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Traceability in FMCG Industries by Application of Blockchain Technology and Smart Contracts

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ABSTRACT

Blockchain and generally decentralized technologies will be used quickly in all industrial fields. Fast-Moving Consumer Goods (FMCG) is one of the areas that has attracted a lot of attention from different perspectives, both in terms of marketing and in terms of contributing to environmental sustainability through the reduction of CO2 production. This study attempts to propose a suitable and near-to-optimal supply chain network for FMCG by using the critical advantages of blockchain technology, especially traceability. With the help of blockchain technology, information can be transferred to this network with greater transparency, traceability, and security. Moreover, the smart contract will provide the possibility of autonomous contract execution among the stakeholders in the supply chain. The smart contract eliminates payment delays, error risks, and the complexity of a traditional contract while maintaining the authenticity and credibility of supply chain interactions.

Keywords: FMCG, Blockchain, Traceability, Smart contract, Sustainability

INTRODUCTION

FMCG – Fast-Moving Consumer Goods, as the name suggests, are quickly moving with low-profit margins; these include the day-to-day products. The FMCG sector in the food industry combines in with additional challenges, including the product's quality and lifecycle. In such a complex supply chain, traceability plays a pivotal role. In its pursuit, numerous traceability technologies have been implemented or are being implemented and currently utilized (Dixit et al., 2019).

The implementation of blockchain technology for traceability in the FMCG sector would play an immense role in better communicating the various possible data from sensors being used for the tracking to the Blockchain, thereby maintaining the privacy of the data being shared among the various parties involved (Aghamohammadzadeh & Fatahi Valilai, 2020; Agrawal et al., 2021).

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Research Objectives

Research Objective 1: Decreasing the level of uncertainty in a multi-level supply chain.

In the evaluation process, there is a questionnaire that will help to better understand the current situation, the acceptability, and so on of a company's supply chain.

1. What are the relative advantages and disadvantages of a blockchain traceability system compared to paper-based and computerized systems?
2. What is the current state of traceability in your supply chain?
3. How willing are you to adopt a Blockchain-based traceability system, and which behavioral factors influence this willingness?
4. Are you open to interoperability (sharing data among other stakeholders)? If not, why not?
5. Level of knowledge of blockchain technology?
6. Are you open to adopting blockchain technology for traceability? If not, why?
7. Does the issue of data immutability concern you?

Whenever there is a technology that is to be adopted, the most challenging part is not the technical requirement. However, it is building out that network of stakeholders from various supply chains to agree on common ground and have mutual trust among each other to share data amongst themselves and to be committed to maintaining the infrastructure necessary.

Research Objective 2: Initializing smart contracts in Blockchain provides traceability solutions effectively.

Smart contracts are digital contracts stored on a blockchain automatically executed when predetermined terms and conditions are met. The data is automatically entered into the block by using a smart contract when the transaction occurs. This safeguard makes it more difficult for potential attackers to modify a shared database. The primary goal of smart contracts is to simplify commercial transactions between parties by eliminating the intermediaries involved in traditional business operations. These contracts strive to eliminate payment delays, error risks, and the complexity of a traditional contract while maintaining authenticity and credibility.

Smart contracts are best seen as automated transaction administrators, as a blockchain is a register for validating transactions, and this is precisely what smart contracts retain from legal contracts. A smart contract can be thought of as the automation of the transactional part of a legal contract, with the assurance that transactions will be carried out effectively and without tampering, which fits in nicely with the need to deal efficiently with the requirements of trust and coordination to deploy Revenue Sharing effectively. Smart contract is a software that runs on a blockchain and executes a digital agreement governed by a set of rules. Therefore, smart contracts for revolutionary supply chain management can take the role of human coordinators where the issues have been addressed. Furthermore, automating the coordinating process can relieve the supply chain of a significant managerial expense.

The supply chain plays a vital role in ensuring that every transaction is delivered to all stakeholders within the organization in a secure manner. In this circumstance, the aim is to identify the challenges in traceability applications with Blockchain technology which provide visibility and information of supply chain and to analyze the solutions and methods.

Literature Review

Traceability Evolution Through Literature

Traceability plays a pivotal role in providing control over the supply chain, and it also assists in the follow-up processes, which can highly be determined by the nature or field of the product we are dealing with in the supply chain. The supply chain is a complex web of networks that includes aspects such as the openness, emergence, and dynamics of it, and these aspects contribute to the interruptions and disruptions in the complex supply chain (Sirkka, 2008).

Traceability, as defined in the United Nations Global compact and Business for Social Responsibility, is "the ability to identify and trace the history, distribution, location and application of products, parts, and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labor (including health and safety), the environment and anti-corruption". The Blockchain has emerged as a possible solution for implementing traceability by creating information paths while ensuring security and data immutability (Mandolla et al., 2019). Blockchain-based traceability enables the secure exchange of information, facilitating product quality monitoring/control, operational monitoring/control, real-time data acquisition, and transparency and transparency throughout delivery (Azzi et al., 2019). Traceability is critical for preventing or promptly responding to food contamination, sickness, medication or pesticide residues, or attempted bioterrorism. "Blockchain is fixing a social problem, not a technological problem." Walmart's blockchain experiment serves a bigger purpose and has a beneficial impact on the Walmart brand through prevention, readiness, and evidence (Caldarelli et al., 2020). Walmart's blockchain solution must be "business-driven and technology-enabled," with the ability to tackle challenges including time efficiency, cost reduction, long-term goodwill, and income-generating. This endeavor needs leadership to organize stakeholders and raise awareness of various technological options to ensure whole-chain traceability (Burkitt, 2014).

Blockchain, the technology behind electronic currency, is a decentralized, distributed ledger that records digital asset transactions. Blockchain emerged as a technology to perform transactions in the cryptocurrency market (Ganesan et al., 2023). Decentralized blockchains provide the same job as many intermediaries in our society, establishing trust and maintaining integrity between transacting parties by verifying and documenting immutable transactions (Khaturia et al., 2022; Lobo et al., 2022).

Additionally, Blockchain is viewed as a solution for supply chain management (SCM) traceability problems (Lu & Xu, 2017) and for generating closer and trustworthy relationships between organizations and their suppliers and through the entire SCM. On the one hand, a blockchain-enabled smart contract (a script that can trigger a transaction) has the potential of bringing high levels of efficiency with a decentralized operation to SCM (Wamba & Queiroz, 2020). On the other hand, Blockchain can be combined with other cutting-edge technologies (e.g., big data analytics, the internet of things, cyber-physical systems, among others) to bring about disruptive impacts in all specialized fields (Aste et al., 2017).

The reviewed literatures can be categorized to three research themes, which are explained in more details in this section. Table I presents the review of literatures from these three themes. Supply chain traceability is the process of tracking the provenance and journey of products and their inputs, from the very start of the supply chain through to end-use. Traceability provides opportunities to find supply chain efficiencies, meet regulatory requirements, connect with and understand the actors in the upstream supply chain, and of course, to story-tell consumers about the provenance and journey of products, often utilizing pictures or scannable QR codes on packaging (Navendan et al., 2022). Blockchains provide end-to-end traceability by introducing a uniform technology language into the supply chain and allowing customers to read the tale of goods on their labels via their phones. Each information contains vital information that might show safety concerns with the product in question. The blockchain record can also assist merchants to monitor the shelf life of items in specific stores and increase controls linked to food authenticity (Galvez et al., 2018).

Smart Contract in Supply Chain

A smart contract is a software that runs on a blockchain and executes a digital agreement governed by a set of rules. Its benefits are:

- **Automation**: Smart contracts may automate a wide range of tasks, subject to the expressiveness of the programming framework in which they are created. Solidity, for example, the programming language for writing contracts on the Ethereum blockchain, is Turing-complete, meaning it can represent any issue that can be solved by a Turing computer, giving smart contracts as much flexibility as possible.
- **Distribution**: Smart contracts, as opposed to software kept on central servers in the client-server paradigm, are duplicated and distributed among all nodes of a blockchain network.
- **High Securities**: Another practical smart contract use cases include securities. With smart contracts, capitalization table management can be simplified and improved. This means no intermediaries between the parties, including security custody chains. It can also be used for dividends, automatic payments, liability management, and stock splits. Also, smart contracts can help reduce operational risk and make workflows digitized (Geroni, 2021).
- **Cross Border Payments**: Trade Finance can also be revolutionized with the help of smart contracts. There is no doubt that it can help in international goods transfer and trade payment initiations using a Letter of Credit (Geroni, 2021).

Table 1. Literature review in defined research themes.

Reference	Research Studies	Traceability	Smart Contract	Data Accessibility
(Centobelli et al., 2021)	Blockchain technology to improve agri-food traceability:	Improvement of Traceability		Essential to implementing data accessibility. Data privacy related to Agri-food industry.
(Kamble et al., 2020)	Modelling the Blockchain-enabled traceability in the agriculture supply chain:	Blockchain adoption in the individual and organizational levels.	Benefits of smart contracts and discussion of numerous opportunities in the current market.	Discussion of data and data standardization and issues related to data monitored steps
(Dabbene et al., 2014)	Traceability issues emerging in the food supply chain industry	Traceability issues concerning policies RFID enabled traceability, secure removal of tracking devices.		
(Sivaganesan, 2019)	Medicine transportation by using Blockchain and verifying the transaction with the help of smart contracts	Traceability methods and stages	Details regarding a transaction with the help of a smart contract	Data access of each transaction
(Agrawal et al., 2021)	Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry	A blockchain-based traceability system would provide all partners with a unique opportunity, flexibility, and authority to trace back their supply network by creating a decentralized ledger.	Account/Balance mode is used to record organic cotton details.	

(Continued)

Table 1. Continued.

Reference	Research Studies	Traceability	Smart Contract	Data Accessibility
(Liu et al., 2021)	Blockchain-based smart tracking and tracing platform for drug supply chain		the smart contract-enabled alert mechanism is designed and developed.	Provides a practical method to guarantee the blockchain network performance in data storage and meets the data privacy requirements of the drug stakeholders.
(Baralla et al., 2020)	Ensuring transparency and traceability of food local products: A blockchain application to a Smart Tourism Region	Local food quality and storage origin assurances by traceability.	Smart contracts with IoT based tracking.	
(Islam et al., 2021)	A Hybrid Traceability Technology Selection Approach for Sustainable Food Supply Chains		Smart contracts are used in a hybrid approach.	Data handling and security are addressed.
(Behnke & Janssen, 2020)	Boundary conditions for traceability in food supply chains using blockchain technology	Importance of each node in traceability		Standardized conditions for data sharing among stakeholders.
(Tsolakis et al., 2021)	Supply network design to address United Nations Sustainable Development Goals: A case study of blockchain implementation in Thai fish industry:	Importance to increase the resilience of supply chains with the help of traceability.		

- **Transparency:** Because smart contracts are built on blockchains, their source code is immutable and available to everybody on public blockchains and all authorized users on permissioned and private blockchains.
- **Trust:** Smart contracts extend the digital trust inherent in single blockchain transactions to the level of complex contractual agreements. As a result, two or more parties who have never met can now communicate through contractual agreements without the need for costly administration and oversight by human third parties (Sirkka, 2008). Using smart contracts will improve the liquidity of the financial assets, improving the suppliers, buyers, and institutions' financial efficiencies. To make smart contracts work in trade finance, especially in cross-border payments and international trade, it is necessary to find an industry standard and implement it accordingly. Automating the coordinating process can relieve the supply chain of a significant managerial expense (Geroni, 2021).

Data Accessibility Through the Supply Chain

The three significant characteristics of blockchain technology - security, decentralization, and transparency - ensure that any application developed is secure and inaccessible to unauthorized parties. In a blockchain network, data tampering is impossible. By encryption, Blockchain enables network security. Every block in a blockchain is linked to the block before and after it. This makes it difficult for a hacker to edit any record since the hacker would also need to change the records or blocks related to the record that he wishes to manipulate or access, which is impossible to achieve in an extensive network with a high number of blocks in a blockchain. For example, for a clinician to get Access to a patient's medical information, the patient's ID must be on the list of that clinician's patients. This system also defines the authorization rules. A medical record is a collection of information that includes the patient's name, date of consultation, allergies, dangerous behaviours, and so on. Grant Access, Revoke Access and Add Participant are the three transactions used to provide the above Access. Thus, this article demonstrates a blockchain-based framework Hyperledger Fabric and the Composer tool (Agrawal et al., 2021).

CONCEPTUAL MODEL

Supply Chain Perspective

In the conceptual model, as shown in Figure 1, it has been explained the flow of transportation and material goods and information flow across the supply network of FMCG. Based on the location of the suppliers, the raw materials are shipped through various means of transport to reach the manufacturing plant. Each of these suppliers has their ERP systems, which track the information regarding the movement of the material and then are finally updated onto a supplier integrated ERP hub, from where the information is collected and connected to the data repository. After raw materials reach the manufacturing plant, once the product is finished and packed, they are transported to the internal plant warehouse. Both the manufacturing plant and the plant

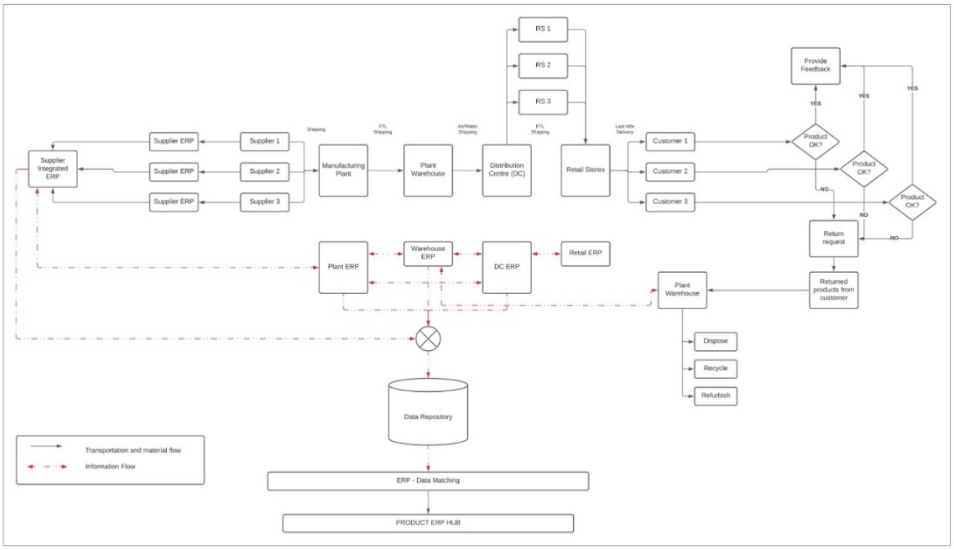

Figure 1: The whole structure of proposed solution.

warehouse have ERP systems that feed all the data/information. This information is again shared among the other parties like the distribution center, plant warehouse to the distribution center. After the products are shipped through the preferred mode of transport, primarily by roadways in full truckloads to the distribution centers, they are sent to the various retailers and the customers through the last-mile delivery from the distribution center. The information obtained from each ERP is shared with the plant warehouse to monitor the inventory levels to ensure consistent supply. All the information/data from the ERP systems are converged at a data repository which are then matched to check for the credibility of the data and with whom it can be shared. The model also gives a gist of the reverse logistics involved if the product is not as per the required standards.

Blockchain Perspective

According to Figure 1, there is an extensive flow of information between various parts of the supply chain network, which is usually managed and controlled in a centralized structure. But, by using blockchain technology, it is possible to control the network in a decentralized manner. In this method, a chain of information blocks is formed, which is called a digital ledger. Figure 2 shows different parts of the blocks in this chain. There is a timestamp in each block, which shows the time of block registration. The other part of each block called "transaction" is the same information that is exchanged among the blocks in Figure 1. The transaction of each block must be verified by another member of the decentralized structure, which is called a "miner". The process of verifying the information finally leads to the digital signature on the block and assigning a hash number to that block. In each block, in addition to its hash, the previous block's hash is also included. So, the chain of blocks is formed. The important advantage of this method is

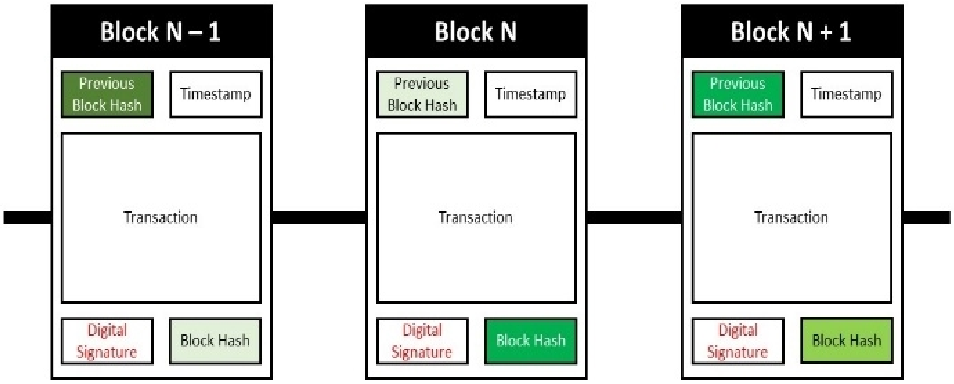

Figure 2: The structure of each block in digital ledger.

that in addition to the possibility of controlling the information exchanged in different parts of the network due to the transparency of the decentralized structure, the security of the exchanged information is also very high because it is not possible to change the information of any of the blocks according to the explained chain of blocks. In this way, information is exchanged between different components of the network with high transparency, traceability, and security.

Use Case Scenario

The supplier sends the raw materials to the manufacturer. The manufacturer receives all the required raw materials from various suppliers. The shipment details and raw material characteristics are measured and updated in the chain block. The information about the shipping details is also mentioned in the chain. The manufacturer produces the final product, then stored in the plant warehouse through the appropriate means of travel. The produced timestamp, the quality characteristics of the product, and quantity are updated to the nodes in the chain. The product through the roadways is shipped to various distribution locations (DC). Various IoT sensors within the truck used to monitor the product are utilized to the maximum, and the entire data is updated onto the block in a chain. Through these DC's they are distributed to various retailers across the region. The timestamps, the quality of product, and information sharing between the DC and the plant warehouse play a pivotal role in ensuring the data matches and compares the inventory levels in real-time. The customers buy the product from various retailers, thereby ending the B2C cycle. In this scenario, the information flow between two nodes is bidirectional, ensuring that anyone within the blockchain network can view the status and track the product (Kaur & Al, 2021).

Once the raw materials are received from the supplier to the manufacturing plant, all the relevant data/information about the characteristics of the material, shipping time, INCO terms are fed into the smart contracts, which are used as a medium for information sharing across the supply chain network on the FMCG sector. Since it is possible to set particular rules, conditions in smart contracts at every single stage of the network, various conditions regarding the product can be cross verified through this, thereby eliminating any that do not comply. Once the product is manufactured, relevant information regarding the quality, quantity, pricing, and so are fed into the smart contract, in terms of shipping information about the lead time, delivery times, are product condition are mentioned, and they are cross-referenced with the set conditions in the smart contract. If they vary, there will be fines that the shipping party will have to comply with. Once the product reaches the distribution center, it is further moved to the retail stores where most customers purchase. The last-mile delivery of the product from the retailers to the customers is a challenging task, but it plays a pivotal role in FMCG B2C. These smart contracts at each stage of the supply network are linked to their respective ERP systems, thereby cross-referencing each stage's data and maintaining high-security standards.

CONCLUSION

The complexity of interaction in FMCG supply chain necessitates the traceability of information and processes among stockholders. Moreover, the complexity of financial interaction among the stakeholders in FMCG is highly challenging due to nature of this industry. This paper has discussed how the use of Blockchain in the traceability of the FMCG industry is beneficial. A conceptual model has been presented that provides information about how the flow of materials and information occurs in the FMCG industry and how they can be tackled with smart contracts. Tracking and tracing the product withholds numerous challenges by focusing on why it is better to use blockchain technology and how they can eliminate human errors and optimize the overall efficiency and effectiveness of the supply network. The conceptual model has also considered the application of smart contract mechanism. The smart contract mechanism facilitates the interaction of stakeholders autonomously and enable the traceability of finical interaction in FMCG supply chain. The paper suggests the application of token model for tracing and sharing the value added yielded in stakeholder collaborations for future studies.

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