of big-data technologies lies in their capacity to process and analyze massive volumes of information beyond the reach of conventional data-analytic approaches, and to identify meaningful patterns and trends therefrom. Accordingly, big data offers new insights and solutions for supply chain management, especially in domains such as demand forecasting, inventory optimization, transportation scheduling, and supplier management.

With the advancement of information technology, supply chain optimization no longer relies solely on conventional experience and historical data; instead, it leverages modern technical tools for dynamic data analysis and real-time decision-making support. Through the deep integration of big-data technologies and supply chain management, enterprises can enhance supply chain transparency, response speed, and overall efficiency. For instance, big-data-driven demand-forecasting models assist enterprises in accurately anticipating future market demands, optimizing inventory management, and preventing overstocking or stock-out events. Transportation optimization systems can dynamically adjust optimal shipping routes and modes according to real-time traffic data and transport conditions, thereby lowering transportation costs and shortening delivery lead-time[1].Furthermore, a study on service-quality competition strategies for big-data-enabled crowdsourcing logistics demonstrates that service prices and commission rates exert positive effects on the quality-control levels of both parties. The price-competition coefficient generates a threshold effect on profits. The adoption of big-data technologies can only improve the platform's own quality-control level and raise profits for both sides, yet it exerts no significant influence on the quality-control level of service providers [2].

Meanwhile, Qi et al. [3] proposed an end-to-end deep-learning framework for the multi-period replenishment problem with uncertain demand and supplier lead times. This framework directly outputs replenishment quantities, circumvents the conventional two-step "prediction-optimization" approach, and requires no prior distribution assumptions. Experiments conducted on JD datasets verify that the framework substantially reduces holding costs, stock-out costs and total inventory costs, improves inventory turnover, and delivers a generalizable automated inventory-management solution.

Despite the promising prospects of big-data applications in supply chain management, existing research still encounters numerous challenges. First, data privacy and security concerns constitute major barriers constraining the deployment of big-data technologies in supply chains [4]. In the implementation of big-data applications, how to safeguard user privacy and prevent data breaches has become a focal concern for enterprises and academia. Second, data-quality issues represent another critical challenge for the adoption of big-data technologies. Data collected from diverse sources frequently suffers from inconsistent formats, incomplete information and excessive noise. Ensuring data quality to improve the accuracy of analytical results remains a critical issue in big-data research. Furthermore, the complexity of real-time data processing constitutes another major challenge. The real-time nature of big data demands efficient data processing and analysis to support instant decision-making, whereas traditional computing architectures and processing methods often encounter computational bottlenecks when handling large-scale datasets [5]. Although the adoption of cloud computing and edge computing technologies has mitigated this problem to some extent, their widespread deployment in supply chains still faces dual challenges of technology and cost.

Accordingly, this review aims to review and analyze the research progress of big data in supply chain optimization, explore its applications across various supply-chain stages, identify major challenges in existing studies, and summarize potential directions for future research. Through a systematic review of existing literature, this study not only offers a comprehensive theoretical framework for academia but also delivers in-depth insights and suggestions for corporate practices.

2. The Relationship between Big Data and Supply Chain Optimization

To comprehensively grasp the existing research progress in the field of "big data applications in supply chain optimization," this paper first conducts a preliminary literature screening using keywords such as big data and data-driven, in combination with related terms including "supply chain optimization," "logistics," and "inventory management." The search databases include English-language databases such as Web of Science, ProQuest, and EBSCO, while Chinese literature is concurrently searched in the China National Knowledge Infrastructure (CNKI) using Chinese keywords such as "data," "supply chain optimization," "driven," and "value realization." Through these databases, we obtained relevant literature covering the applications, technical methods, and practical cases of big data in supply chain optimization. Based on the retrieval results, this paper focuses on literature published between 2011 and 2022. Since 2011, with the rapid advancement of big data technologies, relevant journal articles have begun to appear frequently and have gradually become a significant research direction in the supply chain field. This time frame coincides with the actual period when big data technologies were widely applied to supply chain optimization. Therefore, the literature screening in this paper will focus on reviewing research outcomes within this period to ensure that the selected literature possesses high timeliness and cutting-edge relevance.

2.1. Analysis of English-Language Literature on Big Data–Driven Supply Chain Optimization

2.1.1. An Integrated Framework for Big Data and Supply Chain Optimization

Big-data technologies provide innovative solutions for supply chain management. Especially in supply chain optimization, in-depth analysis of large-scale datasets can substantially improve prediction accuracy and decision-making efficiency. Wang et al. [6] systematically reviewed and classified the applications of big-data business analytics in logistics and supply chain management, defined such applications as supply chain analytics, and constructed a classification framework based on analytical nature (descriptive, predictive, prescriptive) and LSCM priorities (strategy and operation). Meanwhile, they proposed a five-level SCA maturity model covering functional, process-oriented, collaborative, agile and sustainable layers. They emphasized the critical role of SCA in LSCM as well as the methods and technologies for collecting, disseminating, analyzing and utilizing big-data-driven information, and pointed out that managers should regard BDBA and SCA as strategic assets and integrate them into various business activities.

He and Gu [7] proposed an integrated framework that demonstrated how the integration of Internet of Things (IoT) and big-data technologies applied to supply chains. They noted that IoT technologies gathered massive datasets through real-time sensors and smart devices, and big-data analytics transformed these data into actionable information to support real-time supply-chain decision-making. Furthermore, Cui et al. [8] investigated two blockchain mechanisms: vertical cost transparency and horizontal order transparency. They found whether blockchain improves profits depended on the manufacturer's production capacity. A triple-win outcome emerged under sufficient capacity; when capacity was limited, horizontal transparency aggravated double marginalization, and only the adoption of vertical cost transparency yielded superior performance.

2.1.2. Application of the Integration of IoT and Big Data in Supply Chains

The integration of the Internet of Things (IoT) and big data brought transformative changes to supply chain management. The IoT connected devices, sensors and systems via networks, enabling every link in supply chains to acquire substantial volumes of data in real time. Big-data technologies assisted enterprises in forecasting, optimization and decision-making by analyzing these massive datasets. Furthermore, Wu [9] constructed a supply-chain risk-exposure indicator based on text analysis of corporate quarterly conference calls. Validations showed that this indicator effectively captured conventional and systemic risk events. It was closely correlated with changes in firms' behaviours such as inventory buffers, cash holdings and trade credit. Firms with high risk exposure performed worse under unexpected shocks, and the indicator was applicable for empirical research.

2.2. Analysis of Chinese-Language Literature on Big Data–Driven Supply Chain Optimization

2.2.1. Big Data–Driven Pathways for Supply Chain Optimization

Domestic research on big-data-driven supply chain optimization started relatively late. Nevertheless, with the continuous development of big-data technologies, scholars carried out in-depth discussions on data empowerment, supply chain decision optimization, supply chain collaboration and intelligence. As a vital instrument for advancing supply chain optimization, big-data empowerment received extensive attention. Existing studies demonstrated that data empowerment improved the decision-making capacity of supply chain members and optimized supply chain operational efficiency. For example, Qiu et al. [10] indicated that data empowerment assisted supply chain members in making precise decisions and enhanced supply chains' robustness and risk-resistant capacity. Liu and Chen [11] analyzed the influences of data resource mining and sharing on supply chain pricing, and highlighted the role of data empowerment in market pricing and value co-creation. The adoption of big data transformed supply chain decision-making from traditional experience-driven modes to data-driven ones, and helped firms respond rapidly to real-time market fluctuations. Sun et al. [12] showed that big data promoted agile responses of supply chains to demand fluctuations by enhancing firms' dynamic capabilities.

Particularly under scenarios with personalized demands, big data substantially improved supply-chain flexibility and response speed. With the advances in big-data technologies, the intelligence of supply chain management emerged as a new research focus. Hu et al. [13] proposed that e-commerce platforms improved supply-chain collaboration through data empowerment, helped merchants realize value co-creation, and optimized operational efficiency. Zhang and Gu [14] explored how big data drove manufacturers' digital transformation. They optimized coordination among supply-chain members via intelligent decision-making and enhanced supply-chain competitiveness. Fang et al. [15] demonstrated that the establishment of national big-data comprehensive pilot zones significantly boosted corporate green transformation. Such effects were more pronounced for non-foreign-funded, small-scale and non-high-tech enterprises, as well as labor-intensive, capital-intensive and heavily-polluting industries. Green technological innovation, resource-factor allocation and external supervision served as major transmission mechanisms, and the policy generated spillover effects in economically-proximate regions.

2.2.2. Marketization of Big Data Circulation and Supply Chain Optimization

As the market-oriented development of big data accelerated, data transaction and circulation gradually became a key concern among scholars. Market-oriented data circulation not only involved the commercial application of data, but also concerned how market mechanisms boosted the efficient allocation and utilization of data resources. The application of big data in supply chain finance optimized the coordination of capital flow, material flow and information flow, and realized the digitization and intelligence of supply chain financing. Gong et al. [16] proposed that the integration of blockchain and big data offered new solutions for supply chain finance, and delivered remarkable advantages particularly in risk management and financing efficiency. They pointed out that as more enterprises joined the blockchain within supply chains, improved data transparency effectively reduced financial risks and facilitated the inclusiveness and high efficiency of supply-chain financing. In addition, Zhou and Zhang [17] constructed a big-data investment-decision model with partial two-way transparency between upstream and downstream firms to address decentralized investment and incentive issues for demand-related big data in supply chains. They found that two-way transparency always benefited suppliers, whereas forward transparency combined with backward opacity helped improve investment feasibility. Manufacturers suffered merely from insufficient investment incentives, while suppliers exhibited excessive investment incentives under low two-way transparency. Moreover, investment-compensation contracts effectively coordinated incentives for all participants and increased the system-wide investment profit by 5 % to 49 %. Song et al. [18] adopted the perspective of actor-network theory and took GLP Finance as a case to explore the dynamic process through which financial service providers built trust relationships within supply-chain finance networks. They found that trust construction essentially represented a dynamic evolution of conflict generation and resolution among actors, which went through four stages: identifying trust crises, mobilizing trust-related agents, integrating trust elements, and establishing trust systems. In addition, Zhang et al. [19] drew on the management practices of China's high-end equipment manufacturing industry. They addressed new demands and challenges for high-end equipment manufacturing operation management under the internet and big-data environment, and explored the internal structure and innovation modes of network-based collaborative management for high-end equipment manufacturing. They proposed a hierarchical framework for digital collaboration of high-end equipment, which focused on collaborative optimization approaches at three levels: digital collaboration of equipment and equipment clusters, digital collaboration of workshops and factories, and digital collaboration within supply-chain alliances. They further validated the framework through the collaborative management of digital manufacturing for deep-water blowout preventer sets used in oil-well exploration equipment. In addition, Xing et al. [20] focused on the decision-making dilemmas caused by data-sharing transfer costs and big-data-driven price discrimination. They constructed a dynamic game model consisting of suppliers, e-commerce platforms and heterogeneous consumers, and examined platforms' data-sharing decisions under competitive environments. They found that data sharing effectively promoted product innovation, and the level of product innovation acted as a core factor for platforms to voluntarily share data. When price competition among platforms remained weak and the innovation level fell within a certain range, data-sharing levels had room for improvement, and properly-designed incentive contracts strengthened sharing willingness. Participants flexibly distributed the incremental profits of the supply-chain system, and achieved Pareto improvement while raising the degree of data sharing.

2.3. A Comparative Analysis of Chinese and English Literature on Big Data–Driven Supply Chain Optimization

A comparison of the Chinese and English literature reveals that while the research foci in big data–driven supply chain optimization exhibit certain differences, these differences are to some extent complementary in nature.Chinese and English literature place different emphases on data valorization, data application scenarios, and technical pathways, reflecting their distinct research backgrounds and academic traditions.

2.3.1. Differences in Data Application Scenarios

In studies on data valorization, English-language literature mainly focused on the application of big-data analytics in specific scenarios, especially its optimization effects within supply chain management. For instance, Western studies tended to analyze how big data was applied to specific supply-chain links such as demand forecasting, inventory optimization, transportation scheduling and supplier selection. Scholars regarded big data as an essential tool for advancing decision optimization and improving efficiency in supply chain management, and interpreted data value primarily from the perspective of data assets. Western literature rarely delved deeply into data forms and their dynamic evolution processes; instead, it focused more on how big data enhanced the efficiency and flexibility of supply chains.

By contrast, Chinese-language literature centered more on the morphological changes and market circulation of data. It offered relatively unique perspectives particularly on how data elements enhanced their value through market-oriented circulation. Chinese-language studies paid greater attention to the realization mechanisms of data elements. They explored the evolutionary process of data from resources to assets, then to commodities and capital, and particularly emphasized market-oriented data circulation as well as how policy and market mechanisms maximized data value. Xie et al. [21] demonstrated that the digital-intelligent construction of supply chains boosted manufacturing enterprises' new-quality productivity through two paths: resource empowerment (alleviating factor constraints and facilitating capital and new-technology access) and structural empowerment (strengthening internal and external collaboration). Such effects were more prominent for market-lagging firms, upstream enterprises, high-tech industries, and regions with sound digital infrastructure. Therefore, Chinese-language literature produced more in-depth discussions on data marketization, circulation mechanisms and data governance, while it devoted relatively limited discussions to the application of big data in specific supply-chain scenarios.

2.3.2. Differences in Theoretical Perspectives on Data Valorization

English-language literature analyzed data valorization mainly from the perspective of data assets. It emphasized how big data transformed into practically valuable assets and thereby exerted effects in supply chain management. For example, scholars investigated how big-data technologies improved supply-chain decision-making capabilities and optimized inventory and transportation routes. English-language literature contained relatively few discussions on data forms. It focused more on converting data into valuable assets and improving the overall benefits of supply chains through data-driven decision-support systems.

Chinese-language literature focused more on research concerning data elements, especially the changes and development of data forms, such as the dynamic evolutionary process of data from resources to assets, commodities and capital. For instance, numerous discussions on the marketization of data elements existed in Chinese-language literature, particularly regarding how government policies and market mechanisms advanced data circulation and utilization. Such studies emphasized how to effectively integrate and utilize data within supply chains so as to promote supply-chain efficiency and decision-making optimization. Du et al. [22] conducted a case study on Zongshen Group. They revealed that platformization formed a parallel-structured "support-driven" digital-innovation enabling mechanism through six procedures: exploratory bridging, resource accumulation, data activation, space expansion, inclusive evolution, and ecological feedback. The mechanism helped manufacturing enterprises cross two-level digital divides, namely barriers to intelligent upgrading and industrial integration, as well as barriers to ecosystem architecture. Meanwhile, corporate value propositions followed a gradual evolutionary path of "momentum accumulation-progression-upgrading", and shifted from commodity-dominant logic to service-dominant logic, and further to ecosystem-oriented service-dominant logic.

2.3.3. Differences in Research Backgrounds and Paradigms

The differences in research foci and evolutionary trajectories between Chinese and Western scholarship largely stem from their divergent contextual backgrounds. China's digital economy started relatively late but has developed at a rapid pace; particularly with strong government support, digital technologies and big data have been widely adopted across various domains of production and daily life. The Chinese model places greater emphasis on industrial and market advantages, while at the policy level it accelerates market-oriented reforms of data elements. Chinese research focuses more on how policy guidance and market mechanisms can facilitate the circulation and application of data elements, thereby achieving rapid development of the digital economy. In contrast, the digital economy in Western countries, particularly the United States, developed earlier, and its leading advantage in core technologies has provided strong momentum for the sustained growth of its digital economy. The U.S. paradigm places greater emphasis on sustaining technological innovation to consolidate its competitiveness in the global digital economy. Against this backdrop, big data continuously creates new value through the iterative evolution of emerging technologies, industries, and business models; particularly in supply chain management, big data serves as a key component of technological innovation, driving the transformation from traditional supply chains to intelligent supply chains.

2.3.4. Complementarity and Future Research Directions

Although Chinese and English literature differ in their research foci and trajectories, the two bodies of work are complementary in nature. English-language literature places greater emphasis on optimizing data application scenarios and solving practical problems, whereas Chinese-language literature focuses more on the evolution of data morphology and issues of market-oriented circulation. In the future, with the global proliferation and application of big data technologies, research from both Eastern and Western contexts is expected to further integrate, giving rise to a more comprehensive theoretical framework. Particularly in the field of supply chain optimization, future efforts should pay greater attention to enhancing the intelligence and automation levels of supply chains through data empowerment, as well as to realizing the maximum value of big data in areas such as cross-enterprise collaboration and supply chain risk management.

3. Connotation and Characteristics of Big Data–Driven Supply Chain Optimization

3.1. The Connotation of Big Data in Supply Chain Optimization

The connotation of big data in supply-chain optimization mainly resided in its capacity to enhance supply-chain transparency, response speed and decision-making precision by analyzing massive information from multiple data sources. With the continuous advancement of information technologies, supply chain management no longer relied on traditional empirical judgments and historical data. Instead, it realized optimization and collaboration across the whole chain by collecting and processing diversified data from each supply-chain link in real time. Big-data-driven supply-chain optimization held great potential. It not only improved the accuracy of demand forecasting, but also reduced inventory backlogs and transportation costs through dynamic scheduling and real-time decision-making, and effectively boosted customer satisfaction.

Big data not only functioned in optimizing individual links, but also provided real-time and accurate decision-making support for the entire supply chain. It delivered prominent advantages particularly in forecasting, inventory management and operational optimization. Guan et al. [23] adopted the data of China's A-share listed firms from 2014 to 2024 and employed the benchmark regression model to analyze the effect and mechanism of smart logistics development on supply-chain resilience. They found that smart logistics significantly improved the resistance and recovery capacity of supply chains, which indicated a remarkable positive correlation with supply-chain resilience. Its underlying mechanisms lay in cutting corporate transaction costs, expanding market share and raising supply-chain efficiency. Meanwhile, Omoush et al. [24] conducted a systematic review of 99 papers retrieved from the Scopus database concerning digital supply chains, big data and manufacturing lead-time published from 2015 to 2022. They found that big data improved the performance of digital supply chains by enhancing their resilience and innovation capacity. Manufacturing lead-time was positively correlated with digital supply-chain integration, whereas excessively long lead-times undermined the competitiveness of digital supply chains. The study suggested cultivating organizational flexibility, information exchange and adaptive behaviors to facilitate such integration. In terms of operation management, Qiao et al. [25] targeted smart-factory operation management for intelligent manufacturing. They systematically sorted out the system architecture of smart-factory operation management and carried out research from three dimensions: self-organized innovation of service modes, self-learning innovation of knowledge management, and adaptive innovation of scheduling optimization. Specifically, they constructed cyber-physical-system-driven operation and organization modes, proposed big-data-fusion-based approaches for knowledge discovery, human-machine joint reasoning and autonomous learning updating, and developed multiple methods for robust scheduling, dynamic scheduling and adaptive scheduling. Zhou et al. [26] focused on the core research question of how digital-intelligent knowledge orchestration facilitated the evolution of organizational dynamic capabilities. Taking Xiaomi Technology as a case, they extracted mechanisms including knowledge acquisition, decoding, screening, coding, development and exploration. They pointed out that enterprises decoded and reconstructed scattered and static tacit knowledge from internal and external practices into intelligent knowledge modules with artificial intelligence as the core. The further development and exploration of such modules laid the foundation for the formation of organizational dynamic capabilities.

Therefore, the connotation of big data in supply-chain optimization lay not merely in providing data support and decision-making references. More importantly, innovations in technical tools and analytical approaches transformed conventional supply-chain management modes, and shifted supply chains from the past static, experience-driven paradigm toward dynamic, data-driven intelligent management.

3.2. Characteristics of Big Data-Driven Supply Chain Optimization

Big-data-driven supply-chain optimization possessed a set of unique characteristics. Such features enabled the extensive application of big-data technologies in supply-chain management and fueled the transformation of traditional supply-chain management modes. First of all, data diversity and comprehensiveness represented one of its most remarkable features. Supply chains generated highly diverse data sources, which covered internal corporate data such as production, inventory, transportation and sales data, as well as external information including market dynamics, climate changes, consumer behaviors and social-media data. Yang [27] constructed a China manufacturing-transfer index based on global multi-source industrial big data. The paper analyzed the trends and destination countries of China's manufacturing relocation since 2015, and further explored relocation patterns from the perspectives of "active relocation" and "passive relocation". Conrad and Kumar [28] targeted multi-echelon dynamic food supply chains. They adopted big-data mining to analyze decision-making impacts on product quality and determined the state-transition matrix. They applied stochastic optimization to obtain optimal strategies for profit maximization and waste reduction. Experiments showed that this approach outperformed conventional methods in operational efficiency, and optimal strategies exhibited convex changes as quality thresholds became stricter. Gang et al. [6] likewise conducted a systematic review of the application of big-data business analytics in logistics and supply-chain management. They defined such practice as supply-chain analytics and established a classification framework according to analytical nature and the priorities of logistics and supply-chain management (LSCM). Meanwhile, Yu et al. [29] addressed the problems of low computational efficiency and high costs for low-carbon supply-chain networks under the background of low-carbon economy. They designed and optimized China's low-carbon supply-chain networks with the aid of big-data technologies.

In addition, the collaborative capability brought by big-data-driven supply-chain optimization constitutes one of its features. Through data sharing and real-time analysis among supply-chain participants such as manufacturers, distributors and retailers, big data facilitates cooperation across different supply-chain links. Big data enables supply-chain participants to share information and data on a unified platform, guarantees data synchronization across all links, and thus realizes efficient resource allocation and production scheduling. Wang and Ji [30] addressed low-carbon supply-chain design under hybrid uncertainties. They constructed a model integrating multi-level backup measures and emission-reduction investments to maximize profits and coordinate risks among supply-chain members. Their results indicated that supply levels ought to be reasonably configured, and the confidence level for carbon emissions should remain moderate. Backup strategies generated more remarkable effects when disruption risks were high. Information sharing allowed all supply-chain participants to timely grasp the status of other links, and avoided decision-making errors and resource waste stemming from information asymmetry.

Lastly, the application of big data in supply chains is also characterized by accurate prediction capability. Through comprehensive analysis of multiple factors including historical data, market trends, consumer behaviors and seasonal variations, big-data analytics improves the accuracy of demand forecasting in supply chains and prevents excess inventory or stock shortages caused by forecasting errors.

4. An Integrated Research Framework for Big Data–Driven Supply Chain Optimization

The research framework for big data driven supply chain optimization mainly concerns how to integrate big data technologies with various links of supply chain management to achieve comprehensive supply chain optimization. Within this framework, big data is not merely a tool for improving supply chain efficiency, but also a crucial driving force for advancing the intelligence, collaboration and transparency of supply chains.

4.1. Prerequisite Factors: Data Collection and Integration

Big-data-driven supply-chain optimization firstly relies on data collection and integration, which serves as the foundation for all subsequent optimization work. Data collection involves gathering various supply-chain data via sensors, Internet of Things (IoT) devices, Enterprise Resource Planning (ERP) systems and other tools, including inventory data, transportation data and sales data. Dong et al. [31] built a three-tier model to investigate the impacts of traceability technology based on supply-chain data collection and integration. Full traceability generates revenue benefits by waste avoidance. Nevertheless, it makes enterprises vulnerable to price pressure from downstream partners, which may harm some members and raise pollution risks. Network structures shape benefit distribution. All participants gain benefits when there are numerous upstream suppliers, and partial traceability becomes more advantageous under such circumstances.

At the same time, data integration refers to cleaning, denoising and standardizing data sourced from diverse channels to guarantee data quality and consistency. Data diversity and real-time performance require enterprises to possess robust data-processing capabilities, which lay a solid foundation for subsequent data analysis and decision-making support.

4.2. Data Analysis and Modeling: Demand Forecasting and Supply Chain Optimization

After big-data collection and integration comes the phase of data analysis and modeling. As the core of supply-chain optimization, demand forecasting enables enterprises to build demand-forecasting models with big-data technologies based on multi-dimensional information such as historical data, consumer behaviors and market trends. It predicts future market demand in advance and assists enterprises in adjusting production and inventory strategies. For example, Osadchiy et al. [32] found that supply networks amplified the impacts of economic shocks on industrial sales. Economic fluctuations propagated upstream along supply chains and got intensified. Such amplification mainly stemmed from the superposition effect of multi-customer order aggregation and inter-temporal order aggregation, rather than direct transmission via production decisions. The objective of this phase is to deliver accurate forecasting outputs and optimization solutions through in-depth data mining.

4.3. Intelligent Decision Support: Real-Time Scheduling and Resource Allocation

Intelligent decision-support systems driven by big-data analytics help enterprises realize dynamic scheduling and resource allocation for supply chains. Such systems can make automated decisions based on real-time data and optimize key links including production planning, inventory management and transportation scheduling. By integrating machine-learning algorithms and real-time data streams, decision-making systems respond to changes across supply-chain links in real time and deliver instant adjustment schemes, so as to enhance supply-chain agility and responsiveness. For instance, Blaettchen et al. [33] investigated the selection of early adopters for supply-chain traceability technology. They pointed out that big-data-driven supply-chain traceability relied on data sharing and collaboration among enterprises. Nevertheless, the high connectivity of enterprise networks brought great challenges to selecting the minimum-cost seed set. To solve this problem, they proposed an algorithm based on linear programming, which achieved efficient computation by taking advantage of the low tree-width of real-world supply-chain networks. It provided references for optimizing technology diffusion strategies under big-data scenarios.

4.4. Supply Chain Collaboration and Risk Management

Big data enhances the collaborative capability of each link within supply chains. Via information-sharing platforms, supply-chain participants including manufacturers, retailers and logistics providers can share data in real time, guarantee information symmetry and synchronization across all links, and promote collaborative optimization of supply chains. Meanwhile, big data plays a vital role in supply-chain risk management. Based on the analysis of historical and real-time data, enterprises can identify potential supply-chain risks in advance, such as supplier delays, transportation accidents and demand fluctuations, and adopt corresponding countermeasures. Through risk prediction, enterprises can minimize potential risks, respond rapidly once disruptions occur, and maintain the stability and flexibility of supply chains [34].

4.5. Continuous Optimization: Big Data–Driven Intelligent Supply Chains

Big data not only optimizes supply chains in the short term but also advances the development of big-data analytics. With continuous technological progress and data accumulation, supply-chain management systems are capable of continuous learning and optimization to improve the overall efficiency of supply chains. For example, big-data analytics empowers the dual systems of circular economy, namely closed-loop supply chains and reverse omnichannels. Combined with product-return knowledge, it strengthens perception, comprehension and reconfiguration capabilities, and shifts return management from a passive to an active mode. Enterprises need to strike a trade-off between operational capacity for closed-loop supply chains and service capacity for reverse omnichannels so as to improve sustainable performance [35].

5. Conclusion and Future Prospects

5.1. Conclusion

Based on a systematic study of the applications of big data in the field of supply chain optimization, and drawing on a review and analysis of relevant literature published in recent years, this paper summarizes the following research conclusions:

First, this paper systematically synthesizes the current research landscape of big data–driven supply chain optimization. Through an analysis of English and Chinese literature published over the past decade, we find that the application of big data in supply chain optimization has been gradually evolving from a mere technical tool toward systematic and intelligent solutions. English-language literature primarily concentrates on data-driven supply chain management, intelligent forecasting, and the application of optimization algorithms, with research highlights manifested in in-depth explorations of the integration of big data with the Internet of Things (IoT) and artificial intelligence (AI). In contrast, Chinese-language literature pays greater attention to market applications and policy-driven factors, with research highlights lying in a detailed dissection of the data valorization process in supply chain management from an industrial perspective, discussing the specific application models and effects of data in actual operations.

Second, this paper clarifies the connotation and distinctive characteristics of big data–driven supply chain optimization. Building on the analysis of existing literature, we further reveal the core role of big data in supply chain optimization, particularly in specific functions such as demand forecasting, inventory management, and transportation scheduling. The application of big data not only improves the accuracy and responsiveness of supply chains but also promotes intelligent and automated decision-making across various stages. By comparing the similarities and differences between traditional supply chain management and big data–driven supply chain optimization, this paper concludes that the latter exhibits attributes such as real-time capability, intelligence, and collaboration, which enable supply chains to respond more flexibly in dynamic market environments.

Third, this paper constructs an integrated research framework for big data–driven supply chain optimization. The framework encompasses key stages including data collection, data processing, intelligent decision-making, supply chain collaboration, and risk management. In the data collection stage, big data technologies obtain various types of supply chain data in real time via IoT devices, sensors, and other tools; in the data processing stage, data cleaning, integration, and analysis provide an accurate data foundation for subsequent decision support; in the intelligent decision-making stage, decision support systems based on big data automatically generate optimization solutions, enabling automation in production planning, inventory management, and transportation scheduling; and in the supply chain collaboration and risk management stage, through real-time data sharing and analysis, all parties involved can achieve better coordination and early risk warning.

5.2. Future Prospects

Big data–driven supply chain optimization remains in a phase of rapid development, and future progress is expected in the following areas:

First, intelligent supply chains will become the mainstream direction in the future. With the continuous advancement of artificial intelligence (AI), machine learning, and related technologies, future supply chains will evolve toward greater intelligence. The integration of big data and AI will enable more accurate forecasting and optimization across all supply chain stages, driving the transformation of supply chains toward intelligence and automation (Zhao et al., 2017). Future intelligent supply chains will not only automatically adjust production plans, inventory levels, and transportation routes, but also make autonomous decisions in response to changing market demands, thereby improving supply chain responsiveness and efficiency.

Second, the application of edge computing and 5G technologies will accelerate data processing. With the proliferation of IoT devices, future big data–driven supply chains will rely more heavily on edge computing and 5G technologies. Edge computing enables real-time data processing at the data source, reducing latency and increasing processing speed, while 5G technology supports efficient connectivity for a larger number of devices, further enhancing the efficiency of data flow within supply chains. Supply chain management systems that integrate edge computing and 5G will achieve higher real-time performance and responsiveness, providing stronger technical support for intelligent decision-making in supply chains.

Third, cross-enterprise data sharing and collaboration will become a developmental trend. As digital transformation progresses, cross-enterprise data sharing and collaboration will emerge as a critical trend in future supply chain optimization. In the future, all parties within the supply chain can achieve secure data sharing through technologies such as cloud platforms and blockchain, thereby promoting collaborative supply chain operations. Hazen et al. (2018) propose that cross-enterprise data synergy can significantly improve supply chain efficiency and reduce friction among different stages. However, alongside the promotion of data sharing, addressing data privacy and security issues will remain a key research focus in the future.

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