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# Incorporating Block Chain Technology in Food Supply Chain

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## ABSTRACT

*The past decade has viewed the importance of knowledge management and supply chain integration to ensure high profitability and sustainability in the business. Blockchain is the current trending technology that can revolutionize the existing supply chain integration. In order to fully understand the blockchain application in the food supply chain, a comprehensive study of related topics such as Internet of Things, Enterprise Resource Planning and Radio Frequency Identification has been done. The research explores various issues regarding the relevance, applicability, and implications of blockchain technology in the food industry through a literature study. This also focuses on identifying the key variables that can have a significant effect on blockchain implementation. Finally, the paper presents current challenges and future research directions.*

**Keywords:** Blockchain, Internet-of-Things, food supply chain, Enterprise resource planning.

## INTRODUCTION:

The last three years have seen an explosion of interest in Blockchain technology with a great many companies and research institutions focusing on potential applications of this technology across a range of financial, industrial and social sectors. Blockchain technology is still in an early stage of development, with considerable potential for real-life commercial applications. Innovation in Blockchain architectures, applications, and business concepts is happening at a fast pace; it is often characterized by decentralized, open source development, and it is perceived as being disruptive to traditional players in many industries.

Blockchain technology is characterized as an open-source, decentralized, distributed database for storing transaction information. Rather than relying on centralized intermediaries (e.g., banks) this technology allows two parties to transact directly using duplicate, linked ledgers called Blockchain. This makes transactions considerably transparent than those provided by centralized systems. As a result, transactions are executed without relying on explicit trust [of a third party], but on the distributed trust based on the consensus the network. So, applying this technology to improve supply chain transparency has many possibilities.

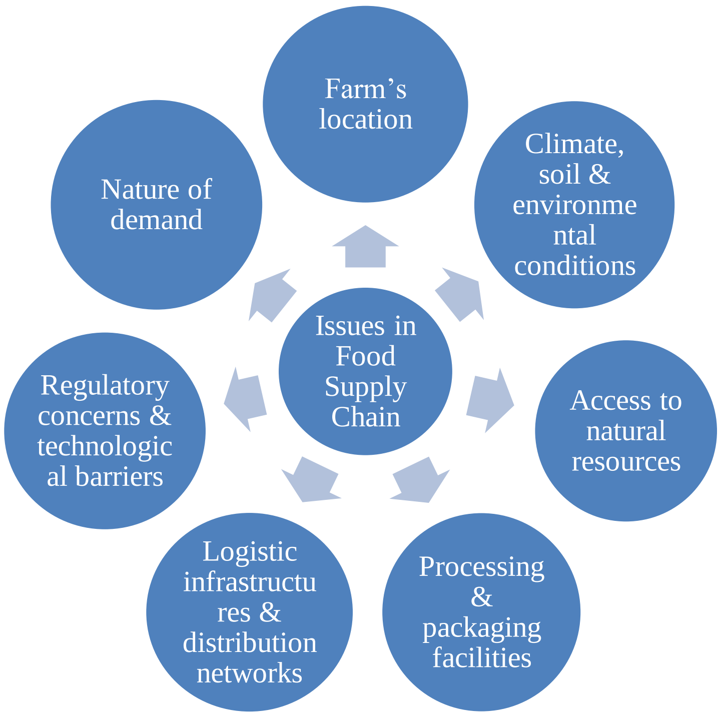
## LITERATURE REVIEW:

Due to the advent of technological advancement, digital supply chain integration is becoming complex and dynamic. Customer demands are becoming more specific and urge to gain information about the product and service received by them, thereby creating the need for better visibility in the supply chain. (Korpela, Hallikas, & Dahlberg, 2017)

The blockchain technology is a decentralized, distributed database that is used essentially for storing information related to transactions that occur. The basic ideology of block chain is to facilitate the transaction through multiple linked ledgers which are called as block chains. This ensures that the transactions are comparatively more transparent when compared to the traditional centralized systems. (Francisco & Swanson, 2018).Thus by making use of the advantages provided by the blockchain that includes unchangeable nature of the records, disintermediation, consensus and the presence of a distributed ledger, the traceability in the food supply chain can be ensured (LIN, SHIH, LIU, & JIE, 2017) Blockchain consists of different blocks where data is stored in the network. This data is accessible only to those who are involved in the concerned network which can be mutually supervised and data can be exchanged. The attractive feature that blockchain provides is the equal level of transparency that it provides to each member in the network, ensuring that all members are on the same page of the book (Hackius & Petersen, 2017). Transparency and trust should be mutual among the supply chain partners. Customers would like to know where their products are from, where can they find the products' lifespan (PwC, 2018). The supply chain can be optimized with the help of blockchain.

**Issues in the food supply chain:**
The various issues concerning the food supply ecosystems are (Accorsia, Bortolinia, Baruffaldib, & Ferraria, 2017)

**Fig 2.1: Issues concerning food supply ecosystems (Accorsia, Bortolinia, Baruffaldib, & Ferraria, 2017)**




Consider the example of a dairy supply chain. The supply chain mainly consists of six activities i.e. production, processing, packaging, storage, transportation, and delivery of milk products to the end consumer.
The various issues in the dairy supply chain management are as follows:

- Poor Quality of Raw Milk
- Milk Collection and Processing Inefficiency due to Knowledge and Technology
- Poor Transport Infrastructure
- Inefficiency in Implementation of Pasteurization Laws
- Lacking Cooling Facilities
- Informal Channel Adulteration and Bargaining Power of Finance and Information
- Farmers Profitability
- Seasonal Milk Supply
- Long Distance from Production to Consumption Locations

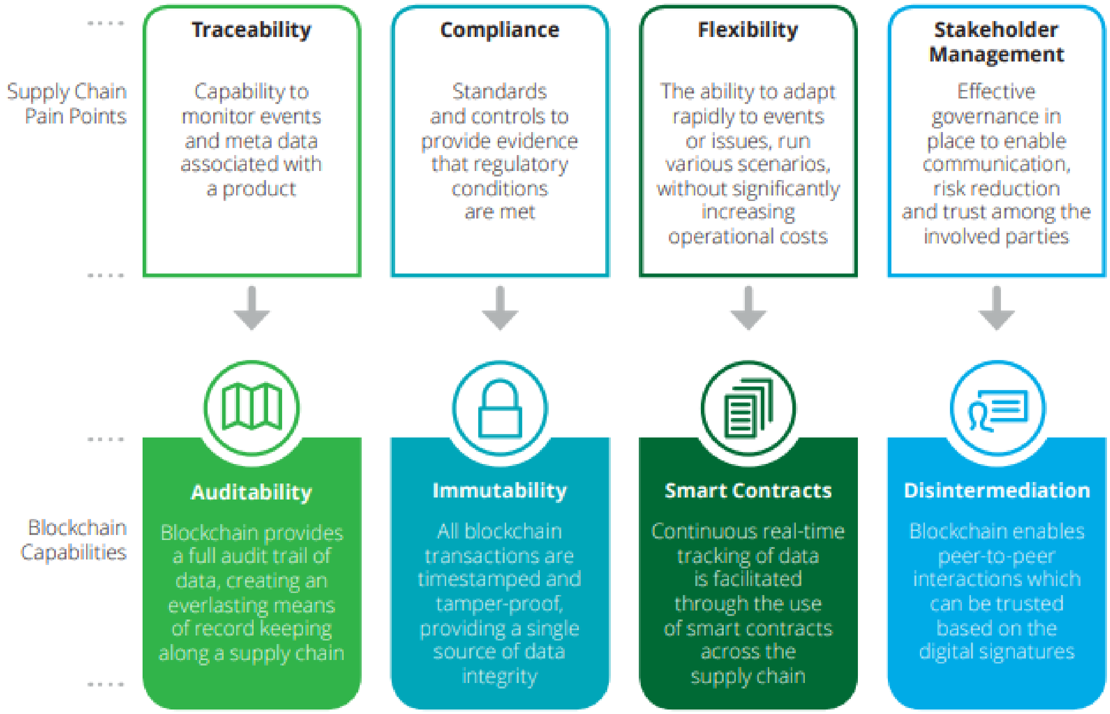
Designing an efficient, hygienic dairy supply chain and establishing an effective milk collection and transportation system in developing countries. One crucial factor in this supply chain is creating trust among the supply chain partners which would help them in building a long-term relationship. This is possible only by improving the communication between them. (Muhammad, Akhter, & Ullah, 2014)

In case of the cold supply chain, an estimate shows that around out of the global cold storage revenues that come from food supplies, almost 50% is wasted in transit due to variations in temperature, carelessness of drivers, and longer delivery times. This affects the shelf life of the product by drastically reducing the life and leading to spoilage even before the products achieve the printed shelf life. (Mphasis, 2016) . To maintain the firms' competitiveness, it has turned out that the logistics maintain transparency and quicker last mile delivery of the products.

**Tackling the Cold supply chain issues:**

This need of the hour can be met by adopting blockchain technology which would ensure cent percent transparency in the system by providing a unique digital identity to each and every product that is under transit and provide real-time data of the same over blockchain. While considering the safety and quality of the food products in the distribution process, it is important that time, temperature and tolerance are considered as the key factors. (Tian, 2016). Thus to ensure safety and quality, the transit vehicles and warehouses can be fitted with real-time temperature and humidity monitoring system using sensors. This data can then be transferred to the blockchain system which will provide visibility to the entire supply chain network thereby reducing the risk of food spoilage. Usage of GPS can help in re-routing of the vehicles so that the distribution network is optimized and freshness of products is ensured.

**Fig 2.2: Blockchain capabilities to tackle supply chain issues (Deloitte, When two chains combine- Supply chain meets block chain, 2017)**




IBM has recently collaborated with Walmart, JD.com and Tsinghua University National Engineering Laboratory for E-Commerce Technologies to launch a Blockchain Food Safety Alliance that would help in enhancing food tracking, food traceability and food safety in China.

The focus of this team is to provide real-time traceability in the food supply chain from 'farm to fork'. The team has also collaborated with supply chain partners and regulators to prepare standards to enable a better food ecosystem. The advantages of this ecosystem creation include ensuring brand owners' data privacy while helping them integrate their online and offline traceability for food safety and quality management channels (Sustainable Brands, 2017). Banker (2018) in his article has given an example of IBM's involvement in blockchain innovation. Being one of the most active innovators in blockchain, IBM has a separate group called the IBM Food trust that focuses on attaining traceability in the food supply chain. They follow the GS1 standards to ensure standardization of communication throughout the supply chain.

Thus in food supply chain blockchain technology helps in creating and maintaining digital product information including details of farm origin, batch numbers, plant and processing information, expiry dates, temperatures of storage and transport system, and the end product shipping details. All these data are digitally connected and the information is fed into the Blockchain at each step of the process. The data obtained at each point is visible to all the supply chain partners and on consensus, the data turns into a permanent unalterable record.
This data helps in ensuring food safety and also support retailers to have a better estimate of the product shelf lives. Blockchain technology has the capability to revolutionize the way the supply chain works by creating value for each supply chain partner. Transactions that require confirmation, settlement, exchange, signature or validation can be supported by blockchain to ensure integrity and transparency.
The Blockchain helps in authenticating the critical elements of information and transaction in the supply chain thereby increasing customer loyalty (Crossey, 2018). As the market becomes more dynamic and volatile, Blockchain helps in providing additional security to the supply chain. Few benefits derived from the literature review can be summarised as follows (Deloitte, Driving Value in Supply chain , 2018)

**Table 2.1: Benefits of implementing Blockchain technology in the Food supply chain.**

| Primary potential benefits | Secondary potential benefits |
|---|---|
| Increase traceability of the food supply chain | Better company recognition due to improved visibility and traceability of products. |
| Reduce losses incurred due to grey market trading | Increased data security due to blockchain features. |
| Improve visibility in the chain and compliance with the safety regulations | Reduce malpractices involved in the supply chain |
| Reduced paper work | Better stakeholder engagement |

Blockchain technology could improve the following tasks: (Vorabutra, 2016)

- **Recording** the quantity and transfer of assets - like pallets, trailers, containers, etc. - as they move between supply chain nodes
- **Tracking** purchase orders, change orders, receipts, shipment notifications, or other trade-related documents
- **Assigning** or verifying certifications or certain properties of physical products; for example, determining if a food product is an organic or fair trade
- **Linking** physical goods to serial numbers, barcodes, digital tags like RFID, etc.
- **Sharing** information about the manufacturing process, assembly, delivery, and maintenance of products with suppliers and vendors.

The food supply chain involves a huge number of supply chain partners whose integration and collaboration has an important role in improving the chain's efficiency. (Fainor, 2018). For the technology to become a solution to the existing problem of the supply chain, every supply chain partner, i.e. from the farmers to consumers, should be in a position to accept and adopt the technology.

## METHODOLOGY:

### Problem Statement:

The research aims to solve the existing critical issues in the supply chain by incorporating blockchain technology in the system.

### Objective:

The objective of this research is to identify the variables that can influence blockchain technology adoption in the food supply chain.
The research involves both primary and secondary data collection. Primary data involves variable identification identified from the data collected across the supply chain demographics that include supply chain partners – suppliers, distributors and supply chain managers of the food supply chain. A questionnaire survey has been followed to obtain the data from the participants where they have to rate the questions based on a Likert scale ranging from 1 to 5.
The secondary data involves identification of variables from an in-depth analysis of the literature review of the journals over the past ten years. The sources of the reviewed papers include different journals from Emerald Insight, Elsevier, IEEE, reports from various consultancies such as Deloitte, BCG and white papers from several other authenticated sources that are related to the research topic. Further, the critical factors that these

variables form a part of are obtained using factor analysis.
The research aims at obtaining a solution to the following research question:
**RQ1:** What are the critical factors that can influence blockchain adoption in the food supply chain?
**RQ2:** What can be the key challenges that the supply partners can face during this technological transformation?

## FINDINGS AND DISCUSSION:

### Findings:

The data collected from the various survey participants have been analyzed using IBM SPSS 21. The variables have been grouped into different factors using Factor Analysis.

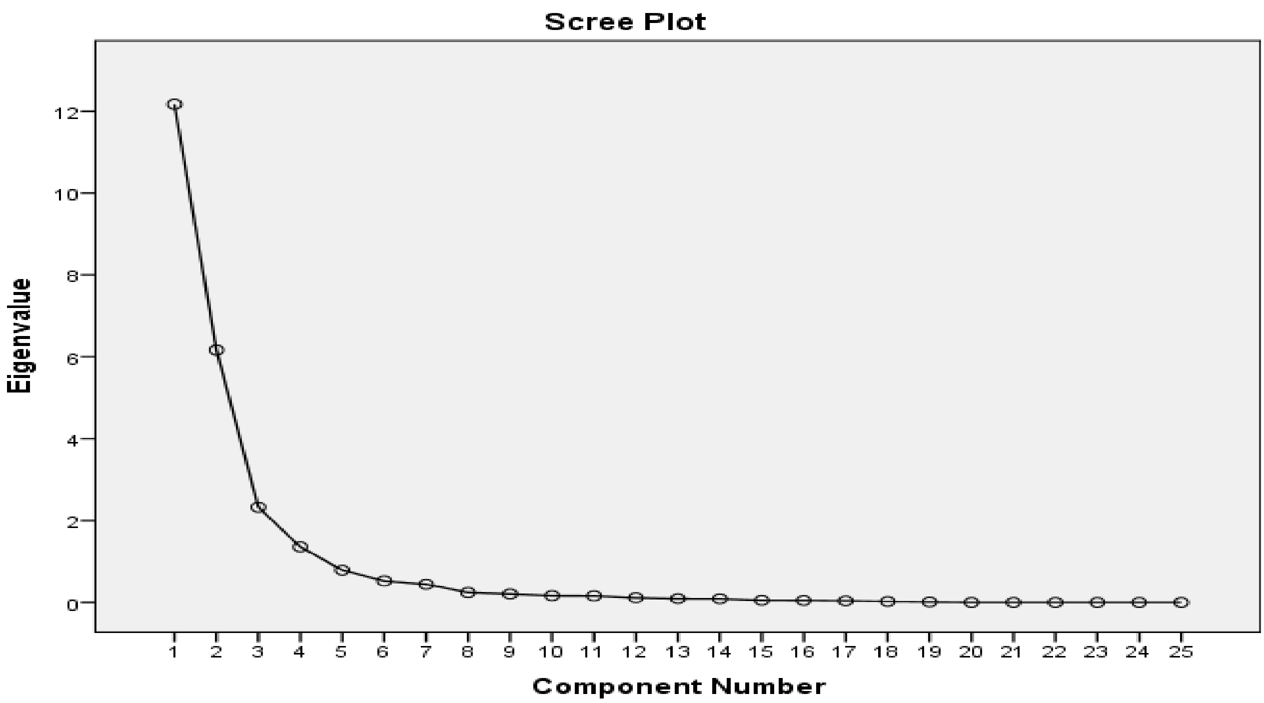
**Table 4.1: KMO and Bartlett's Test**

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .793 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 657.882 |
| | df | 91 |
| | Sig. | .000 |

Since the value of KMO statistics is greater than 0.5, factor analysis can be analysed for the given set of data. Bartlett's test of sphericity testing for the significance of the correlation matrix of the variables indicates that the correlation matrix is significant as indicated by p-value. Here the p-value is less than 0.05, assumed level of significance, indicating rejection of the hypothesis that the correlation matrix of the variables is insignificant. In Fig.4.1 there is a scree plot that gives the details of a number of factors identified.

### Scree Plot:

**Fig 4.1: Scree Plot**




The plot clearly shows that there are four factors that distinctively classify the variables.

**Total Variance Explained:**

**Table 4.2: Total Variance Explained**

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 12.168 | 48.674 | 48.674 | 12.168 | 48.674 | 48.674 | 11.838 | 47.351 | 47.351 |
| 2 | 6.166 | 24.664 | 73.337 | 6.166 | 24.664 | 73.337 | 5.290 | 21.158 | 68.509 |
| 3 | 2.324 | 9.298 | 82.635 | 2.324 | 9.298 | 82.635 | 2.751 | 11.005 | 79.514 |
| 4 | 1.357 | 5.427 | 88.062 | 1.357 | 5.427 | 88.062 | 2.137 | 8.548 | 88.062 |

This table indicates that the total variance explained by the 4 factors is 88.062%.

**Rotated Component Matrix:**

**Table 4.3: Rotated Component Matrix**

| | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Difference in Company Culture | -.975 | | | |
| Top level management commitment to the technology change | .975 | | | |
| Convinience | .975 | | | |
| Increased flexiblity | .975 | | | |
| Lack of latest management tools | -.954 | | | |
| Social Acceptance to new technology | -.954 | | | |
| Increased response time | -.949 | | | |
| Increased visibility and traceability | .883 | | | -.302 |
| Complexity in Business Processes | .862 | -.472 | | |
| Improve shelf life management | .847 | | .379 | |
| Faster payments and affordable finance | .805 | | .477 | |
| Authority and aunthenticity of information | .634 | .602 | | |
| Quality of the information | .322 | -.888 | | |
| Integration with IOT | -.322 | .888 | | |
| Helps in locating stolen products | .331 | -.804 | | |
| Supporting targeted recall | .353 | -.726 | | -.311 |
| Sharing Economy | | .689 | .479 | |
| High Investment | .437 | .684 | .508 | |
| Lack of Regulatory framework | .437 | .684 | .508 | |
| Reduce Fraudlent transactions | -.372 | | .768 | .380 |
| Incresed Operational Efficiency | -.567 | | -.664 | |
| Improved information sharing | -.409 | | -.605 | |
| Increased consumer participation and loyalty | .353 | | | -.865 |
| Issues of Privacy and security of data | | .419 | | .709 |
| Change management | -.537 | .535 | | .538 |
| **Extraction Method:** Principal Component Analysis.<br>**Rotation Method:** Quartimax with Kaiser Normalization.[a] | | | | |

From the above table, we can identify the variables corresponding to the factors in which the factor loadings are greater than 0.5. The variables which appear in one factor does not appear in another.
The identified factors and their corresponding variables have been tabulated below:

**Table 4.4: Factors and corresponding variables**

| Sl.no | Factors | Variables |
|---|---|---|
| 1 | Organization | • Top level management commitment<br>• Lack of the latest management tools<br>• Social Acceptance of new technology<br>• Complexity in the business process<br>• The difference in the company culture<br>• Flexibility (The ability to adapt rapidly to events or issues, run various scenarios, without significantly increasing operational costs)<br>• Convenience |
| 2 | Information | • Authority and Authenticity of information<br>• Quality of information<br>• Integration with IoT<br>• Regulatory Framework<br>• Information Sharing<br>• Targeted recall<br>• Shelf life management<br>• Response time<br>• Locating stolen products |
| 3 | Financial Aspects | • Faster payments and affordable finance<br>• Sharing economy<br>• Investment decisions<br>• Fraudulent Transaction<br>• Operational Efficiency |
| 4 | Security | • Consumer participation<br>• Change management<br>• Privacy and security of data<br>• Visibility and traceability |

**Diffusion of technologies in Block Chain:**
Artificial intelligence (AI) is the latest technology in supply chain analysis (Min, 2008). AI which works on the basis of neural network involves collecting information from various database sources, which are then analyzed to obtain various insights. Information in the supply chain is to be obtained from procurement, warehousing, production, distribution, and transportation (Navickas & Gruzaukas, 2016). The main application of AI is IoT i.e. Internet of Things. IoT can be used in the agricultural supply chain to monitor the quality of the fresh foods as per the food safety standards thereby reducing the loss due to wastage, theft, and spoilage. The perishable nature of these agri-based products marks the need for high-temperature control, visibility, and transparency in the supply chain. IoT can aid this need with the help of RFID and other sensors. These sensors would be able to provide real-time information on the products thus supporting the supply chain process such as production, distribution, warehousing, and transportation. Accorsia et.al (2017) identifies how IoT can act as a systematic approach to tackle issues in the food supply chain

Though these are theoretically easy to prove, the gap between the theory and practical application is still huge due to the lack of development in technologies, which on improving can have a large positive impact on the food supply chain efficiency. (Gu & Jing, 2010)

Big data and social media analytics is another support system that can be utilized for improving the supply chain. Real-time data collection would involve a huge amount of data collection that needs to be processed and analyzed to gain informational insights. Real-time information on the product and process will help in cost optimization and improving transparency in the supply chain. Social media analytics has helped in obtaining huge amounts of data in a very short period of time from a diverse audience. Various supply chains have made use of social media data to improvise and increase their efficiency. Consumer opinion of various food products was obtained from Twitter and the root cause of issues that affected consumer satisfaction was identified (Singh, Shukla, & Mishra, 2017)

**ERP and Blockchain:** With an interoperable blockchain, the existing ERP system can be integrated to obtain the existing data from the system. Blockchain helps in bridging the gaps in technology, transparency and support ERP integration effectively. Using the existing system can reduce the resistance to change among the supply chain partners.

**RFID and Block Chain:** RFID is one of the existing technology that is readily available to use to ensure traceability and transparency. In the initial stages of blockchain implementation, RFID can act as the most reliable source of information about the product. As found in the testing of the tuna supply chain (refer section ..), the information can be used to trace the provenance of the food. By including encryption of data in the RFID tags, security can also be assured. RFID tags are temperature resistant and can efficiently measure temperature below zero degrees thereby widening their application to frozen food supply chain ns (Abad, et al., 2009). Information is then automatically entered to the blockchain which can drastically reduce human errors. And eliminate manipulation of data thereby ensuring the safety and quality of the product. (Tian, 2016)

**Internet of Things and Block Chain:** The integration of blockchain and IoT technologies can ensure enhanced traceability in the chain thereby reducing the risks in the food supply chain (Honghui, Zhu, Zhongjon, Hanyu, & Xiaorong, 2015). Blockchain would ensure that every supply chain partner is informed about the product, its characteristics and its position in the chain that can ensure security and prevent tampering and fraudulent activities. IoT can ensure free information visibility in the system. (Deloitte, 2017)

**Block Chain Implementation Cases – A Global View:**

The first testing of blockchain technology in the supply chain was conducted in the tuna supply chain of Indonesia. blockchain implementation in the fish supply chain. The test tried to integrate blockchain in the existing auditing mechanism. In the testing phase, the fishermen had to send an SMS message that helped to get the details of the type of fish they caught, the person who caught the fish, location, and characteristics of the catch. This collected information was then tagged to these fishes using RFID, or QR code till the end consumer of the supply chain. (oliverwyman, 2016). The entire information is then added to blockchain which helped in creating end-to-end information available avoiding the need for the interface that would have otherwise existed.

Similarly, Walmart and IBM have tried to create a blockchain called Hyperledger Fabric that supports companies to collaborate on the research and development of blockchain. Walmart has tested blockchain in the mango (food) supply chain, where the food shipments were digitally traced and recorded using blockchain. Starting from the farms where mangoes were produced, numeric tags were tagged to them, and at each point were the mangoes moved from one supply chain link to another, the status was noted and logged. Thus information on the mangoes was now available in 2 seconds. (Hackett, 2017).Walmart has also employed blockchain technology to track pork meat sales in China which has helped the entire supply chain partners to trace to the provenance of the meat (Consultancy.uk, 2018). The current research by Walmart focuses on implementing blockchain to eradicate the manual tracking and inspection system in the supply chains.

**Challenges and risks involved in Block Chain:**

Currently, the key challenges in adopting Blockchain for supply chains are: (Banerjee, 2018)

1. **Infrastructure and network:** Blockchain works on a strong internet-connected platform supported by necessary IT infrastructure which can be challenging for the developing economies to adapt.
2. **Interoperability**: Blockchain would be adopted by the firms in the supply chain, only if it can communicate with the existing IT systems and support the firm to seamlessly work.
3. **Costs of on-boarding and maintenance**: The supply chain partners in the initial stages have to on-boarded into the system which can be cost incurring.
4. **Data storage cost on Blockchain (data per transaction)**: The data generated in the Blockchain is stored on the cloud and requires huge storage space as the data has to be stored permanently and indefinitely
5. **Data validation latency**: The blocks in the chain will be valid only if all the miners involved in the chain validates it. This process currently takes up 8 to 19 minutes or can be longer. But if this blockchain technology has to be used for the food supply chain, this latency should reduce to seconds.
6. **Payload size restriction**: Lack of standards in the payload, mainly due to the network and infrastructure is another challenge for implementing the blockchain.
7. **Regulatory and legal acceptance**: Absence of a legal framework is another important issue faced by the supply chains who have tried adopting this technology. This is a big challenge to overcome as this can cause trust issues among the partners in the chain.
8. **Trust:** Trust is one of the critical factors of the supply chain that also proves to be a challenge in blockchain implementation. Implementing blockchain technology can increase visibility and traceability in the supply chain. But it is very important that there should be trust between supply chain partners so that they are ready to share their data.

## CONCLUSION:

Blockchain is the new technology that can create an impact on the food supply chain. Many companies such as IBM and Provenance have invested in blockchain to support various firms to adopt the new technology and improve their supply chain efficiency. The research has been able to cover the perspective of blockchain, issues pertaining to the existing food supply chain, and blockchain capabilities that can help to improve the supply chain pain points. The exhaustive literature review analysis along with the primary data obtained from the key supply chain partners has helped in identifying the critical factors that have to be considered while adopting blockchain in the various clusters of food supply chain in the Indian context. The paper has also identified some of the global cases where blockchain technology has been experimentally implemented in the food supply chain The future of this paper could relate to identifying and developing a model that can help in the blockchain adoption in the supply chain.

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**FIGURES:**

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