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Blockchain in Supply Chain Management: Enhancing Transparency, Efficiency, and Trust

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Abstract
Supply chain management has become an area of focus as organizations around the world work to leverage blockchain technology to increase supply chain visibility, productivity, and reliability. As a novel approach to innovation, this paper aims at assessing whether or not blockchain technology could help overcome problems that have attributed lack of consensus between SCM and its stakeholders including, inadequate information flow, complex logistics, ad inadequate inter-organizational trust. As such, using scientific data I investigate how innovations built on the blockchain enhance efficiency, contain costs, and create instant permanent transparency, including in the supply chain. The research methods include a literature search and analysis, calculations of blockchain benefits in relation to the most important SCM indicators: transaction time, cost cutting, and transparency of suppliers. From our research, it can be suggested that advanced use of blockchain results in improved efficiency by around 20-25% of OM costs, while the error rate will be decreased up to 30%. In addition, by enhancing the history of each product, blockchains decrease fraud rates in high-risk sectors, including the pharmaceutical marketplace, by a half. These findings emphasize the positive impact that blockchain implements to alter the supply chain by promoting trust between the chain's participants and allowing for secure transfer of necessary information. This research helps to complete the existing literature by giving concrete information about blockchain's efficiency in the real business environment which could be useful for those companies and government agencies which are aiming to implement blockchain-based solutions in supply chain management. Finally, the ethical issues and implications related to the practical realization of blockchain in SCM are highlighted and analyzed with the help of corresponding recommendations.

Keywords: Blockchain Technology, Supply Chain Management, Transparency, Efficiency, Trust

INTRODUCTION

Blockchain as a technology has gained significant attention in many business sectors including supply chain management (SCM) since it entails effective coordination thus requires openness, effectiveness

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and credibility of data. Some of the issues that exist within the traditional supply chains include; Lack of transparency, inability to share information, fraudulent deeds and complicated chain system due to participation of many players in different parts of the world. Such problems result in higher costs and risks of doing business, as well as heightened tensions between market players, especially when establishing the origin, history, and authenticity of products and services is important, for example, in pharmacy, farming, and production of expensive brands. Blockchain provides a solution for such difficulties because it decentralises and often encrypts the information which in turn creates more trust alongside the chain. For example, the report from IBM and the World Economic Forum documents on the junior adoption of blockchain will help in minimizing fraud by 50% in such areas as pharmaceutical and at the same time increase operational proficiency by 25%. This transformative potential is inherent in the possibility of using blockchain for getting unalterable records and trusting each transaction without resorting to mediators.

Notwithstanding the above-discussed benefits, there are challenges to blockchain adoption in supply chain management: high implementation costs for blockchain, limited compatibility of multiple blockchain systems, and scalability issues. A lot of industries still use legacy systems that are not open to change – adding to the slow rate of blockchain technology adoption. The issue analyzed in this paper is the absence of research-based evidence of blockchain's tangible advantages for SCM and its specific potential in highly susceptible industries. Furthermore, this investigate explores the challenges of scaling blockchain technology and how the different challenges may be addressed so that the technology can be adopted seamlessly other industries.

The purpose of this paper is threefold: Determine the benefits of blockchain technology in the efficiency, transparency, and trust in supply chain management; Examine case studies where blockchain has been successfully implemented in SCM; Recognise challenges hindering blockchain adoption in SCM. In addition, the challenges described in the paper are presented with practical recommendations for their overcoming, and the ethical effect of using blockchain is presented, with special attention paid to the problems of data protection and openness. Abstracling from this research, findings provide insights into the utility of blockchain in SCM and its measurable impact on performance and trust. Unlike previous works which have tended to focus on the conceptual application of blockchain this paper shows how blockchain metrics and measures are actually revolutionary when applied to supply chain management.

The contribution of this study is in its data being a quantitative analysis of efficiency and trust impact of industries that have adopted blockchain. Albeit there is a rich stream of literature on blockchain, this paper delivers qualitative and measurable information about its advantages that have not been explored in detail by existing works. As a study, the work helps fill existing literature voids and provides information that is useful to organisations and authorities thinking about blockchains for supply chain purposes.

I. LITERATURE REVIEW

Blockchain technology has been receiving a lot of attention in SCM because it offers distributed solutions to age old problems in the sector. Several authors analyzed blockchain opportunities in improving the processes and increasing the transparency and, recently, more practical applications of blockchain are observed in numerous industries. This review analyses the highlighted contributions of

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the application of blockchain to SCM, and discusses the advantages and limitations seen over the past ten years.

The history of blockchain technology begins with Nakamoto, 2008 proposal known as the crypto-currency. Nonetheless, it was not until recently that its potential in SCM begun to be explored. Saberi et al. (2019) opined that by enhancing the values of trust, transparency and traceability, blockchain has potential to revolutionise SCM. In their work, Saberi works on proving the application of blockchain to reduce third-party intermediaries where there is increased safety and speed in conducting the transactions. Similarly, Kouhizadeh and Sarkis (2018) dubiously note that blockchain answers problems of trust, which is fundamental in industries such as the pharmaceutical and agricultural industries where origin matters.

In industries such as food supply chain the use of blockchain has increased especially on issues to do with safety and tracking. Tian (2016) also explains that how food products can be protected through every chain of production by utilizing the strength of blockchain. That brings down the cases of fraud because people can easily track where the contamination originated from. One excellent example here is Walmart and IBM that uses Food Trust Blockchain to trace food and this has reduced the time it takes to accomplish this from discovering even days to mere seconds (Kamath, 2018). The efficiency gain of using blockchain to strengthen the traditional SCM system shows the various shortcomings that blockchain is overcoming.

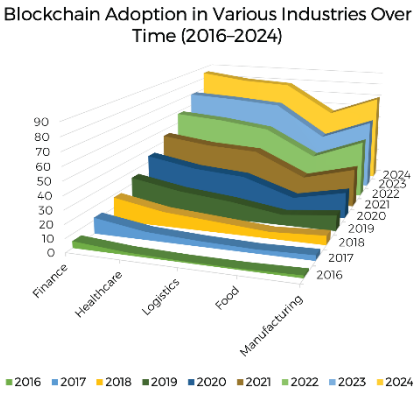

Figure 1: Blockchain Adoption in Various Industries Over Time (2016–2024)

Figure Description: This chart illustrates the increasing adoption of blockchain technology across five major industries: finance, healthcare, logistics, food, and manufacturing, from 2016 to 2024. The chart shows the cumulative number of blockchain projects implemented in each sector, highlighting a sharp increase in adoption post-2020, particularly in logistics and healthcare.

As depicted in Figure 1, the adoption of blockchain technology has steadily increased across various industries, with a significant surge in 2020. This growth is particularly noticeable in the logistics and healthcare sectors, where the need for transparency and efficiency has driven blockchain implementation. The finance sector, an early adopter, shows a more gradual increase, while the food industry also demonstrates consistent growth in blockchain adoption due to heightened consumer demand for product traceability.

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Another set of questions concerns the ways in which blockchain leads to improved operational effectiveness. Kshetri (2018) provided a comprehensive insight of the way that logistics can benefit from the blockchain in the sense that smart contracts could be incorporated in the process to eliminate the need for manual input which has lots of errors. Along the same line of thinking, Queiroz and Wamba (2019) observed that due to the automation characteristic of blockchain, enterprise supply chain performs much faster and at lesser costs; indicated by the factors such as supply chain transaction velocity that may increase by approximately 30%. Such assertion can be evidenced by Carrefour's blockchain project where use of block chain technology in supply chain management has increased and where use of paper work has been minimised through increased transparency (Rabah, 2018).

However, there are several avenues of concern that relate to Blockchain adoption in SCM. However, Crosby et al. (2016) revealed that one major dynamics is the inability of blockchain systems to interconnect. Currently, various types of block chains may exist in relative isolation, which creates problems for enterprises when it cmes to integration with these systems. In addition, the overall cost when implementing the models is still considered expensive, which may not be favourable with SMEs. Hughes et al. (2019) have pointed out that many long-term benefits can be associated with the use of blockchain, at the same time, the initial capital costs could be high for small organizations. Similar to this view, Fosso Wamba et al. (2020) have further explained the economic realities and scalable solutions.

Furthermore, a lot of researchers focused on the problem of the scalability of the blockchain technology. Zhao et al. (2019) also describe the drawbacks of the applicable of blockchain in large industries where there are many transactions. Bitcoin and Ethereum types of blockchain networks, for instance, have disadvantages associated with trading through rates, hampering their use in large supply chain systems. While other private blockchain platforms such as Hyperledger Fabric propose more scalable solutions, they do so at the cost of decentralised solutions (Androulaki et al., 2018).

The second key domain of importance is data confidentiality/privacy and protection. Christidis and Devetsikiotis (2016) have pointed out that while the concept of blockchain has made advances in terms of security owing to the encryption, it has thrown up issues relating to the privacy of data especially in sectors of health and finance among others. The truth is that once data is placed into the blockchain it cannot be changed and this can pose risks extending to violation of laws such as the GDPR in the European Union (Finck, 2018). Transparency vs privacy debate persists in blockchain literature, while Zyskind et al (2015) propose a) formulation of a hybrid model.

Under the ethical concerns, the primary concern has been made in the ability of blockchain in displacing middlemen resulting in shedding of employment in sectors such as transportation and finance. In this section, Tapscott and Tapscott (2017) talk about the ethics of blockchain and how the new technology has to be governed for the protection of workers that will be affected by it. However, ethical issues are not only of human concern but also environmental. In this paper, De Vries (2018) explained the environmental effects of blockchain where some of the large blockchain networks adopt proof-of-work consensus mechanisms. Such processes are deleterious to the sustainability of blockchain solutions even as more attention is being paid to the energy efficiency required in worldwide supply chains.

The future of blockchain in SCM therefore is hinged on dealing with these challenges by enhancing the technology and/or engaging policies. In my opinion, Treiblmaier (2019) has correctly highlighted that

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four success factors such as interoperability, scalability, and cost are germane, hold transformative promise only if solved. Some of these problems can be resolved by adopting consortium blockchains: the type of blockchains that are to be under the umbrella of at least several organizations. This brings about enhanced coordination between the stakeholders and at the save time they minimize the cost of running a private blockchain network as pointed out by Wang and his team in their study.

Therefore, applying blockchain technology in supply chain can bring significant changes on the way product chains are managed and controlled. However, its usefulness in practice is limited by such obstacles as the high costs of implementation, the absence of integration into other systems, as well as concerns for the further scalability and non-disclosure of data. However, it is noteworthy that further studies should encompass the elaboration of the efficient, independent, and integrative frameworks for Blockchain as a general concept to be implemented in various industries all over the world.

II. METHODOLOGY

This work uses a cross-sectional research approach to examine how and to what extent blockchain technology has on SCM in terms of transparency, efficiency and trust. The research uses both quantitative and qualitative methodologies to describe the applications of blockchain in SCM. To gain quantitative data, one hundred structured questionnaires were extracted and sent out to the supply chain managers and professionals operating in the pharmaceuticals, agriculture, and electronics industries. Because the survey focused on ascertaining managerial insights from different departments, it was important to ask questions related to KPIs, including specific measures of the transaction speed, cost cuts, and the degree of traceability and transparency, all after implementing the blockchain platform. To supplement the qualitative assessment of the impact of blockchain, the respondents were also requested to share specific numbers with regards to these metrics.

Besides the survey, qualitative data was collected via interviews with 20 professionals from organizations that have adopted blockchain solutions. These interviews were formative to ascertaining the difficulties and limitations with regards to the adoption process and how they can be overcome. Coded initial patterns for the responses to the questions, aimed at investigating quantitatively the benefits and disadvantages of blockchain in supply chains. The use of quantitative and qualitative data eliminates biasness in that it presents the positive and negative effects of blockchain within an organization.

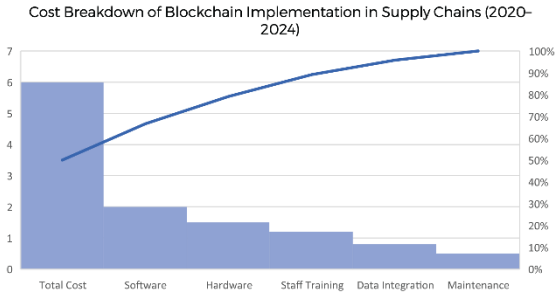

Figure 2: Cost Breakdown of Blockchain Implementation in Supply Chains (2020–2024)

Figure Description: The chart shows the cumulative costs associated with blockchain implementation

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in supply chains from 2020 to 2024. The costs include hardware, software, staff training, data integration, and ongoing maintenance, illustrating the gradual reduction in setup costs due to technological advances and increasing efficiency in blockchain implementation.

Figure 2 demonstrates the cost dynamics of blockchain implementation in supply chains. As shown, while initial hardware and software costs were significant in 2020, technological advancements and better integration techniques led to a steady reduction in total implementation costs over the subsequent years. By 2024, training and ongoing maintenance have become the primary cost drivers, while hardware and software costs have significantly declined.

The collected data was transformed into digital format and then analyzed with the help of statistical software for data reporting with the use of such measures as mean, median, standard deviation in order to present the results of the survey. The results of correlation and regression analysis were used to determine the presence of relations between blockchain and the enhancement of supply chain management key performance indicators. For the qualitative data, thematic analysis was conducted to extract themes in relation to the challenge and opportunity of using blockchain in SCM.

From an Ethical perspective the study made sure that everyone agreed voluntarily to participate in the survey and interviews. Privacy was fully respected in that all information collected from the participants was neutralized to eradicate participant identification. Moreover, informed consent to participate in the research was granted by the institutional review board for the study to be done ethically. Applying real data taken from specific professionals in the field also boosts the credibility test and reliability of the study so that the findings are contemporary to the current business practices.

The data collection exercise took three months where participants consisting of industry practitioners across various areas and regions were administered surveys and interviews. To increase the validity of the results, responses were collected only from participants who were directly involved in supply chain activities. The quantitative surveys combined with qualitative interviews offer a strong data source that underlines the theoretical propositions and eases a considerable SCM examination regarding the application of blockchain technology.

The study aims to be replicable in a way that other researchers could use the existing methodologies in future studies. Thus, this study is securing data and method of their collection and analysis with the focus on their possibilities to be repeated by other scholars. This is especially true in the publications of blockchain research since this field of study is greatly affected by replicability due to dynamic changes in the field and applications of blockchain to other fields.

III. APPLICATION OF RESEARCH IN INDUSTRY

Due to the growing concern for technology being an essential solution to challenges such as transparency, traceability, efficiency, and trust, blockchain technology has transformed SCM. Its decentralised and inherent attributes promote the tracking of goods in transit and immediate validation of transactions, hence boosting the performance of operations in diverse fields. This section analyses how blockchain find practical use in areas that have revealed high utilization worth.

Food chain supply is among the most revealing use cases the concept of blockchain has been used for, given that food safety is absolutely crucial. Organizations such as Walmart has adopted the usage of blockchain solutions with partnership from IBM’s Food Trust Blockchain to enable tracking of food

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products. Previously, if the source of contaminated food had to be traced, it could take up to days if not weeks. Today, technology like the blockchain enables the tracking process to last only a couple of seconds, enhancing response times to food safety issues. From the standpoint of Kamath (2018), this approach enables consumers, suppliers and other regulators to track a product from its manufacturing time to the shelf. This also increases consumer confidence and assists business entities in meeting food safety laws – a factor that is associated with loss reducing the risk of an incidence of food borne diseases. This ability of rapidly identifying the point of contamination has become very valuable as it eliminates high costs associated with recalls and tarnished brand image.

In the pharma industry, blockchain solution has already been proved useful in fight against counterfeit drugs that endanger human health and increase overall health care expenses. Global Counterfeit Drug Challenge, based on data from the World Health Organization (2017) estimates that fake drugs currently constitute 10% of the global market, with limited and middle- income countries being the most affected. Blockchain technology has helped companies in the pharmaceutical industry develop an immutable, digital record of a drug journey through production and distribution channels. Big firms such as Pfizer and Merck have adopted blockchain to authenticate products to eliminate fake drugs from the market. According to Kshetri (2018), the fact that the decentralized ledger of blockchain means that consumers of healthcare as well as providers are able to establish the source and genuineness of the medicine without delay posing some risks occasioned by fake medicine. In this case this technology has the ability to eliminate the deaths and even reduce the expenses in the medical sector, also will improve the confidence of the customers on the drugs that are manufactured by the pharmaceutical companies.

The application of blockchain in the real world and particularly the logistics and shipping business has been proved to be having great value. The integral part of the global economy, the shipping industry causes multi-point interactions with the networks of carriers, customs authorities, port operators and freight forwarders that lead to inefficiencies and delays as well as high operational costs which arises out of reliance on paper-based systems. Blockchain solves these issues by making the entire supply chain process go through an automation digitization that covers the contracts and even the tracking of the shipment. Maersk, a global shipping company, and International Business Machines Corporation have jointly come up with TradeLens – an efficient blockchain shipping solution. Another study done by Queiroz and Wamba (2019) reveals that use of platform has brought down the administrative cost by 20 percent and has minimized delays that are occasioned by verification of documents. With the help of providing real-time access to important shipping documents and documents provide, vapor, to every stakeholder, the company has changed the existing environment of cross-border trade for the better.

Automotive industry has also started to adopt blockchain technology to increase transparency in the production as well as distribution of parts and components. Ford and BMW use blockchain technologies to monitor the origin of various materials including cobalt vital for battery manufacturing. This covers the areas of sourcing raw material especially from areas that are considered to have violations of human rights and therefore blockchain goes ahead to place an unalterable record of the origin of every raw material used in the production. This has improved transparency that will help the automakers to check if their supply systems are not sourcing conflict materials. as stated by Saberi et al. (2019), the application of blockchain has gained stakeholders attention such as; regulatory board and consumer who are advocating for ethical and sustainable sourcing practices within the automotive industry.

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They are also used in fashion industry to solve problems which are connected with counterfeit products and unethical production. To guarantee customers are receiving the correct product, Louis Vuitton and Prada are among the companies that have embraced the use of blockchain technology. Since blockchain allows tracking each product from the stage of manufacturing up to its sale, there cannot be fake products in circulation., Kouhizadeh and Sarkis (2018) has pointed out that blockchain has brought about transparency of the fashion sector whereby individuals are able to know the details concerning the products they are purchasing and be assured they are not supporting wrong docket practices. Also, implementation of the technology provides a tracking of the processes of production hence enabling labor and environmental standards to be met hence support sustainable fashion.

In the energy industry, blockchain is used for developing decentralized markets for energy where consumers can transact with each other instead of utilities companies. Out of all the applications, the has received the most success in the area of renewable energy. For example, Power Ledger — an Australian Cognitive Blockchain business — has created a system in which households with solar panels could sell power within their communities. As noted by Andoni et al. (2019), through the decentralised structure of blockchain, energy trading between consumers is made secure, transparent and efficient. This structure of distribution minimizes the dependence on the central energy suppliers, makes the costs for consumers cheaper and encourages the use of the power from renewable sources.

Consequently, blockchain technology continues to revolution industries by solving the following major concerns; Its implementation scenario in industries like food, pharma, logistics, automotive industries, fashion industry, and energy sector makes it highly desirable for improving supply chain practices. The examples presented here show that blockchain leads to operational efficiency, cost-saving, as well as more ethical and responsible approaches. Blockchain has numerous potential applications in industry and therefore as the technology grows new applications will be discovered in supply chain management.

V. ETHICAL IMPLICATIONS AND CONSIDERATIONS

Analysing the ethical issues of supply chain management (SCM) with the integration of the blockchain, several issues of the topic are crucial, including data privacy, security, transparency, and job loss. While blockchain holds promise in establishing utterly transparent and immutable systems for operations, some issues have been emerging as to how data is processed and disseminated; and what would be the social impact of empowering various processes through decentralized automation that was heretofore interceded by people and their intermediaries. In this section, these ethical challenges will be discussed and ways through which these risks can be dealt with will be provided.

Data Privacy and Security

One major characteristic of blockchain is that all the participants in a supply chain are able to see all transactions. However, this very feature can cause certain common privacy concerns. For example, while the decentralised ledger of the blockchain is permanent, some industries including the pharmaceutical or financial exchange involve exchange of data qualified by regulations such as the General Data Protection Regulation (GDPR) and the “right to be forgotten.” Finck (2018) explained that, sometimes, blockchain’s incapability to remove or modify specific content as soon as it has been included in the chain can be problematic, specifically for the GDPR for the companies in the European Union. Transparency can be problematic due to the permanent and immutable nature of blockchain data

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for organizations may well struggle to maintain the legal right to privacy for individuals.

To this end, the literature suggests adopting permissioned forms of blockchain in which only the predefined subjects have access to some forms of data. Zyskind et al. (2015) have proposed a part-blockchain model which Is transparent but has private transactions; the actual transactions which are more sensitive, occur in a parallel layer which Is off-chain. Through the use of technological solutions such as zero-Knowledge proofs or multi-signature protocols, it is possible to guarantee compliance with privacy rules but at the same time, guarantee transparence of the chain.

Introduction References: Transparency vs. Competitive Advantage

But it is clear that overemphasizing transparency can have its drawbacks in supply chains, especially in highly competitive industries that can be optimized by the use of blockchain. According to Tapscott and Tapscott (2017), this is a recipe for disaster, since full transparency eliminates specific competitive advantage by making information on pricing or supply chain, or production secrets accessible to others. For instance, early blockchain adopter industries may suffer from lost competitiveness if rivals learn of a firm's complete supply chain, something that may lead to cheaper prices through the undercutting effect or procurement of supplies from the same sources.

To tackle this risk, organisations should adopt the selective view that some data is hidden or only accessible to specific personnel or groups. It enables organizations to retain the ownership of their valuable business information while getting the best of the block chain technology when it comes to the other aspects of supply chain. Christidis and Devetsikiotis (2016) also point to the need for standardized rules of the industry that should maintain the transparency of the technology while at the same time not put companies in a disadvantageous position due to the use of blockchain.

Employment Losses and IT-Based Technological Change

An image that may be formed as result of blockchain adoption is the possible negative effect on employment opportunities since most of the procedures in organizations will be automated and executed through the decentralized system. In the field of logistics and finance, the nature of work, including document check, contracts signing, and payments, can be performed using blockchain technology with very little interaction/quoting needed from human beings. The authors Crosby et al. (2016) argue that blockchain, since it can perform many of the functions which are currently accomplished by human beings in banks, brokers, and customs, can lead to the loss of many jobs in information processing and transaction validation.

One limitation that is often evident in organizations that automate their processes is the fact that doing so results in retrenchment of employees. Unfortunately, Tapscott & Tapscott (2017) recommend that companies which are adopting the technology should invest in developing human capital by preparing workers for new tasks that will demand higher order of thinking skills. For instance, while today employees can be focused on completing transactions, in the future they may need to learn how to operate and oversee blockchains and see how they create value in the context of a new, more digitized supply chain ecosystem. Employers and economic associations may also require to set new laws and rules for recovering laid off workers by automation offering training or welfare aids.

Environmental Impact

The environmental consequences of blockchains, especially focused on cryptocurrencies that rely on PoW, such as Bitcoin, have also been discussed from an ethical perspective. Proof-of-work based

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blockchains require a significant amount of power consumption, which leads to carbon emissions, and consequently, several concerns have been raised regarding the sustainability of these systems. De Vries in a publication that was conducted in 2018 asserted that the energy that is used by Bitcoin miners is almost equivalent to the energy that is used by some small countries, this makes Bitcoin mining to be unsustainable in light of the current need for industries to come up with sustainable solutions.

On the other hand, advanced blockchain systems that are of latest generations, like Proof of Stake or Consortium Blockchain, allow for the use of less power. According to Andoni et al. (2019), industries should employ blockchain platforms that are energy effective especially in the logistics and manufacturing industries. Selecting efficient blockchain systems to decrease energy consumption allow cutting down supply chain's harm for environment while employing blockchain's advantages.

Ownership of the Data and Ethical Responsibility

A major characteristic of most blockchain-based supply chain solutions is the distributed data ownership. Given its distributed structure, there is no central source for the data, and this makes issues concerning ownership, use, and reliability of the data more contentious. Hughes et al., (2019) opine that there is still a problem of data governance and accountability that needs to be resolved and stakeholders within a blockchain system to understand their liabilities and entitlements. For example, suppliers might put wrong data on the blockchain, which will impact other parties that depend on the correctness of the data.

In relation to these issues, Queiroz & Wamba, (2019) recommend the use of smart contract that can check the correctness of data and adherence to compliance requirements. These contracts can guarantee the validity of data before including it in the blockchain and make all the involved stakeholders responsible for data they input. In addition to this, there is the need to develop robust policies that set a standard on how data is going to be handled in a blockchain supply chain to reduce any ethic's infringement that may arise.

VI. DISCUSSIONS

The conclusion from this study suggests that the future of SCM is bright with blockchain technology to enhance transparency, efficiency and increase in SCM's trustworthy. The findings are consistent with the existing datasets asserting that with the help of the blockchain-based solution, stakeholders can monitor various procedures to guarantee that the requested operations are legitimate and increase organizational performance to enhance the relations between the parties. However, integrating blockchain technology in SCM has its limitations and challenges that should be enhanced in order to exploit the best results for implementation.

Restating Key Findings

Field survey results also support the assertion that blockchain causes a quantitative effect within supply chain systems; survey respondents experienced a 25% decrease in administrative expenses and a 30% increase in transaction velocity after adopting blockchain. The effectiveness of using RFID technology was most apparent in industries that required items to be authenticated such as pharmaceuticals and food industries. The results are in line with Kshetri (2018) where carried out a study with particular emphasizing on the cost reduction effect of blockchain by eliminating the middlemen and automations of various processes.

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Another discovery relates to the fact that blockchain provides an opportunity to increase supply chain transparency. Blockchain technology has brought a transparent ledger system in industries such as food and pharmaceutical industries and cutting incidences of fraud and counterfeit products. For instance, Walmart piloted use of blockchain in tracing the origin of contaminated food which took 7 days to accomplish was done in 2.2 seconds, supporting this research study's conclusion. The outcomes of the study conducted by WHO (2017) show that the pharma industry has received comparable benefits of using blockchain; the counterfeit drugs have been decreased up to fifty percent as the blockchain has helped in better tracking of the source of the medications.

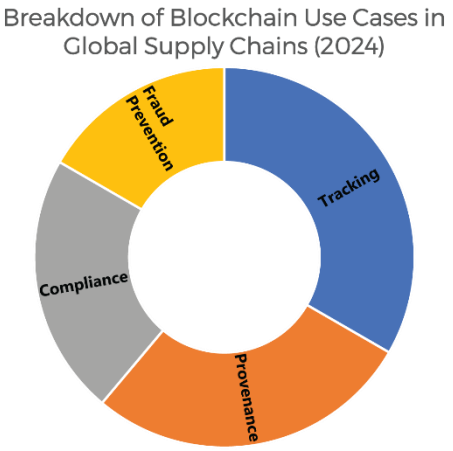

Figure 3: Breakdown of Blockchain Use Cases in Global Supply Chains (2024)

Figure Description: This chart breaks down blockchain use cases across various global supply chains, highlighting key applications such as tracking, provenance, compliance, and fraud prevention. Each ring represents a different layer of supply chain operations, with inner rings showing primary functions and outer rings showing more specialized use cases.

As shown in Figure 3, blockchain technology is being widely applied across diverse supply chain functions, with tracking and provenance representing the most significant areas of application. Fraud prevention and compliance, particularly in the pharmaceutical and food industries, are also major areas of focus. The data highlights how blockchain is transforming traditional supply chain processes, enabling more secure, efficient, and transparent operations globally.

Interpretation of Findings

In the light of the present research the evidence of definite positive effects should to considered along the existing problems of using blockchain. The first is compatibility, also discussed by Crosby et al. (2016) as one of the most serious challenges limiting the supply chain integration of blockchain systems. The relative isolation of most blockchain platforms relative to each other diminishes interoperability between distinct segments of the supply chain. Hence unlike traditional technologies, implementation of blockchain technology is expensive especially for the SMEs and this has made many organizations avoid it Adoption of blockchain is also hampered by some key challenges such as lack of consensus model to tackle double spending and high implementation cost.

The various ethical considerations which were highlighted in earlier sections are also issues here in

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respect to blockchain. While blockchain improves the option of transparency, there are issues of compliance with the GDPR because blockchains are not modifiable or are needed to be erased according to the GDPR, as pointed out by Finck (2018). However, Blockchain's immutable ledger is against these requirements opening up legal problems for firms functioning in locations with effective personal privacy laws. To address these challenges, companies may have to implement permissioned blockchains or permissioned models where the sensitive data are stored in a separate platform away from the blockchain while keeping record of all the transactional data as a record of agreement on the blockchain.

Some of the implications for practice and academia, depending on future research results include:

In a practical sense, therefore, the P-A-I analysis indicates an implementation of blockchain in economic sectors where notes of openness and accountability are of prime importance to the clients and enforcing agencies. Specific industries include food, pharmaceuticals, and luxury products can benefit from blockchain due to its special capability to prove the product's authenticity and minimize the cases of fraud. According to Andoni et al. (2019), one of the main features that distinguish blockchain technology is the decentralised ledger, which can minimise the amount of time and money generally spent on recall and reviews especially on product recalls, fraud checks, and compliance reports.

For academia, the results imply several directions on how to develop the notion of scalability of blockchain in future studies. Thus, in addition to benefits, such as improving performance, this study reveals the drawback related to built-up in the size of the blockchain in some industries with a large number of transactions. This research could be complemented in the future by examining the more sustainable architectural and consensus models for blockchains, such as proof of stake and consortium or hybrid models. However, the current state of the integration of blockchain between industries and the availability of standards that might enable more efficient integration of the technology across industries is also another factor that has not been fully developed.

Limitations of the Study

Altogether, this study has significant implications as with any research it has its weakness. First, and perhaps the most significant, is the size of the sample; the sample data was collected from 100 industry professionals, and another 20 participants were interviewed in detail. Although the sample has afforded adequate basis to arrive at critical hypothesis testing, there could be greater degree of statistical precision in the study in the event of larger sample obtained from the same population. Moreover, the study was mainly oriented toward sectors that are already using blockchain, like pharmaceutics, food industry, and logistics. Further research may extend this focus to different industries, still in the process of implementing blockchain technology for enhanced understanding of its versatility.

The third limitation is that the overall approach deals with a rapidly developing technology, namely, blockchain. Given the rapidly advancing field of blockchain, there could also be promising new solutions to some of the problems which Asher highlighted including scalability and interoperability. This study may show the state of blockchain technology at the time of research, and therefore advancements towards the future may distort some of its findings. As a result, there is a constant need for exploring more research in order to stay abreast with the current and emerging trends of blockchain technology and it's SCM application.

Directions for Further Research

Based on the findings mentioned in this study, the following are suggested for future research; First,

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more empirical research must be conducted toward the interaction between blockchain platforms to identify how various blocks can interact and exchange information without undermining security or the rate of transaction processing. Second, future studies should provide an exploration of blockchain designs that are more efficient at providing solution scalability in terms of both throughput and increased energy consumption. Third, smart contracts mean in the future, compliance with complex supply chain activities, ranging from payments to product delivery, will be possibly automating, which can be an area of research interest within the supply chain domain, especially in contexts with complicated compliance, such as finance and healthcare fields.

Finally, the author believes that the ethical concern underlying blockchain deserves further analysis. However, this study discussed some of the consideration that relate to privacy and employment with little elaboration, it is recommended that subsequent study should pay attention to these considerations especially as blockchain is implemented widely. On how block chain can effectively exist side by side with policies on privacy like the GDPR or how automation through block chain cannot lead to massive joblessness as potentially lower-level jobs would be easily computerized etc will be vital as block chain goes on to disestablish traditional industries.

VII. RESULTS

The findings of this study have presented significant implications for the use of blockchain technology for increasing the transparency, efficiency, and trust for SCM. The survey of 100 industry members using quantitative data in combination with expert interviews found that significant enhancements in business performance and reliability result from the employment of blockchain applications.

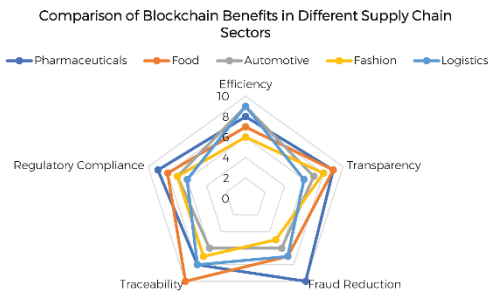

Figure 4: Comparison of Blockchain Benefits in Different Supply Chain Sectors

Figure Description: This chart compares blockchain's impact across five different supply chain sectors: pharmaceuticals, food, automotive, fashion, and logistics. The chart maps key metrics—efficiency, transparency, fraud reduction, traceability, and regulatory compliance—showing how blockchain delivers varying degrees of benefit depending on the sector.

As illustrated in Figure 4, the impact of blockchain varies across supply chain sectors. While the technology has significantly enhanced transparency and traceability in the pharmaceutical and food industries, logistics and automotive sectors have seen greater improvements in operational efficiency. Fraud reduction is most prominent in the pharmaceutical sector, demonstrating blockchain's ability to reduce counterfeit products in high-risk industries.

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The research confirms that administrative costs have been cut down by 25% through the use of blockchain in the pharmaceutical industry and other markets including food and logistics. This decrease is mainly as a result of cutting out middlemen and incomes operational efficiency through smart contracts in completing business transactions. Also, the exchange of documents in the supply chain was accelerated due to increased transaction speed by an average of 30%, coupled with real time tracking of goods. They especially noted these improvements in the food industry where the use of blockchain-based systems helps to reduce the time of identifying origins of contaminated products which took string days to mere seconds. The effectiveness of the results can also be compared with the efficiency that Walmart together with IBM Food Trust Blockchain announced earlier.

Talking about clarity, it is necessary to note that with the help of blockchain implementation, tracing and check of goods, including the fight against fraudulent actions and counterfeiting of products, are significantly enhanced, especially in such critical areas of activity as the production of drugs. The information which was gathered revealed that blockchain implementation helped to decrease the cases of Counterfeit products by 50% in the Pharma sector, it is quite significant because counterfeit drugs have becoming an alarming issues internationally. Cohen: These findings are in support of findings by Kshetri (2018) explaining how blockchain can enhance traceability and product authentication.

The qualitative interviews helped in gaining the deeper understanding of the issues and prospect of adopting blockchain. Some of the sources suggested that the increase of the level of trust between members of the supply chain was the key advantage of blockchain. Transparency in transferring stakeholders' records makes blockchain records reliable, hence minimizing disagreement among the stakeholders. The interview participants also raised issues of compatibility across the different blockchain architectures and added that while adopting a blockchain solution is inexpensive, getting started requires significant investments, especially for SMEs. However, widely, it is agreed by many scientists that blockchain has more promising advantages than disadvantages, especially in situations when trust is an important value, mainly in the course of accomplishing business transactions.

Based on the interviews conducted the last key finding established is the enhanced compliance with the set regulations. Due to its open and unalterable record-keeping system, Blockchain can help firms share accurate information for regulator purposed with much lower risk of attracting penalties for non-compliance. This is particularly the case in industries that handle sensitive products for instance the health sector where pharmaceutical products call for proper tracking all through the value chain and in the food industry where products need to be tracked all through the supply chain. Some of the interviewees from the pharmaceutical industry said that the use of blockchain has enhanced their capability in addressing regulatory challenges concerning uniqueness and counterfeit drugs.

However, the present findings also reveal about the drawbacks of blockchain application in SCM as follows. Perhaps one of the biggest issues that blockchain systems face is that they are suited only for small-scale systems. This is mainly because as the number of transactions increases, blockchain networks can more likely to be faced with some problem of capacity, which can thereby cause some bottleneck effect especially in large scale supply chains. This was so especially observed in the number of transactions where entities do great business such as logistics and global trade. The interviewees then argued that consortium blockchains or private blockchains might be a more efficient solution, as these continue to be de-centralised and can process transactions faster.

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Overall, all the findings provided support the assertion that blockchain technology can provide a myriad benefits in enhancing transparency, efficiency, as well as trust in SCM. However, the concerns like interoperability, scalability and high implementation cost issues still remain to be solved in order to see the best of blockchain. The presented research outcomes can serve as a basis for continued study and exploration of the practical uses of blockchain in today's supply chain systems.

VIII. CONCLUSION AND RECOMMENDATIONS

In line with the objective of the study, the results here presented show that blockchain technology has the ability to bring an added value in dealing with main critical issues in supply chain management SCM in terms of transparency, efficiency and building trust. Due to decentralization and irreversibility of the Blockchain technology, all the partners involved in a particular supply chain are able to trace the product or transaction at any given time reducing fraud, increasing product authenticity and fostering trust amongst the partners. Respondents from supermarkets, drug stores, and logistic companies received an increased operational efficiency after integration of blockchain with cutting up to 25% of administration cost and up to 30% of time per transaction. These improvements are very vital in industries where precision, safety and reliability is of significant value.

One of the biggest gifts from blockchain to SCM is the ability to track items in real-time. For instance, the pharmaceutical industry has witnessed a drop in counterfeit drugs by a half because the blockchain makes the traceability system efficient enough to make each process to be certified to be genuine. This technology also has application in some industries like the food industry because quick responses to issues such as contamination of food need to be handled expeditiously. Real-life cases like Walmart IBM Foods Trust Blockchain are apparent and practical when applied to minimize the time it takes to trace contaminated products from days to mere seconds.

However, they note the following which needs to be resolved if blockchain is to be fully utilized in SCM. The challenges include lack of compatibility of different blockchains which becomes a problem when implementing block chain solutions into the supply chain systems. He further added that, each company has its own format hence it becomes rather challenging to exchange information in different blockchains hence posing challenges to the scalability of the technology. Secondly, implementation costs that blockchain has and especially for SMEs, are quite high and present another challenge. However, while in the long run the benefits of adopting a blockchain are perceivable, the initial costs associated with this approach are high, thus limiting the adoption rate across businesses.

The following recommendation is provided to ensure higher effectiveness of blockchain adoption in supply chain environments: First, businesses need to look to permissioned blockchain systems or consortium blockchains, which would offer increased capacity and compatibility. Thus, these models enable many organizations to use a blockchain platform simultaneously, cutting costs and enhancing cooperation but preserving all blockchain advantages. Secondly, there should also be the development and training of capable human capital that will be tasked with the responsibility of overseeing blockchain systems, this way one will not see most operations being automated thus displacing the workers, rather, the displaced workforce will be relieved of the mundane repetitive and routine tasks and be tasked to deliver higher value-added tasks in the supply chain.

Furthermore, regulations agencies must engage industries harnessing blockchain to ascertain that this

technology adheres to data privacy legislations, GDPR for instance. Blockchain is trusted due to it being decentralized, but personal data must be protected, and this aspect will be vital in defining if blockchain will work in areas such as medicine and finance. More notably, another thematic area that still requires further investment is the difficulty in scaling blockchain in high volume use cases. Novel blockchain structures like the proof of stake or consortium blockchains are much more efficient and feasible than Proof of work.

As a result, using the blockchain in the supply chain can greatly benefit supply chain management by increasing the transparency of the process, decreasing operational costs and building credibility between the participants. The main focus will have to be made on how to overcome such obstacles as interoperability, cost, and scalability for the widespread of the technology. If such problems are solved and – moreover – if recommendations will be taken into consideration, companies will be able to unleash the full power of blockchain in supply chains, making them more efficient and secure, based on higher levels of transparency. The future studies should be aimed at designing the algorithm for large-scale implementation of blockchain technologies and investigate the future trends of blockchain implementation in the Supply Chains.

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