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Application of Blockchain Technology for Product Tracking in Project Supply Chains with a Focus on Chain Stores: Using the Futures Wheel Foresight Method

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ABSTRACT

The future is undergoing astonishing transformations. Technologies are reshaping the structure and nature of our world at a tremendous pace every day. Artificial intelligence and blockchain can be regarded as two of the most significant future technologies, whose full scope of influence remains not only unknown but is also triggering waves of remarkable changes, catching many businesses off guard and transforming numerous processes and chains. Today, achieving a comprehensive product information chain from production to sale is a critical issue that matters greatly to consumers. This is especially emphasized in the food industry. Knowing the components of a product, who produced it, on what date, the transportation systems and methods used, and the time taken to reach the customer are all crucial elements in service quality. In this context, the use of blockchain technology proves highly efficient. Blockchain is capable of decentralized and immutable storage of verified data and has the potential to render current financial payment methods obsolete by replacing them entirely. At present, many large organizations such as Walmart chain stores are utilizing this technology, particularly in the management of their supply chains. This article investigates the application of blockchain technology in the product supply chains of chain stores using the Futures Wheel method, an exploratory tool for examining the consequences and impact of this technology in the retail industry. The implications of blockchain in the retail sector and chain stores were studied across 18 dimensions, based on expert opinions and global experiences. Given the many unknown aspects of this technology, experts participated in two specialized panels in a brainstorming-friendly environment and identified 18 positive consequences of blockchain for product tracking and traceability. The most important contribution of this study for consumers is the confidence it provides regarding their purchases.

Keywords: Blockchain; Supply Chain Management; Product Traceability; Chain Stores; Futures Wheel

Introduction

In recent years, the global supply chain landscape has undergone transformative changes driven by digital technologies. Among these, blockchain has emerged as a powerful tool capable of enhancing visibility, traceability,

security, and trust in complex, multi-tiered supply networks. As supply chains become increasingly globalized and interdependent, the demand for transparency and reliability has reached unprecedented levels. Blockchain, originally designed to support cryptocurrencies, has evolved into a foundational technology with the potential to redefine the very structure of modern supply chains (Gong et al., 2024).

The decentralized, immutable, and transparent nature of blockchain makes it an ideal candidate for mitigating many of the traditional challenges in supply chain management, including data manipulation, product counterfeiting, delayed information sharing, and a lack of trust among stakeholders (Jeanneret Medina et al., 2024; Kaur et al., 2024). Its application spans multiple industries—pharmaceuticals, agriculture, automotive, and energy—offering opportunities for efficiency, cost reduction, and risk mitigation (Mohamed et al., 2023; Wang et al., 2023; Yadav, 2024).

One of the critical values of blockchain technology in this domain lies in its ability to facilitate real-time traceability. The system's cryptographic security features ensure the integrity of transactional records across distributed nodes, enabling the verification of a product's provenance from its origin to the point of consumption. In industries such as pharmaceuticals, where the risk of counterfeit drugs is alarmingly high, blockchain-based traceability systems are not only desirable but imperative (Jaleel, 2024; Wedha et al., 2023). Similarly, in the food supply chain, the technology has shown promise in reducing waste and addressing food safety concerns by enabling rapid identification and isolation of contaminated goods (Ejairu et al., 2024; Revathi et al., 2024).

Despite its advantages, blockchain adoption is not without hurdles. Technological complexity, high implementation costs, regulatory uncertainty, and interoperability issues remain significant barriers to widespread integration, especially among small and medium-sized enterprises (SMEs) (Kaur et al., 2024; Singh et al., 2023). In the Indian SME context, for instance, organizational readiness, technological infrastructure, and financial limitations have been identified as key obstacles (Rahman, 2024; Rijanto, 2024). Even in technologically mature sectors such as automotive and healthcare, resistance to change and a lack of standardized blockchain protocols continue to hinder scalability (Kamble et al., 2023; Meier et al., 2023).

However, the emerging consensus in literature and practice underscores that the long-term benefits of blockchain integration far outweigh the short-term costs and complexities. For example, in the humanitarian supply chain, blockchain offers the capability to streamline financial flows and improve accountability in resource allocation, which is critical in post-disaster relief operations (Negi, 2024). In the agricultural sector, it facilitates crop index insurance by accurately capturing and recording weather and yield data through smart contracts, enhancing farmers' financial security (Omar, 2023).

An equally critical concern in supply chain research is how to anticipate the future implications of disruptive technologies like blockchain. Traditional predictive models often fail to capture the systemic, nonlinear, and cascading effects of technology-driven transformations. As a result, there is growing interest in foresight methodologies such as the Futures Wheel—a structured visual tool designed to explore the first-, second-, and third-order consequences of emerging trends and innovations (Hakimi et al., 2024; Haldive et al., 2025). Developed to promote creative thinking and scenario generation, the Futures Wheel facilitates a deeper understanding of both direct and indirect impacts, allowing policymakers and business leaders to anticipate unintended consequences and design more robust strategies.

In the context of blockchain-enabled supply chains, applying the Futures Wheel method provides a systematic framework for mapping the multidimensional effects of technology adoption. For instance, implementing blockchain in pharmaceutical logistics may not only improve drug traceability but also reshape regulatory frameworks, alter consumer trust dynamics, and shift the competitive landscape across borders (Mohamed et al., 2023; Petratos & Faccia, 2023). Similarly, the integration of blockchain in green energy supply chains could catalyze environmental performance, enhance supply chain resilience, and encourage the sharing of green customer data (Mohamed et al., 2023; Wang et al., 2023).

Furthermore, scholars have highlighted the interplay between blockchain and agency theory, emphasizing the role of transparency in reducing information asymmetry and aligning interests across supply chain actors (Jeanneret Medina et al., 2024). When trust is institutionalized through transparent, tamper-proof ledgers, the need for intermediaries diminishes, leading to cost efficiencies and faster decision-making. In a comparative study of the United States and

African supply chain ecosystems, blockchain was shown to improve trust, visibility, and data interoperability—benefits particularly valuable in regions with weak institutional infrastructures (Ejairu et al., 2024).

Blockchain is also contributing to the evolution of circular supply chain models by enabling the tracking of materials through multiple life cycles and facilitating closed-loop systems (Meier et al., 2023). In this respect, it supports dynamic capabilities such as adaptability, resilience, and innovation—attributes that are increasingly vital in today's volatile market environment. For example, in the automotive industry, blockchain has demonstrated measurable impacts on sustainable supply chain performance by enhancing integration and stakeholder collaboration (Kamble et al., 2023).

Simultaneously, researchers have explored the synergy between blockchain and other advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), and machine learning. These integrations expand the functional scope of blockchain from a mere transaction ledger to a predictive, autonomous, and intelligent decision-making tool (Gong et al., 2024; Sarfaraz et al., 2023). For instance, blockchain-enabled smart contracts can automate compliance checks, payment releases, and contract enforcement, reducing administrative burden and human error (Rahman, 2024; Wang, 2024).

In developing economies, the application of blockchain in supply chain finance is emerging as a game changer. With limited access to credit, SMEs in countries like India and Indonesia face liquidity challenges. Blockchain-based financing platforms can offer real-time, verified data to lenders, enabling them to assess creditworthiness more accurately and reduce lending risk (Rijanto, 2024; Yadav, 2024). This approach democratizes access to capital and improves financial inclusivity—both of which are central to equitable economic growth.

Still, the complexity of blockchain adoption necessitates holistic research frameworks that capture economic, organizational, regulatory, and behavioral dimensions. This study, by employing the Futures Wheel methodology, seeks to bridge this gap by systematically identifying and evaluating the long-term consequences of blockchain integration in supply chain systems.

Methods and Materials

To identify the possible and probable consequences of a subject, various methods and mechanisms can be employed. Scenario planning is among the most commonly used techniques in discovering future outcomes. In addition to scenario planning, the Futures Wheel method is also recognized as one of the prominent foresight tools for identifying and uncovering potential and probable future consequences. Jerome C. Glenn, as the originator of this method, has outlined multiple applications for it. Some of the most important uses of the Futures Wheel include:

- Discovering consequences;
- Revealing layers of change;
- Organizing and synthesizing;
- Testing ideas before implementation;
- Creating simple scenarios;
- Generating creative ideas;
- Forecasting hidden consequences.

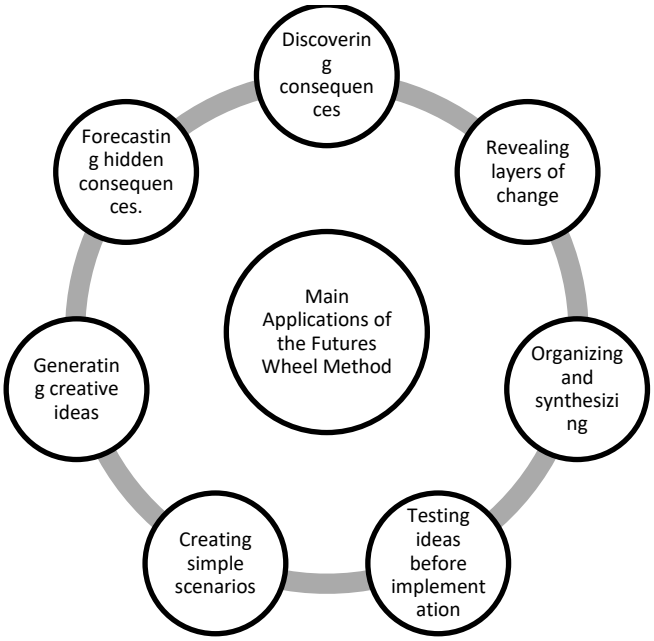

Figure 1. Main Applications of the Futures Wheel Method

Applying the Futures Wheel to uncover possible and probable future consequences requires certain prerequisites. As Glenn asserts, the wheel attempts to focus on a single issue or topic and identify various political, economic, social, technological, environmental, and military consequences across multiple layers. To identify such a wide range of consequences, it is necessary to organize and engage experts from all relevant fields, either through panels or interviews. Glenn emphasizes that the Futures Wheel is a creativity-driven method and that completing the wheels requires brainstorming and the revelation of hidden consequences—consequences often identified during ideation sessions. Another crucial prerequisite of the Futures Wheel is environmental scanning. Environmental scanning is conducted to monitor developments related to the subject of study. It is vital because it enhances our ability to detect weak signals and, in turn, enables us to perceive signs of change earlier than others. Additionally, environmental scanning is essential for tracking the latest developments in the studied field, which is crucial for completing first-, second-, and third-order consequences in the Futures Wheel.

The figure below illustrates the general schematic of the methodology used in this research. The first step begins with a literature review, during which an effort is made to identify and map key components, driving forces, consequences, and positive and negative feedback loops in the system under study. The second step, environmental scanning, begins simultaneously with the first and continues until the end of the study. Environmental scanning is extremely helpful in identifying consequences, as it collects the latest incidents, events, consequences, and feedback loops. To do this, one can use web search engines, social media, expert networks, academic forums, and field observations on a daily basis. To ensure a powerful environmental scan, it is necessary to develop a robust scanning system.

The third step involves interviews with experts, specialists, and stakeholders. These interviews are conducted in the form of in-depth discussions, aimed at evaluating and supplementing the findings from the literature review and environmental scanning. In this study, expert interviews were conducted through panels. These experts and stakeholders were selected based on their familiarity with blockchain technology. Due to their continuous engagement with the topic, they were able to provide more informed and expert opinions.

The fourth step is the organization of brainstorming sessions. In many studies, steps four and five are conducted concurrently, meaning that brainstorming sessions are held in parallel with the construction and refinement of the Futures Wheel. In these sessions, individuals—regardless of their rank, title, or position—gather in a friendly and informal environment and attempt to identify various consequences of blockchain technology in supply chains and

processes within chain stores. These sessions play a crucial role in revealing layers of change, uncovering hidden consequences, and generating newer ideas.

In the final step, the researcher codes and categorizes all the data collected from the previous steps and proceeds to construct or complete the Futures Wheel. For this purpose, the researcher(s) write the central topic in the middle and then map the first-order consequences. Based on the first-order consequences, the second-order consequences are mapped, followed by the third- and fourth-order consequences. Figure 3 illustrates the process of constructing the Futures Wheel.

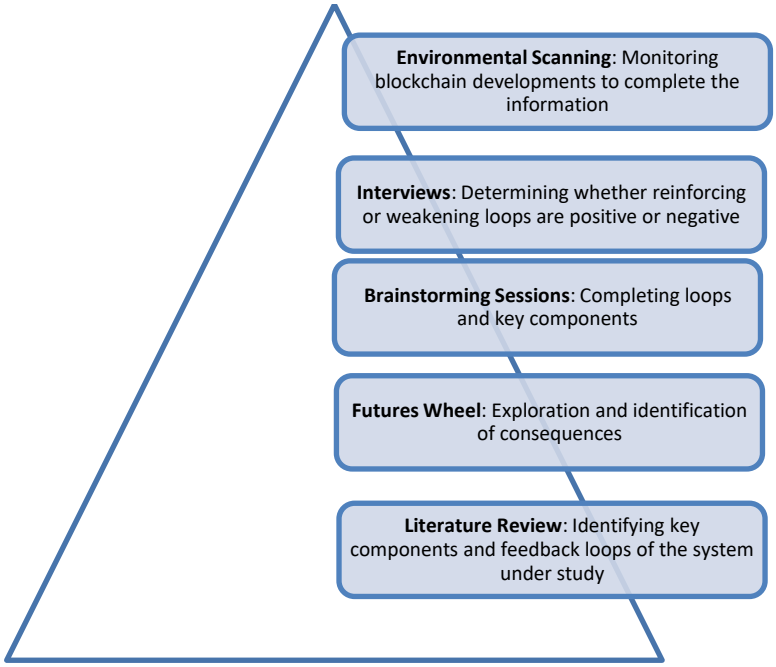

Figure 2. Steps in Implementing the Research Methodology

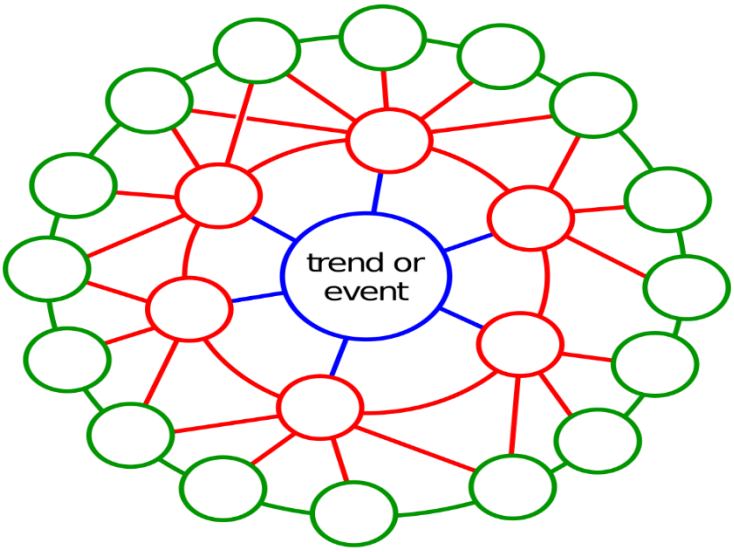

Figure 3. A Sample Futures Wheel for Identifying Future Consequences

To identify the experts, we used the *Reputation and Competency Model*. According to this model, we first referred to dissertations, articles, lectures, books, and other published works related to blockchain technology, supply chains, and their consequences, resulting in a list of 45 researchers. Each of them was asked to identify five of the most well-known experts in this field. In the next step, from among these names, those mentioned more than three times were selected

and invited to participate in the panels and brainstorming sessions. The findings of this study are based on the analysis of insights from 17 experts regarding current trends and possible future events.

Findings and Results

Today, a significant amount of information is being exchanged in the retail industry. Retailers are striving to enhance customer satisfaction, reduce costs, and improve service by focusing on specific indicators. Blockchain technology, as an enabling operator, can effectively assist store owners (the retail industry) in achieving their goals. In the retail domain, blockchain can help improve various business processes (supply chain, sourcing location, method of product and raw material production, customer orientation, etc.). Based on expert panel discussions, some of these processes are elaborated. The evaluated items lead to increased customer satisfaction, improved shopping habits, safer purchases, and better profit margins for both store owners and consumers.

Expert assessments and insights in the panels indicate that both consumers and producers are increasingly inclined toward fair transactions and regulated commerce. This upward trend has made the certification of fair trade practices a priority. Modern organizations must compete with major rivals, and one of the most crucial competitive elements is transparency. Combining machine learning techniques, artificial intelligence, and blockchain technology can deliver entirely transparent supply chain services. This system starts with farm-level production by farmers, proceeds with payment via blockchain platforms to sellers, and continues through to the final consumer, while all related information is recorded throughout the process. In line with the "farm-to-home" initiative, farmers will also have access to a mobile app allowing them to view the final outcomes of the supply chain. Moreover, using the Stellar blockchain platform, they can benefit from features such as instant payments and permanent traceability. This platform enables all industry stakeholders to access the information stored on the blockchain. This efficient supply chain enhances productivity, fosters industry growth, and ensures mutual benefits for all parties involved.

Nowadays, people no longer fully trust health or quality labels printed on product packaging. They prefer to know how trustworthy a product is and whether it was sourced from a healthy origin. Blockchain can provide that reassurance by clearly indicating where and how a product was sourced.

The following model illustrates 18 key advantages that chain stores can gain by adopting blockchain technology, followed by an explanation of each benefit.

Using the Futures Wheel method in expert panels, each of these items can be examined through a foresight-oriented approach. Given the limitations of this article, a comprehensive Futures Wheel could not be drawn for all dimensions. Instead, a general Futures Wheel has been used to explore the overall dimensions and consequences of this technology.

1. **Supply Chain**: One of the key roles in the supply chain is transportation tracking. Blockchain can be used to record information on transportation, including location, time, responsible personnel, temperature, packaging, and production conditions. It also enables store owners to buy or sell from any supplier within the network. Blockchain-based exchanges allow retailers to stay informed about each other and about distributors through a shared network.
2. **Customer Profiling**: Blockchain can help collect customer data to identify purchasing patterns and ordering behavior. These insights can be used to understand individual preferences in different conditions and to maintain reliable inventory levels.
3. **Transparency**: Information stored on the blockchain will be visible to store customers and suppliers, allowing them to see where a product was made, who purchased it, and who the final supplier was.
4. **Authentication and Fraud Prevention**: Blockchain can validate product authenticity for consumers by using historical records to increase confidence in product quality and prevent counterfeiting and fraud.
5. **Customer Loyalty Measurement**: Blockchain can enhance loyalty programs by storing data related to customer commitments and guarantees, allowing deep analysis and enabling all customers to access their loyalty records.

6. **High-Speed Information Transfer**: In chain stores, real-time knowledge of product sales is crucial for timely restocking. Blockchain's rapid data transfer facilitates accurate inventory planning, preventing stockouts and ensuring higher sales.
7. **Real-Time Access to Transactions**: With blockchain, all transactions across store branches can be instantly accessed, aiding evaluations such as branch ranking and planning for marketing and sales.
8. **Elimination of Central Servers**: Maintaining central servers for high-volume chain stores is costly. Blockchain removes the need for centralized servers, resulting in significant financial savings.
9. **High Security and Data Integrity**: Given the increasing volume of conflicting data and the value of transactional records, blockchain ensures that customer, supplier, and vendor data remains immutable, preventing manipulation and reducing associated costs.
10. **Customer Data Access**: Chain stores can offer customers access to their purchase history and product details via blockchain, enhancing transparency and protecting customer data from third-party access.
11. **Supply Chain Data Access**: Blockchain records every stage of transfer from seller to logistics and to the buyer. Tracking package content, environmental conditions, and other details is essential, especially for perishable items like produce. For example, customers can trace meat from livestock farms to delivery, verifying its safety in seconds. Encrypted private keys of sellers, couriers, and buyers enhance security.
12. **Branch Information Access**: Blockchain allows instant access to all data on branches, including customer demographics and best-selling products. These insights enable accurate market forecasting and cost-saving strategic planning.
13. **Precise Product Traceability**: This method is more effective than traditional ones in tracing the source of contaminated food products, reducing waste and facilitating timely recalls of defective items. It ensures only safe products remain on the shelf, resulting in time and cost savings.
14. **Food Industry Fraud Prevention**: These benefits are only possible if the input data is accurate. Since the food industry is prone to human errors, regulatory compliance is typically validated by a third party and stored on central servers or paper, which are vulnerable to hacking, high maintenance costs, and fraud. Blockchain solves these vulnerabilities.
15. **Food Security Importance**: Food security and self-sufficiency are critical due to population growth. Reducing waste and improving traceability of agricultural products using blockchain helps ensure sustainable food supplies. Several studies have highlighted the role of blockchain in this context.
16. **Product Origin Traceability**: In today’s world, consumers often don’t know where their food originates or if it comes from a safe source. Current labeling systems may not provide reliable traceability. Blockchain provides end-to-end tracking. For example, an E. coli outbreak linked to contaminated lettuce from Arizona affected 34 U.S. states and caused five deaths. Blockchain-enabled farmers can show exact details like the sheep's entry date into the processing facility, proving compliance with health standards.
17. **Product Insurance Enablement**: Blockchain facilitates agricultural insurance by making the supply chain transparent. When a product is lost, the insurer can validate the claim without extensive investigations. Certificates for fruits and vegetables can also be issued via blockchain, proving origin, quality, and absence of contamination efficiently and accurately.
18. **Reduction of Overhead Costs and Waste**: Blockchain eliminates paperwork, cutting administrative costs and returning savings to consumers. By removing intermediaries, it reduces transaction costs, enabling small farms to compete with large corporations. Blockchain also empowers farmers to set their prices and helps premium brands showcase why they command higher prices.

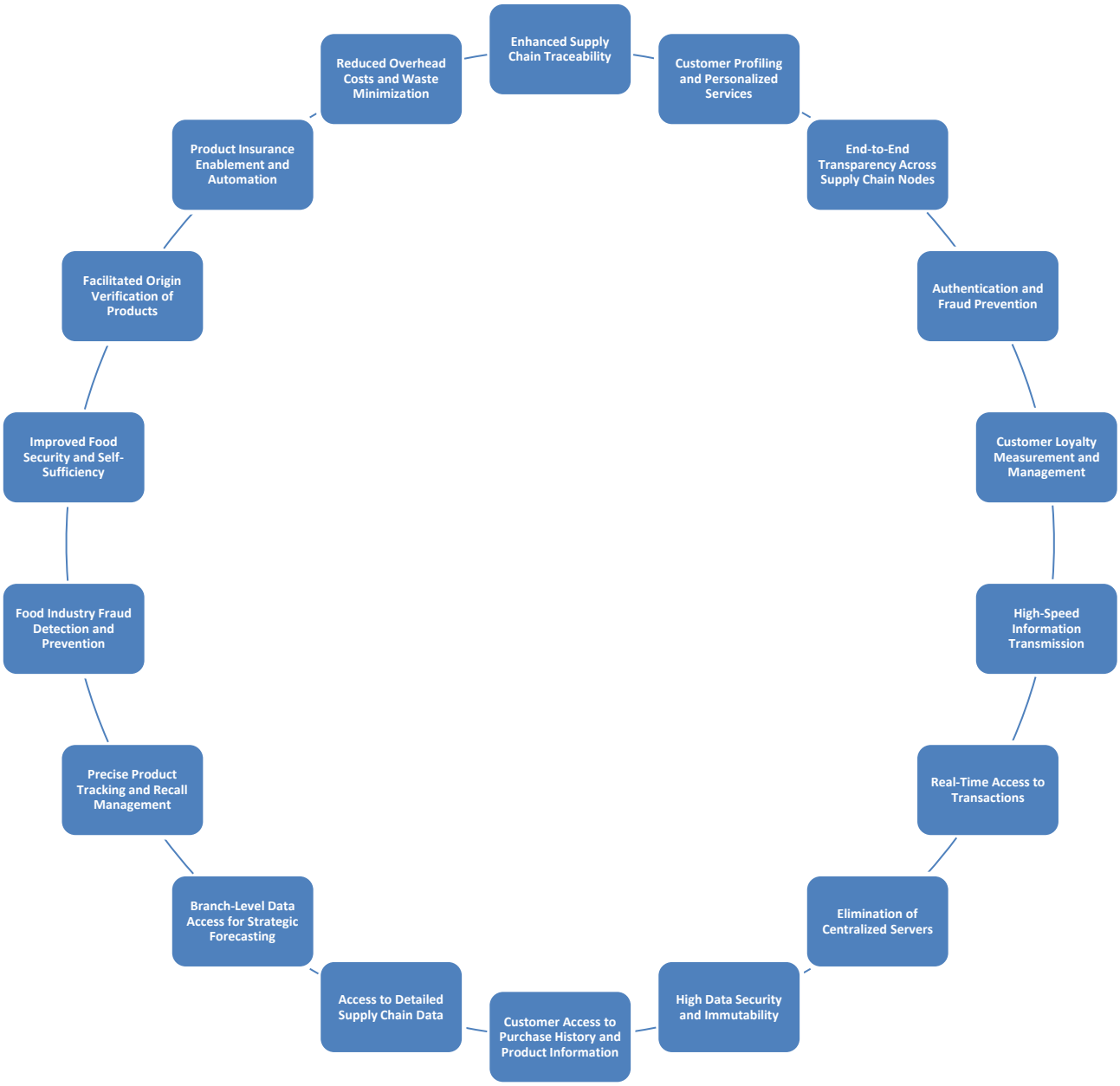

Figure 4. Conceptual Model

If a foodborne disease outbreak occurs, retailers have limited time to determine where the contaminated items originated and which stores they were distributed to (Tian, 2016).

Today, a significant amount of time is required to trace the source of contamination and restore consumer trust in food safety (Popper & Lohr, 2017). Maersk—the world's largest shipping company—uses blockchain to enhance existing IT systems in the supply chain through a transparent ledger, enabling the tracking of food item movements. This initiative is regarded as a major advancement over Walmart's previous studies involving barcodes or automated identification technologies, which relied on central databases and trust among participants (Hackett, 2016, 2017).

In early pilot projects, Walmart and IBM both digitally tracked internal movements (e.g., pork from small Chinese farms to Chinese retail stores and international shipments from Latin America to U.S. stores) (Popper & Lohr, 2017). In these pilot cases, data such as the producing farm, package numbers, factory and processing data, expiration dates, and shipping details were recorded on the blockchain and made instantly accessible to all network members. During foodborne outbreaks, such data enables Walmart to identify the origin of the issue within seconds. Over the year, additional pilot programs with expanded datasets were planned. Ultimately, Walmart believes that if updating food

shelf-life data is considered a parameter for optimizing the supply chain, blockchain could contribute to reducing food waste (Shaffer, 2017). The primary goal of this approach is to ensure traceability of products from supplier to retailer. The immutability of the data underscores a strong emphasis on data privacy.

This solution is primarily focused on product traceability—specifically in the sense that people can know the origin of their products and the companies involved. The accuracy and authenticity of products can be verified through this method. A practical example of traceability is the identification and recall of defective products or the detection and removal of specific batches of surplus or waste items. Without traceability, suppliers and buyers may be forced to discard significant amounts of product, resulting in income loss. Given that traceability is a highly specialized method, aspects of it should not be overlooked. Integrating blockchain with supply chain operations could become one of the simplest ways to reduce costs.

The following figure illustrates a sample supply chain system where various types of information can be stored via blockchain structure and smart contract support. According to Shetri (2018), blockchain applications are primarily concerned with trust-related issues in the supply chain. Enthusiasts of decentralized applications are embracing and developing this technology to help businesses remain competitive. The figure below shows an example of blockchain application in supply chain management for tracking a product from “farm to table” and storing additional information on smart contracts and the blockchain.

In general, the development and implementation of blockchain solutions in the supply chain are still in early stages. The more this technology evolves, the more opportunities it will offer to companies in the future (Nowiński & Kozma, 2017). Particularly for enhancing collaboration between supply chain partners, blockchain technology has the potential to provide various innovative solutions.

According to existing research, different definitions of traceability have been offered by organizations, regulators, and scholars (Aung & Chang, 2014). Studies by Olsen and Borit (2013) concluded that even in scientific articles related to this topic, many ambiguities and contradictions remain (Olsen & Borit, 2013). Research findings indicate that most scientific literature defining this term refers to the “ISO” standard.

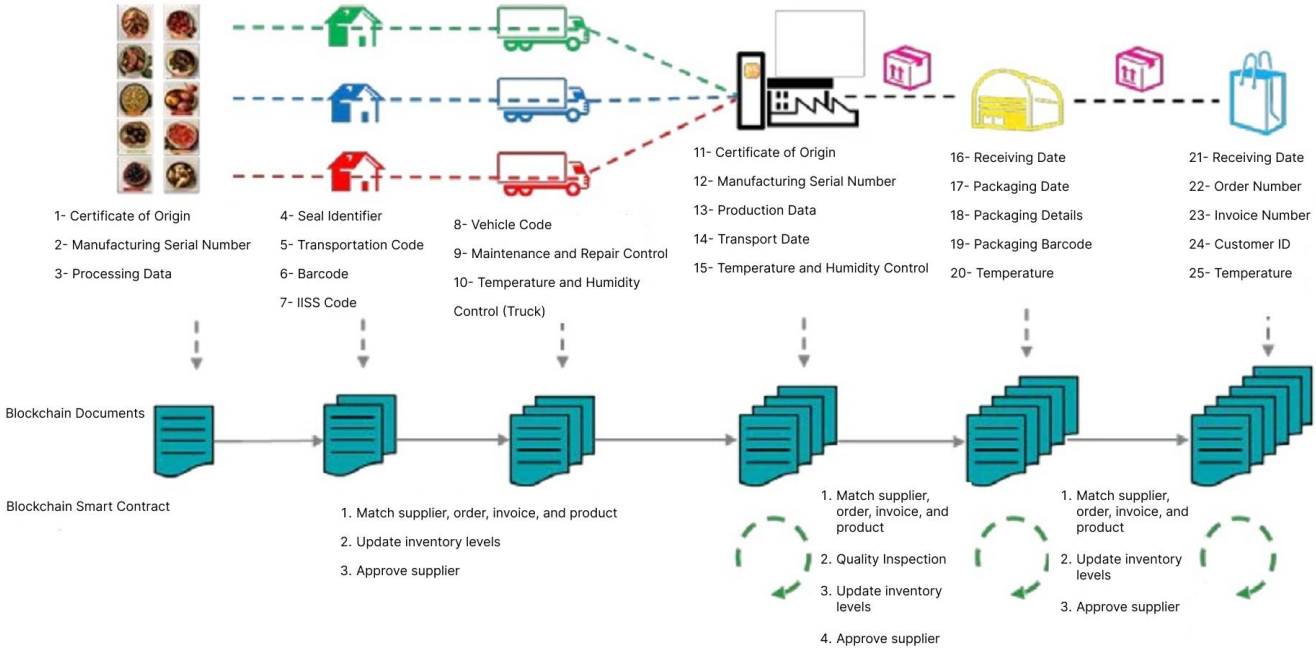

Figure 5. Blockchain Applications in Supply Chain and Logistics

Discussion and Conclusion

The findings of the present study, based on the Futures Wheel method and expert panel analysis, highlight the multifaceted and transformative impacts of blockchain technology in supply chain management, particularly within retail and pharmaceutical contexts. The structured foresight exercise revealed 18 distinct positive consequences ranging from improved traceability and fraud prevention to enhanced customer loyalty, data security, and decentralized logistics architecture. These outcomes are consistent with the growing body of literature affirming blockchain's disruptive potential in redefining the strategic and operational boundaries of supply chains (Gong et al., 2024; Kamble et al., 2023).

One of the key results of this research was the identification of blockchain's role in enhancing traceability and transparency across supply chain nodes. Expert panel discussions confirmed that with blockchain's immutable ledger, organizations can now track a product's journey from origin to consumption with real-time precision. This aligns with previous empirical studies, particularly in sectors like agriculture and pharmaceuticals, where traceability is mission-critical (Hakimi et al., 2024; Jaleel, 2024). For example, blockchain has enabled the recording of packaging, temperature, origin, and logistics data in secure decentralized systems, dramatically improving food safety outcomes and product recalls (Ejairu et al., 2024; Yadav, 2024). These mechanisms empower both suppliers and consumers by minimizing information asymmetry—a key issue previously emphasized in agency theory-based models (Jeanneret Medina et al., 2024).

A second important finding pertains to data security and fraud prevention. Blockchain technology, through its decentralized and tamper-resistant structure, was identified by experts as a critical enabler of secure transaction processing, particularly in high-risk environments where counterfeiting is prevalent. This is especially relevant in pharmaceutical and electronics supply chains, where product integrity is vital. The findings mirror those of (Kaur et al., 2024), who reported that blockchain-based authentication tools reduce the risk of counterfeit goods by allowing real-time product verification. Additionally, in humanitarian supply chains, where accountability is paramount, blockchain has been shown to strengthen auditability and safeguard financial flows (Negi, 2024).

The study also found notable improvements in supply chain financing enabled by blockchain, specifically through the automation of smart contracts and real-time visibility into asset flows. Experts emphasized the utility of blockchain-based financial platforms in resolving payment delays and enhancing trust between suppliers and financiers. This insight reinforces the conclusions of (Rijanto, 2024) and (Wang, 2024), who demonstrated that blockchain enables dynamic financing models such as receivables-based lending and invoice discounting, particularly beneficial for SMEs. Furthermore, by linking product movement data with financial contracts, blockchain facilitates seamless and fraud-resistant integration of logistics and finance functions (Gong et al., 2024; Sarfaraz et al., 2023).

Another salient insight pertains to decentralization and cost reduction. Experts agreed that blockchain adoption allows the elimination of centralized servers and intermediaries, which traditionally act as bottlenecks in logistics and data flow. This decentralization is not only economically advantageous but also enhances resilience against cyberattacks and system failures. These observations are consistent with the findings of (Meier et al., 2023), who argued that blockchain supports circular supply chains by reducing system complexity and resource consumption. Similarly, (Mohamed et al., 2023) demonstrated that blockchain contributes to lower environmental costs and improved green performance by promoting data visibility and collaboration among actors.

The Futures Wheel framework also captured blockchain's impact on customer engagement and personalization. Expert feedback highlighted that blockchain-enabled loyalty programs can store customer behavior data, allowing businesses to offer more targeted promotions and post-sale services. This level of personalization, as shown in the work of (Revathi et al., 2024), not only strengthens customer retention but also improves marketing effectiveness. Furthermore, consumers' ability to access detailed product histories builds trust and reinforces ethical and sustainable consumption behaviors (Rahman, 2024).

Additionally, the analysis uncovered blockchain's value in regulatory compliance and standardization. By embedding compliance protocols into smart contracts, companies can ensure that regulatory requirements are automatically met

during the transaction lifecycle. This is particularly significant in industries governed by strict safety, environmental, or trade regulations, such as pharmaceuticals and cross-border food logistics (Omar, 2023; Wedha et al., 2023). The integration of compliance into blockchain architecture reduces administrative burden and mitigates risks of non-compliance penalties, as further evidenced by (Wang et al., 2023) in the context of green supply chains.

However, the study also revealed potential organizational challenges, particularly in terms of blockchain readiness, inter-organizational trust, and digital infrastructure disparities. Many experts warned that despite its potential, blockchain implementation is hindered by uneven levels of technical literacy, lack of standardized protocols, and concerns about data governance. These constraints echo findings from (Singh et al., 2023) and (Kaur et al., 2024), who identified resistance to change, cybersecurity concerns, and regulatory ambiguity as major inhibitors to blockchain diffusion, especially among SMEs and in developing economies.

Furthermore, the collaborative dimension of blockchain was repeatedly emphasized in expert discussions. The decentralized nature of the technology promotes cross-enterprise collaboration and transparency, which are essential for achieving integrated supply chain performance. This observation is supported by (Kamble et al., 2023), who showed that blockchain integration enhances both horizontal and vertical alignment among stakeholders, leading to more agile and resilient supply networks. Similarly, (Haldive et al., 2025) emphasized that real-time data sharing fosters stakeholder synchronization and efficient decision-making in medicine supply chains.

The adoption of blockchain also emerged as a driver of innovation ecosystems. Through its integration with artificial intelligence, IoT, and machine learning, blockchain enables predictive analytics, autonomous logistics, and responsive inventory management. This technological convergence, as argued by (Petratos & Faccia, 2023) and (Sarfaraz et al., 2023), is poised to redefine the digital capabilities of firms and create new business models that transcend traditional supply chain paradigms. As a result, blockchain not only enhances operational efficiency but also positions firms to compete in digitally disrupted markets.

Finally, this study confirms that blockchain is a strategic enabler of sustainability and resilience in global supply chains. By allowing companies to monitor emissions, energy consumption, and waste generation across the supply chain, blockchain supports the transition toward more sustainable practices. It also enhances the ability of supply networks to absorb disruptions, be it pandemics, geopolitical instability, or natural disasters (Meier et al., 2023; Mohamed et al., 2023). The role of blockchain in building adaptive and sustainable supply systems is further supported by (Jeanneret Medina et al., 2024), who emphasized its alignment with triple bottom line objectives.

Despite the comprehensive insights derived from the Futures Wheel method, this study is not without limitations. First, the methodology is largely qualitative and exploratory, relying on expert judgment and interpretation, which may introduce subjectivity. While expert panels were carefully selected using the reputation and competency model, there remains the possibility of cognitive bias and groupthink. Second, the study is limited in scope to the perspectives of a select group of experts familiar with blockchain in specific contexts, which may not fully capture the diversity of applications across all supply chains. Third, the rapidly evolving nature of blockchain technology means that findings may become outdated as new protocols, standards, and innovations emerge.

Future studies should consider employing mixed-method approaches by integrating Futures Wheel outcomes with quantitative scenario modeling or simulation-based techniques. This would enhance the robustness of foresight exercises and allow for sensitivity analysis of key variables. Longitudinal studies could also track the actual impact of blockchain integration over time, providing empirical validation of anticipated outcomes. Moreover, comparative studies across industries and regions—particularly contrasting mature markets with emerging economies—could offer nuanced understanding of context-specific drivers and barriers. Investigating the intersection of blockchain with ESG (Environmental, Social, and Governance) goals may also yield valuable insights for policy and strategy.

Practitioners aiming to adopt blockchain should prioritize inter-organizational collaboration and invest in digital infrastructure and employee training to ensure seamless implementation. Start small with pilot projects targeting high-risk or high-value supply nodes before scaling enterprise-wide. Engage regulatory bodies early to align blockchain use with compliance standards. Additionally, emphasize stakeholder education to build trust and address resistance. Leverage blockchain not merely as a record-keeping system but as a strategic enabler of customer trust, operational

agility, and environmental responsibility. Finally, embed blockchain within broader digital transformation strategies to unlock synergistic value across technologies.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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