

Applied Research on the Impact of Big Data, Cloud Computing and Cloud Storage on Smart Manufacturing Supply Chain

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Abstract: The rapid advancements in big data, cloud computing, and cloud storage technologies are profoundly reshaping the operational models of smart manufacturing supply chains. The integration and application of these technologies not only drive the enhanced data collection and analysis capabilities across various supply chain segments but also significantly improve the accuracy of demand forecasting, the rationality of resource allocation, and the scientific nature of decision support. Consequently, the collaborative efficiency and dynamic response capabilities of supply chains have been substantially elevated, providing robust technological backing for enterprises in navigating the intricately volatile market environment. Nonetheless, while reaping the benefits of these technological advancements, challenges such as data security and privacy protection, system integration, and technical selection cannot be overlooked. By judiciously selecting technology platforms, reinforcing data security management, and continuously investing in technological advancements and talent cultivation, the holistic effectiveness of smart manufacturing supply chains will be further optimized.

Keywords: Big Data; Cloud Computing; Cloud Storage; Smart Manufacturing; Supply Chain.

1. Introduction

Smart manufacturing, serving as the cornerstone of the new industrial revolution, is redefining the competitive landscape of global manufacturing. The supply chain, being the lifeblood of manufacturing enterprises, directly influences their survival and development through its efficiency and flexibility. However, traditional supply chain models have shown significant shortcomings in addressing market demand fluctuations, resource allocation, and information sharing. The rise of big data, cloud computing, and cloud storage

technologies offers novel approaches to supply chain management. Through real-time data collection and analysis, precise demand forecasting, and efficient resource scheduling, the agility and intelligence of smart manufacturing supply chains have been substantially enhanced. The deep integration of these technologies not only optimizes the operational efficiency of supply chain segments but also presents unprecedented opportunities and challenges for supply chain management. The framework of the smart manufacturing system (management, administration, and functioning) and its working mechanism has been presented in the Figure 1.

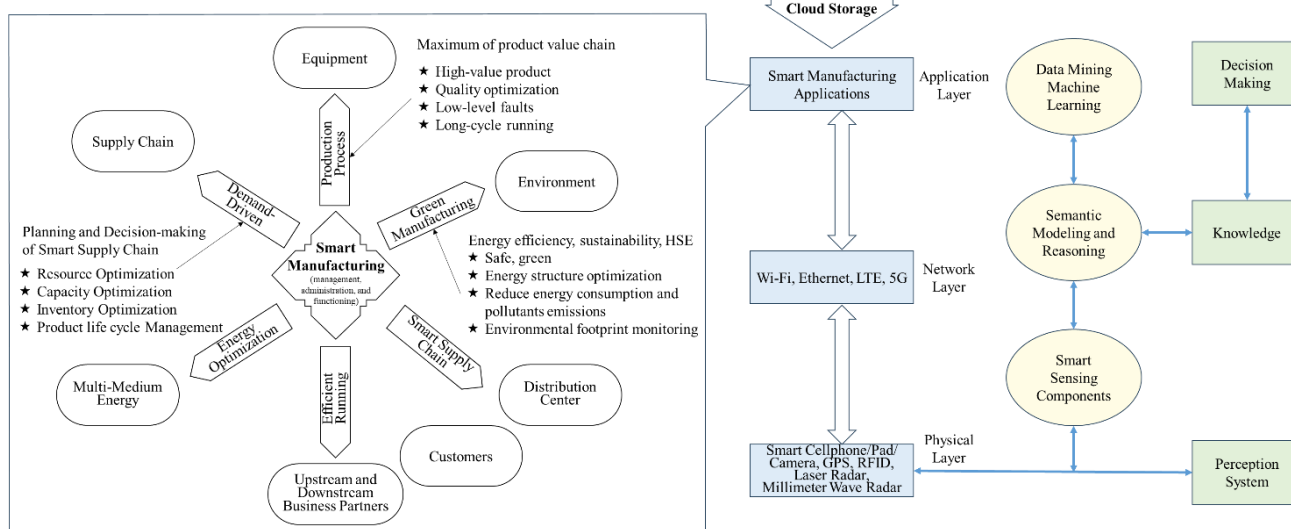


Figure 1. The framework of the Smart Manufacturing System (management, administration, and functioning) and its Working Mechanism

2. The Status quo and Challenges of Smart Manufacturing Supply Chain

The current state of smart manufacturing supply chains

finds itself at a critical juncture marked by rapid transformation and evolution. Traditional supply chain models, once robust, have begun to reveal their limitations when faced with increasingly complex market landscapes. Historically, supply chain management often relied on

experience and historical data, resulting in decision-making that was comparatively slow, lacking in real-time adaptability and flexibility. In scenarios where market demands shifted or unforeseen circumstances arose, the supply chain's agility often proved insufficient. This approach, once adequate, now seems inadequate in an era characterized by escalating demand for customization, shortened product lifecycles, and intensified global competition. The advent of big data, cloud computing, and cloud storage technologies has heralded new opportunities for supply chain management, yet these advances also present significant challenges. The digital transformation of supply chains is not an overnight feat; many enterprises are still grappling with how best to leverage these cutting-edge technologies. The issue of data silos persists, with disparate information systems failing to integrate effectively, impeding data flow and real-time information sharing, which in turn undermines the overall coordination efficiency of the supply chain. Additionally, extracting valuable insights from vast amounts of data and utilizing them effectively remains a formidable challenge for businesses. Moreover, the global nature of smart manufacturing supply chains complicates management. International supply chains involve coordination across multiple countries, time zones, and regulatory standards, with any fluctuation in any single link capable of triggering a ripple effect throughout the entire chain. Against the backdrop of escalating geopolitical risks and frequent natural disasters, the resilience and risk-mitigation capabilities of supply chains are increasingly scrutinized. Enterprises must not only upgrade their technological infrastructure but also undergo a paradigm shift in their operational mindset. Supply chain managers must cultivate enhanced data acumen and technical comprehension to navigate the ever-changing market dynamics and technological hurdles [1].

3. Convergence Application of Big Data, Cloud Computing and Cloud Storage in Smart Manufacturing Supply Chain

3.1. Supply chain data collection and analysis

The supply chain generates an immense volume of data daily, ranging from machine sensor data in production workshops to location information in logistics transportation, and including customer orders and feedback. These data streams serve as the "neural signals" of the supply chain, transmitting real-time status across various stages. However, traditional supply chains lack effective tools and platforms to comprehensively and instantaneously capture this data, often relying on manual records or fragmented systems, resulting in lagging information flow and inadequate decision-making bases. The advent of cloud computing and cloud storage has broken through the bottleneck of data acquisition. By deploying various IoT technologies, such as sensors, RFID tags, and GPS devices, at every node of the supply chain, data can be collected in real-time and automatically transmitted to the cloud. This implies that changes in production progress, fluctuations in inventory levels, and conditions during transportation can all be swiftly captured and reflected on a unified platform. This allows management to access a panoramic view of the supply chain anytime, anywhere. This not only enhances information transparency but also enables each participant in the supply chain, from suppliers to

manufacturers to logistics service providers, to make more precise judgments based on the same data. However, merely collecting data is insufficient; the crux lies in analyzing and utilizing this data. Big data technology plays a pivotal role here, as it helps enterprises uncover hidden patterns and trends through deep mining and analysis of vast datasets. For instance, by analyzing historical sales data and market demand fluctuations, companies can more accurately forecast future market trends, thereby adjusting production plans and inventory strategies. Additionally, through real-time analysis of transportation data, enterprises can optimize logistics routes, reducing transportation costs and time. The powerful computing capabilities of cloud platforms enable these complex data analysis tasks to be completed swiftly, even achieving real-time analysis and feedback. This efficient data processing capability provides supply chain managers with unprecedented insights, enabling them to make rapid and scientific decisions in the face of complex and volatile market environments [2].

3.2. Supply chain demand forecasting and optimization

The marketplace is in constant flux, and consumer demands are prone to fluctuations at any moment due to a myriad of factors. Traditional forecasting methods often rely heavily on historical data and empirical judgment, lacking the requisite flexibility and precision. Under such a paradigm, enterprises are either saddled with inventory surpluses or confronted with stockouts, both of which directly impact sales and customer satisfaction. However, the integrated application of big data, cloud computing, and cloud storage is offering a novel solution to this conundrum. Cloud computing platforms boast formidable data processing capabilities, capable of real-time collection and analysis of data from multiple channels, including social media trends, e-commerce platform sales data, macroeconomic indicators, and even external factors such as weather changes. Through the deep mining and modeling analysis of these data by big data technologies, enterprises can obtain more comprehensive and dynamic demand forecasts. For instance, the demand fluctuations of a seasonal product might be closely related to weather changes. By incorporating these external data into the analysis model, enterprises can preemptively adjust their production plans, thereby avoiding being caught off guard by sudden surges in demand. Furthermore, big data technologies can continuously optimize the prediction models through machine learning algorithms. The system automatically adjusts its parameters based on the deviations between each forecast and the actual situation, resulting in increasingly accurate future predictions. This self-learning characteristic transforms demand forecasting from a static to a dynamic process, shifting from experience-driven to data-driven. For example, promotional activities on e-commerce platforms often influence the short-term demand for products. By analyzing these promotional data in real-time, enterprises can swiftly adjust their supply chain strategies to ensure sufficient product supply and avoid missing out on business opportunities. The optimization of demand forecasting directly leads to an enhancement in the overall efficiency of the supply chain. Inventory management becomes more scientific; enterprises can plan production and procurement rationally based on forecast results, avoiding excesses or shortages in inventory. The logistics and distribution sectors also benefit, as transportation plans can be adjusted flexibly

according to demand changes, reducing unnecessary warehousing and transportation costs. Nevertheless, demand forecasting is not infallible—markets are inherently fraught with uncertainties. However, big data and cloud computing technologies undoubtedly equip enterprises with enhanced insights and adaptability, allowing them to swiftly adjust strategies and minimize risks even in the face of unexpected circumstances.

3.3. Supply chain collaboration and decision support

Traditional supply chain management often operates in silos, with poor communication across different stages, resulting in inefficient collaboration among suppliers, manufacturers, distributors, and retailers. This leads to a sluggish response throughout the entire chain, unable to quickly adapt to market changes. However, the integration of big data, cloud computing, and cloud storage is now dismantling this fragmented information landscape, enabling more efficient collaborative operations among supply chain stakeholders. The cloud computing platform provides a unified data sharing and collaboration hub for all stages of the supply chain, where all relevant parties can access and share information in real-time. For instance, manufacturers can monitor suppliers' inventory levels and delivery progress instantaneously, while suppliers can adjust their supply strategies based on manufacturers' production plans. This transparency and real-time sharing of information significantly enhance the collaborative efficiency of the supply chain, allowing each participant to make more precise decisions based on the same data. Big data technology offers robust data support and analytical capabilities for supply chain collaboration. By analyzing vast amounts of data, enterprises can identify potential bottlenecks and optimization points within the supply chain, thereby devising more scientific collaborative strategies. For example, by analyzing historical transportation data and logistics routes, companies can optimize their transportation plans, reduce transit times and costs, and improve delivery efficiency. Additionally, by analyzing suppliers' delivery records and quality data, enterprises can better evaluate and select suppliers, ensuring the stability and efficiency of the supply chain [3]. Decision support systems represent another significant application of big data and cloud computing technologies in supply chain management. Traditional decision-making often relies on managers' experience and intuition, whereas decision support systems provide scientific decision-making suggestions through data analysis and modeling. For instance, in response to market demand changes, the system can generate multiple response strategies based on historical data and predictive models for managers to choose from, evaluating the merits and risks of each option. This data-driven decision-making approach not only enhances the scientific nature and accuracy of decisions but also significantly shortens decision-making time, enabling enterprises to respond more swiftly to market changes. Achieving supply chain collaboration and decision support also requires corresponding adjustments in corporate culture and organizational structure. Enterprises need to foster a more open and collaborative organizational culture, breaking down barriers between departments and stages to facilitate the sharing of information and resources. Additionally, managers need to shift their thinking patterns, placing greater trust and reliance on data analysis outcomes, making data the core

foundation of decision-making. The application of big data, cloud computing, and cloud storage technologies is transforming supply chain management into a more intelligent and efficient process. The supply chain is no longer a series of isolated stages but a tightly integrated whole, where each participant can make more precise and scientific decisions with the support of data and technology.

4. Implementation Measures of Big Data, Cloud Computing and Cloud Storage in Smart Manufacturing Supply Chain

4.1. Technology selection and platform deployment

In the realm of smart manufacturing supply chains, the implementation of big data, cloud computing, and cloud storage constitutes the very first and most critical step in the technical selection and platform deployment processes. The correct technical choices pave the way for subsequent enhancements in supply chain efficiency and data-driven decision-making. When making these technical selections, enterprises must thoroughly consider their specific business requirements and supply chain characteristics. For instance, some manufacturing enterprises have high demands for real-time data processing, especially in the production phase, where any delays can lead to disruptions on the production line or quality issues. In such scenarios, the computational capabilities and response speed of cloud computing platforms become fundamental. Choosing cloud service providers with strong concurrent processing capabilities and low-latency responses ensures smoother data flow across all supply chain segments, thereby facilitating efficient operations in production, logistics, and other areas. In contrast, the selection of big data technologies necessitates a particular focus on data processing and analytical capabilities, as the types and scales of data faced by different enterprises can vary significantly. Some enterprises may generate vast quantities of data daily, encompassing production data, sales data, customer feedback, and more. Here, selecting big data platforms capable of supporting massive data storage and complex analyses is crucial. Additionally, the platform's scalability must also be thoroughly considered. Regarding cloud storage, security and reliability are non-negotiable factors in selection, as supply chain data often involves core business secrets of the enterprise. Any leakage or loss of such data can have unimaginable consequences. Therefore, opting for cloud storage services that offer high security and robust backup mechanisms is paramount. Furthermore, the scalability of the storage system and its compatibility with big data and cloud computing platforms are key areas to evaluate. The process of platform deployment likewise requires meticulous planning. Cloud computing platform deployments are relatively flexible, allowing enterprises to choose between public cloud, private cloud, or hybrid cloud solutions based on their actual needs [4].

4.2. Data security and privacy protection

In the realm of smart manufacturing supply chains, the application of big data, cloud computing, and cloud storage has rendered supply chain management more efficient and intelligent. However, the concomitant issues of data security and privacy protection are not to be underestimated. Data

breaches or illegal utilization can not only incur significant financial losses for enterprises but also severely compromise their reputation and customer trust. Particularly within the supply chain framework, where data exchange among participants is highly frequent, ensuring that this data remains secure and unaltered during transmission, storage, and processing has become an essential challenge for enterprises undergoing digital transformation. The deployment of cloud computing and cloud storage, while greatly facilitating supply chain management, also augments data security risks. Given that data is stored in the cloud, inadequate security measures by cloud service providers or vulnerabilities in a company's own access controls can allow hackers various means to acquire critical business data. Examples include supplier information, customer orders, and production plans. The leakage of such data can result not only in the loss of trade secrets but also jeopardize a company's competitive edge in the market. Consequently, when selecting cloud service providers, enterprises must conduct stringent reviews of their security measures, ensuring they encompass multilayered protection systems, including data encryption, firewalls, and intrusion detection technologies. Data privacy protection is equally critical, especially in the collaborative efforts across the supply chain's various stages, where different enterprises often need to share sensitive data, such as inventory levels and production schedules. While this data sharing enhances supply chain coordination efficiency, it also poses risks of privacy breaches. Therefore, companies must establish stringent data access and sharing mechanisms, ensuring that only authorized personnel can access and utilize this data. Additionally, data desensitization techniques can be employed during the data sharing process to remove sensitive information, thereby mitigating the risk of privacy breaches. Ensuring data security and privacy protection is not solely reliant on technical measures but also necessitates complementary management and institutional frameworks within enterprises. For instance, the establishment of comprehensive data security management systems, regular data security training for employees, and fostering a heightened awareness of data security across the organization are imperative.

4.3. System integration and cooperative management

Through the integration of big data, cloud computing, and cloud storage, the feasibility and efficiency of system integration and collaborative management have been significantly enhanced. However, numerous challenges remain. In practice, many enterprises' supply chain systems are often built incrementally, with different segments employing systems from various suppliers. These systems differ in data formats, interface standards, and communication protocols. To achieve system integration, the first step is addressing these technical disparities to ensure seamless interconnection and free-flowing data. Here, the advantages of cloud computing platforms become apparent, as they can integrate disparate systems onto a unified platform through consistent interfaces and standards, enabling centralized management and real-time data sharing. This allows for operations such as adjusting production plans and monitoring inventory levels via a single platform, eliminating the inconvenience and errors associated with switching between systems. System integration goes beyond technical alignment, it also involves the orchestration of business

processes. For instance, the production department may need to adjust its plans based on sales orders, while the procurement department must anticipate raw material needs according to the production schedule. If systems across departments fail to collaborate, the resulting delays in information transmission could lead to production hold-ups or inventory overstock. Leveraging big data technology, real-time data collection and analysis across supply chain segments can empower enterprises to make more precise decisions, ensuring cohesive operations among departments. For example, changes in sales data can be instantly reflected within the production department, prompting timely adjustments to production plans, and the procurement department can similarly adapt based on the latest production schedules. The entire supply chain operates like a finely tuned machine, with interconnected components moving in harmony. Nevertheless, while the concept of system integration and collaborative management seems straightforward, its execution is far from simple. Beyond technical challenges, enterprises must also make adjustments in organizational structures and management processes. After all, no matter how advanced the systems, if organizational paradigms and management styles remain unchanged, the effectiveness of collaborative management will be compromised. Therefore, in implementing system integration and collaborative management, enterprises must not only focus on technical issues but also foster changes in management and culture, driving a collective shift in mindset to truly achieve digital transformation in the supply chain [5].

5. Conclusion

The application of big data, cloud computing, and cloud storage technologies within the realm of smart manufacturing supply chains has not only revolutionized the traditional management models of supply chains but also illuminated the path for the future development of supply chains. Through the implementation of these technologies, significant enhancements have been realized in supply chain transparency, responsiveness, and collaborative efficiency. However, issues such as data security, system integration, and the shortage of skilled personnel that arise during the technological implementation process necessitate serious attention. Enterprises must judiciously select technical platforms that align with their specific needs, enhance data security and privacy protection, focus on system integration and collaborative management, and continuously invest in technical advancements and talent cultivation to remain invincible in the fiercely competitive market landscape.

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