IMPACT OF BLOCKCHAIN ON THE PERFORMANCE DIMENSIONS OF SUPPLY CHAIN MANAGEMENT

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ABSTRACT

This paper explores the contribution of blockchain to the performance dimensions of Supply Chain Management (SCM), with a specific focus on addressing traceability issues in the international food supply chain. The paper reviews literature related to blockchain in SCM and its effects on performance dimensions. Technical aspects of blockchain and the desired outcomes of traceability in the food supply chain are discussed. The paper concludes with findings, offering insights into the impact of blockchain on the performance dimensions of Supply Chain Management.

Keywords: *Blockchain, Supply Chain Management (SCM), Traceability, Performance Dimensions, International Food Supply Chain.*

INTRODUCTION

Supply Chain Management (SCM) plays a pivotal role in today's globalized business environment, and the integration of emerging technologies has become paramount for enhancing its efficiency and performance. This paper focuses on the significant contribution of blockchain technology to the performance dimensions of SCM, with a specific emphasis on addressing traceability challenges within the international food supply chain. As businesses strive to ensure the authenticity and safety of their products, the adoption of innovative solutions, such as blockchain, has gained prominence. This introduction provides an overview of the key themes explored in the paper, including the role of blockchain in SCM, its impact on performance dimensions, and the specific application in mitigating traceability issues in the complex landscape of the international food supply chain. Through a comprehensive review of relevant literature and an examination of technical aspects, this paper aims to offer valuable insights into the transformative potential of blockchain technology within the realm of Supply Chain Management.

LITERATURE REVIEW

a) Blockchain in Supply Chain Management (SCM)

Blockchain was first introduced in 2008 by a pseudonymous person called Satoshi Nakamoto for a peer-to-peer financial transaction procedure named Bitcoin (Nakamoto, 2009). Bitcoin, a digital currency, provided a revolutionary transparent and immutable procedure without a central authority. But the blockchain technology on which bitcoin was based could have many more implications (Swan 2015). Blockchain is a de-centralized transaction and data management technology (Crosby 2016) that allows consumers and companies to store and exchange value, eliminating the need of intermediaries. It has the potential to create more transparent, efficient and secure systems (Zeng et al. 2018).

Blockchain in a supply chain could enhance traceability (Lu and Xu, 2007). Blockchain could improve traceability, efficiency, and decrease waste in a food supply chain (Francisco and Swanson 2018). Blockchain in a supply chain could contribute to transparency (Queiroz and FossoWamba, 2019). Sensitive information in a supply chain is also protected by blockchain. Robust cybersecurity and increase in trust can be achieved by blockchain (Kshetri, 2018) (Ying, et.al, 2018). Integrating blockchain, Internet of Things (IoT), and smart contract in a supply chain could save time and cost (Christidis and Devetsikiotis, 2016).

Thus, blockchain in a supply chain contributes towards traceability, transparency, efficiency and information security.

b) Impact of Blockchain on Performance Dimensions of SCM

The various performance dimensions of SCM (Kshetri, 2020) are:

1. Reducing costs
2. Assuring quality of products
3. Increasing speed
4. Increasing dependability
5. Reducing risks
6. Facilitating sustainable practices
7. Enhancing flexibility

The impact of blockchain on each of the performance dimensions of SCM mentioned above is discussed in detail below.

1. Reducing Costs

A quarter of the original equipment manufacturers (OEMs) by 2023 will utilise blockchain to source spare parts. The accuracy of the usable parts will improve by 60% and cost will reduce by 45% (Ellis, 2019).

A blockchain project involving brewing company AB InBev, software company BanQu, Zambian and Ugandan farmers resulted in the reduction of supply chain costs by 15% (Murray, 2019).

Blockchain ensures cost reduction by eliminating paper-based processes and air courier expenses. For example, Maersk implemented blockchain (Groenfeldt, 2017) in their supply chain and observed significant cost savings.

Unlike other Information and Communications Technology (ICT) systems such as radio-frequency identification (RFID), blockchain can be implemented without devices, reading hardware or any process to attach tags to cases or pallets. Therefore, blockchain implementation costs are marginal or low if IoT has already been used to detect, measure, and track key SCM processes.

Blockchain makes unit level entity identification possible. As the cost of digital networks is very low, it makes sense to generate a blockchain code even for small transactions. A single apple's or a blueberry packet's entire supply chain history can be recorded by blockchain (O'Marah, 2017).

For retailers blockchain's traceability function offers cost saving solutions. Walmart for instance found that tracing a fruit's supply chain history took 2.2 seconds (Kshetri, 2020). In a crisis situation involving contaminated food products or auto parts, blockchain can be used to quickly identify such products/parts and then strategically removed, instead of recalling the entire batch/product line, thus avoiding financial losses.

Blockchain enables effective response if tainted products are discovered in the supply chain. Thus, blockchain aids in building customer confidence and also ensures that the dangers of customer getting ill are negated.

2. Assuring Quality of Products

Blockchain facilitates track-and-trace applications (Westerkamp, et al., 2020) which can assure quality of products in a supply chain. One of the key mechanisms is the verification of Chain of Custody (CoC). It discourages supply chain partners to use low quality and counterfeit ingredients in their products. Alibaba, a Chinese company is using a blockchain solution called "Food Trust Framework". This solution helps in improving the integrity and traceability of food supply chains in order to fight against low-quality and counterfeit products in China.

Blockchain also allows faster response and quicker feedback to supply chain partners. This can have a major positive impact on the quality of products. For example, the British-Dutch multinational consumer goods company Unilever was able to address product quality issues in its tea leaf supply chain using blockchain technology Provenance's platform. This platform allowed the company a direct connection with the farmers for real time feedback.

3. Increasing Speed

Blockchain increases the speed of various operations in a supply chain. Blockchain facilitates digitisation of physical processes and reduction in interactions and communications which leads to increase in speed.

Cryptocurrency (Orcutt, 2020) has also facilitated increase in speed of supply chain operations. Small businesses and firms have benefited by making payments in cryptocurrencies rather than in major international currencies like US Dollar and Euro. The usual banking process is complex and requires many supporting documents and is time consuming and expensive. By making payments in cryptocurrencies, business owners or firms can not only avoid the disadvantages of the bank wire transfers, but can also avoid import taxes.

4. Increasing Dependability

A higher degree of dependability is achieved by implementing blockchain in the supply chain. This is possible as immutable data for quality, physical state and location are available for verification. For example, Gemalto, a Thales company utilizes blockchain technology to exert pressure on supply partners to be more responsible and accountable for their actions in transporting temperature-sensitive medicines from drug manufacturers to hospitals located in hot climates. The responsibility and accountability shift when the drugs move along the supply chain. Drugs are delivered to the hospitals in a state that meet regulatory requirements.

5. Reducing Risks

Blockchain provides various mechanisms to address risks associated with a supply chain. It provides solutions to identity management of participants as well as the IoT devices in a supply chain (Alam, 2016).

Blockchain provides immutable information regarding the participants taking action and time & date of the action taken. In permissioned blockchain, only participants mutually accepted in the network can engage in transactions in specific touchpoints. Example of a permissioned blockchain is the IBM/Maersk platform which is built on IBM's Hyperledger Fabric protocol. This will boost trust among participants in the supply chain and reduce risk.

The Keyless Signature Infrastructure (KSI) blockchain implemented by Guard Time Federal on Lockheed Martin's external software is an example of how risk can be reduced. KSI's integration into digital-based manufacturing equipment ensures detection of unauthorized software when third-party routine maintenance is performed (Biesecker, 2020). KSI also ensures data integrity by verifying that the data in the network is not compromised.

Precision parts manufacturer Moog has launched a blockchain service called Veripart. This service ensures that the right software file is downloaded to 3D print a new part. The service also guarantees the software file cannot be hacked (Casey and Wong, 2017).

6. Facilitating Sustainable Practices

Customers want companies to support recycling, invest in charities and take actions to demonstrate social responsibility (Haller, 2020). With blockchain, companies can demonstrate their sustainability-related practices. Blockchain promotes transparency and ensures that middlemen and other actors in supply chains do not engage in unethical behaviours (Treiblmaier, 2019). A combination of blockchain with other technologies such as IoT and big data analytics can help companies to monitor and evaluate social sustainability performance of their supply chains (Venkatesh et al., 2020).

Customers are increasingly becoming concerned about the sources of products they use such as food and beverages, pharmaceutical, and cosmetics (Scott, 2017). Blockchain addresses the issue of fake labels related to source, production, process standards, and other aspects. Customers can have access to data that will confirm whether the products they are about to buy have been produced in an environmentally sustainable manner and whether human right violations or child labour were involved in their supply chain (Dierksmeier, 2020).

7. Enhancing Flexibility

Flexibility can be defined as a supply chain's ability to adapt to the changing competitive environment in order to provide products and services in a timely and cost-effective manner (Swafford et al., 2000). A higher degree of flexibility can be achieved in supply chains by using blockchain technology.

In international supply chains, the information flows in processes such as the letters of credit (LC) and bills of lading are very complex and intricate. During COVID 19 pandemic, documents related to cross-border trade transactions could not be carried in airplanes as there was a worldwide lockdown. They were carried in ships instead, thus increasing the time taken for to settle invoices (Fig.1). Also, most of the documents could not be delivered to banks, as they were closed. Some banks started accepting scanned copies of the documents sensing urgency. But this practice is prone to frauds. Blockchain can negate the risks of fraud and is more secure and flexible (Tan, 2020).

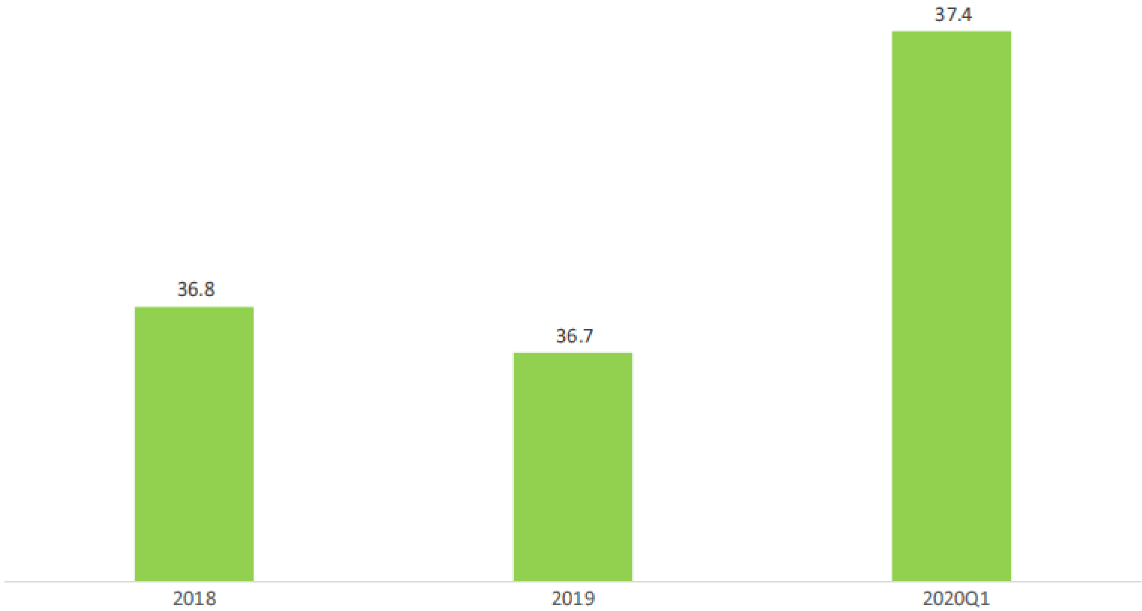

Fig. 1 Average Time to settle invoices (Kshetri, pp 56,2020)

c) Limitations of Blockchain Technology

Blockchain technology has a lot of strengths and potential to disrupt the way we exchange value in supply chain management. But it also has a few weaknesses and challenges that limit its widespread adoption. Some of the weaknesses (Farahmand, 2017) are summarised below:

1. Scalability

Blockchain technology design is such that, it requires participant node in the network to come to a consensus to verify a transaction to deter fraud. The consensus algorithms used to add a new block are computationally wasteful by design because every node performs the same task. This requires a huge number of resources and energy. As the size of the blockchain grows, the verification time increases and more storage capacity is required. Therefore, issues related to computational scalability, efficiency, complex data management and blockchain maintenance need to be addresses before blockchain becomes a mainstream technology.

2. New Technology Risk

As blockchain is a new technology, there is a lack of understanding of its components and functions. Developmental and implementation costs are higher. Since blockchain is a distributed network, the value creation is more when organizations across industries work together. Individual efforts lead to wasted efforts and delay in adoption.

3. Regulation Uncertainty

Blockchain technology is transformational. Therefore, it requires a total change from current way of doing things. Regulatory authorities are finding it difficult to introduce any standards addressing the governance challenges or multi-stakeholder cooperation opportunities. Lack of regulations has resulted in the organizations being exposed to compliance, legal and regulatory uncertainties in implementing blockchain enabled cases.

4. Security

A blockchain platform's value is driven by its security. The platform is not completely immune to security vulnerabilities and breaches. Anyone can read or write transactions provided they show sufficient computing power and achieve consensus on a public blockchain. For example, Bitcoin. This can also lead to black market trading. Bitcoin mining is only viable for a small number of participants as the resource investments are high. As a result, majority of the validators operate in countries with cheap electricity, leading to network centralization and the possibility of collusion (Berke, 2017).

Also, private keys can be stolen to steal bitcoins. Lack of regulations means that there are no rules to recover stolen bitcoins or distinguish stolen keys from legitimate transactions.

TECHNICAL ASPECTS OF BLOCKCHAIN & TRACABILITY OUTCOMES

a) Blockchain Technology

Blockchain technology is founded on a globally distributed ledger that supports the properties of a large peer-to-peer network to verify and approve transactions (Tapscott and Tapscott, 2016). The distributed ledger holds chronologically ordered, cryptographically signed and immutable transaction records, which are accessible to any participant in the network. The historical records cannot be altered or deleted without the consensus of the majority of the network as copies of blockchain are globally distributed across the network. This increases trust in the network. Transactions can be viewed and traced by authorised specific users as well as larger network participants with access rights. This ensures the value exchange decentralised and transparent. The cryptographic signing of records also ensures the data security of the transactions stored on the blockchain. The properties of blockchain are shown in Fig. 2.

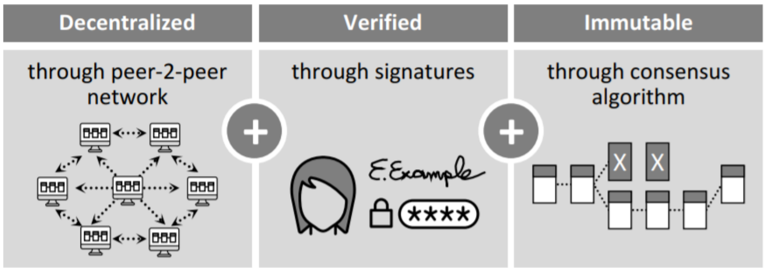

Fig. 2 Properties of Blockchain (Hackius and Peterson, 2017)

Blockchain can also be visualised as a chronologically ordered chain of blocks. Each new block (Fig. 3) will have information of addresses entitled to receive the exchange value and also contains the digital address (hash) of the previous block (Catalini et al., 2017).

Fig. 3 Blocks in a Blockchain (Catalini et al., 2017)

If there is an attempt to tamper with the transaction information recorded in a block, the hash for that specific block would be altered and it will no longer point to the hash of the previously verified block. Thus, it is difficult to tamper with records without achieving consensus in the network. Common types of blockchains are depicted in Table 1 shown below:

	Public blockchain	Hybrid/consortium	Private blockchain
Overview	Fully decentralized with no central authority; "proof-of-work" or "proof-of-ownership" is used to ensure record authenticity	Quasi-centralized where a consortium of entities controls the record authenticity	A central authority acts as a trusted intermediary to control and ensure record authenticity
Permission	Permissionless—anyone can read and write	Permissioned—selected participants can make changes	Permissioned—write permissions are centralized to one entity
Transaction verification	Records are verified by majority of the "miners" reaching consensus on the authenticity	Transactions are verified by the consortium	Central authority verifies transactions
Data storage	Records are distributed; a copy of the entire record is available to all users of the peer-to-peer network	Records are distributed throughout the consortium	Records are stored by the central authority
Transaction cost	Low cost for transactions	Transaction cost agreed to by the consortium	Transaction cost dictated by one entity

Table 1. Common types of Blockchain (Laaper, et. al, 2017)

Blockchain uses encrypted communication protocols which allow data exchange in a more secure and distributed manner without the risk of the intervention of intermediaries. Data is shared directly from machine to machine.

b) Traceability in Food Supply Chain

1. Contaminants

In an international food supply chain, contamination is a huge problem that needs to be addressed. The identification of the source of contamination, geo-location of the origin of food product and the other food products affected from the contamination is necessary. This process is required so that the contaminated food product can be removed from the stores.

Delay in the identification of contamination source can lower the consumer's trust in the retailer's brand. Due to negative publicity, the retailer may lose its valuable customers to competitors. Also, consumers may fall ill after consuming the food product. This can attract legal lawsuits. There can be loss of revenue and wastage of the food product.

Therefore, the challenge is to identify the precise point of contamination quickly.

2. Counterfeits

Conscious customers want proof that their food products were grown organically. An organic label can be fake. Moreover, continuously reinforcing and proving food product authenticity incurs significant recurring costs for the retailer. The brand value of the retailer is at stake. Therefore, the challenge is to identify the counterfeits quickly.

3. Implementation of Blockchain in Food Supply Chain and Traceability Outcomes

In order to identify contaminants and counterfeits, the IBM blockchain platform (IBM, 2021) developed through open-source collaboration in the Hyperledger community, including the newest Hyperledger Fabric v1.0 framework and Hyperledger Composer blockchain tool is implemented. Hyperledger Fabric is an open source blockchain for business. The benefits of Hyperledger Fabric are shown in Fig. 4. The blockchain used, is a permissioned blockchain type (Table 1).

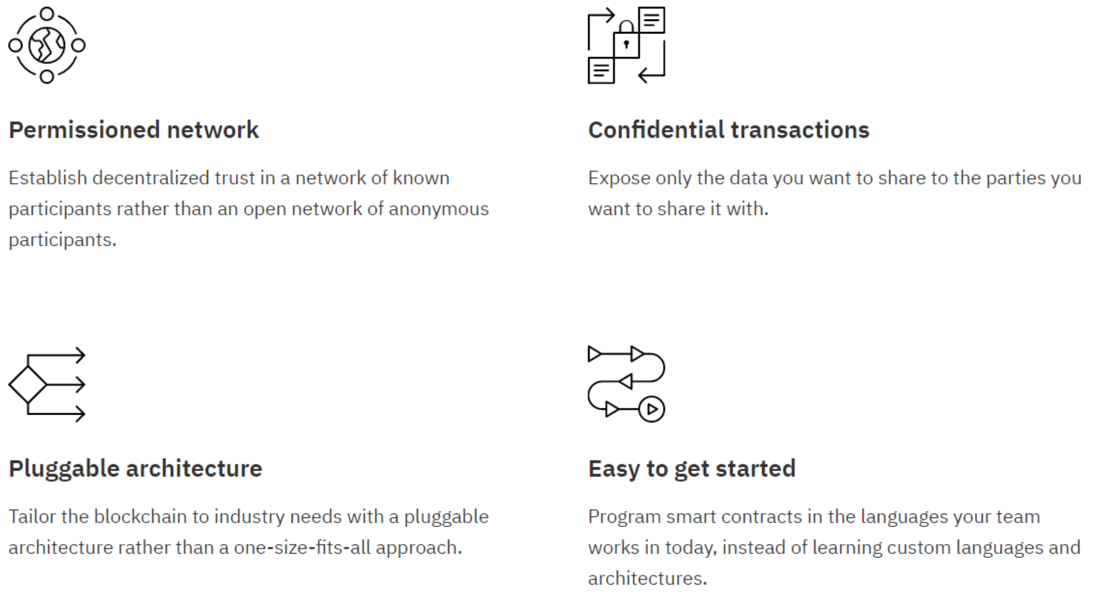

Fig. 4 Benefits of Hyperledger Fabric (IBM, 2021)

The entire history of food products through entire international supply chain providing traceability of food from "farm to fork" is held by the blockchain.

The contaminated food product is identified in a matter of seconds as compared to days. This efficiency will reduce the response time when contamination is discovered as well as make it possible to perform selective recalls. This process also creates the trust between the participants in the entire international food supply chain.

Blockchain also provides a solution to the retailers wherein they can share reliable information with customers, who are cautious on product contents, origins, purity, and authenticity. Retailers can sell their food products at a premium rate as customers are willing to pay for higher quality food sources which can provide assured proof of product origin and purity, as well as the accuracy of ingredient listings. Thus, blockchain provides solutions for counterfeits.

DISCUSSION AND CONCLUSIONS

The International food supply chain industry is facing major challenges today in the backdrop of COVID-19 pandemic. With the increase in food counterfeits and challenges in ensuring food safety, the demand for traceability has increased. Each participant organisation in the supply chain has its own system of handling transactions, leading to information discontinuity, delayed financial data flow and higher risk for food fraud. Blockchain will ensure food authenticity and safety.

The three main challenges, faced to implement a blockchain food safety solution for the international food supply chain industry are technology maturity, ecosystem complexity, and governance of running the solution. The technology will mature over time. Ecosystem can be led by a consortium if the food safety solution needs to be successful. The effort will not be worthy if the entire industry is not involved. Governance of running the solution must address a few questions. The questions are Who can join the ecosystem? Who can operate the ecosystem? Who can see the data? Who decides if there is a dispute within the ecosystem and how is it resolved? Who governs management questions around the ecosystem?

Also, as the risks of implementing blockchain technology are high, a risk assessment has to be carried out by the organisation. But in the international food supply chain industry, which will be impacted by blockchain more than other supply chain, the benefits of blockchain outweigh the risks posed.
Blockchain technology will allow supply chain organisations to make important strategic decisions based on their capabilities that support the end value creation. Also, organisations will have to adapt their business models and organisational structures to effectively capture and deliver value created from the adoption of blockchain technology in supply chains.

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