

Economic, Social & Environmental Benefits of Block chain Adoption in Supply Chain Management: An Indian Perspective

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Abstract: With Bitcoin gaining popularity over the years, the technology behind it called Blockchain Technology has also gained recognition. BCT's inherent properties provide potential solutions to the conventional problems of common supply chains. This paper explores the potential economic, social, and environmental benefits of BCT adoption in the supply chain in the Indian context. The study found that BCT in SCM has the potential to remedy many trade and economic problems in India. Socially, it can eradicate malpractices incorporated in many firms and organisation. Environmentally, it can help both government and private players manage their supply chains and in turn resources to cut down on greenhouse gases and optimised the use of resources.

Keywords – Blockchain Technology, Economic, Environmental, Social, Supply Chain Management

I. Introduction

In this world with enhanced customisation, it is extremely crucial for achieving efficiency and responsiveness in the supply chain. It can help businesses gain a competitive edge by utilising the advantages of contemporary technology [1]. The supply chains have become more complicated as a result of the expanding firm sizes, varied product lines, and variety of geographic markets they serve. Due to the adoption of lean retailing strategies, manufacturers are facing many difficulties to compete in niche markets by offering customised items, while retailers are reluctant to place large orders. Predicting demand, scheduling production, and organising orders have therefore become very difficult in such an unpredictable environment [2]. To alleviate these problems digitalisation of supply chains has become extremely crucial. Blockchain Technology (BCT) is one of the few technologies which has emerged as a solution to such a problem. BCT was first proposed by an unidentified programmer with the alias Satoshi Nakamoto in 2008 [3]. BCT consists of a decentralised ledger, which stocks data in 'blocks'. They are appended together in sequential order which creates an indestructible chain. The chain is then shared and circulated to all the participating units. This type of design has the prospect to address distrust in the normal supply chain by providing features such as enhanced traceability and immutability [4].

It is approximated that the advantages put forth by BCT can bring an enhancement in one-third of supply chain processes [5]. Although, blockchain technology has a lot of challenges to conquer. Many firms lack an organised system and scope for scaling up and adopting BCT. Technical know-how, data governance and privacy-related concerns remain unaddressed. Many firms are dubious of excessive prices of BCT implementation. The efficacy of BCT applications other than in the finance sector still remains unclear [6]. Despite such challenges early research and pilot programs have revealed that BCT implementation has shown promising results in SCM.

A literature review on BCT has revealed that most of the studies are focused on the agricultural sector in India. There is little focus on the economic, social, and environmental impact of BCT adoption in SCM in India. This study uses an exploratory approach and intends to provide an exhaustive understanding of the same.

The rest of the paper is organised in the following manner: in section 2, a literature review on the developments in BCT in SCM was conducted. In section 3, economic benefits; then in section 4, the social and environmental benefits of BCT adoption in India were addressed. In section 5, the conclusions and limitations of the study are presented.

II. Literature Review

Technically, Blockchains are cryptographically secured peer-to-peer distributed networks, where new data can be appended to the existing data and existing previous data stored is immutable (very difficult to modify), and only editable when peers are in consensus [7]. Primarily, blockchains consist of five layers and all these layers with

unique functionality run on top of internet protocols and permit relevant parties to conduct economic transactions without the necessity for a reliable third party [8]. Blockchain also proves its utility as a registration and inventory system which documents, traces monitors, and trades in all asset classes, whether legal, physical, financial, or electronic [9].

In BCT, every transaction is registered into a ledger over a set period of time, resulting in the formation of a 'block'. Each of the transactions happening is recorded in a block as it occurs. Each block is in connection with the blocks that come before and after it, making existing stored data immutable: A single actor cannot change or delete these blocks. rather, these blocks are validated and regulated with help of automation and established protocols [10]. All these chains of blocks are chained with the help of a “hashing” function [11]. When a new exchange or an alteration of an existing transaction occurs then it is added to a blockchain, a significant portion of the nodes in the blockchain network perform algorithms to review and validate the record of the proposed discrete block. When the majority of nodes validate the signature and history then the new block of the transaction is allowed to append to the chain of blocks [11]. As a result, when combined with advanced encryption technologies and the verification procedure, it protects information in blockchain ledgers in opposition to unwanted access or tampering [12].

2.1 Why is Blockchain technology crucial in supply chains?

2.1.1 Transparency, Authenticity, Trust and Security

Given the buzz around BCT, understanding how blockchains could improve supply chains is crucial. Transactions enabled by blockchain provide transparency to the involved businesses who adopted it. For example, blocks will be produced which entails information of each transaction at every stage of business ranging from the manufacturing of products to distribution and at last to the sale of the product. This degree of visibility and transparency is critical for increasing product traceability and verifying product authenticity and validity. Also, for live tracking, it could further be integrated with RFID tags and GPS [13]. Recorded data is distributed among all participants and each of the participants can open and monitor the activities and product position in real time [14][15].

Increased transparency allows for an auditable track of a product's footprint and helps companies in maintaining the track record of the product where the place of origin is key. Transparency established via BCT builds trust across the supply chain [16]. Earlier, the trust between the businesses or actors (buyers and sellers) in the supply chain was built up via various mechanisms such as banks and physically signed documentation which operated as a vital channel for business transactions between the actors or businesses [17] [18]. Establishing the confidence across supply-chain, long-term financial and relational commitments were frequently necessary [19]. Whereas BCT which comes with trust embedded into its platform, supply chain operations can be executed without the need for complex trust-building mechanisms between companies [20]. BCT-enabled supply chain offers increased security as it helps in protection against fraud, and tampering by avoiding fraudulent transactions and stolen merchandise recovery [21][22]. Security achieved is only possible due to established checks and balances, one of the most important features of BCT [23]. Stored data records become immutable once it joins this chain of blocks which is only possible due to the consensus characteristic of this distributed network.

2.1.2 Cost/waste reduction and Efficiency

Blockchain implementation makes supply chains and logistics efficient, as the technology speeds up the exchange of data streams between participants [15]. Subsequently, companies might shorten the time consumed during transportation, enhance inventory control, and finally resulting in lesser waste and costs. Smart contracts are a critical component in increasing supply chain effectiveness, are completely digital and created by computer programming languages. Similar to a conventional legal document, a smart contract's rules and consequences are outlined and include rewards, penalties and obligations [24]. Blockchain systems can automatically enforce these smart contracts, which greatly automates and streamlines supply chain operations [25]. These contracts are especially helpful in making intricate outsourcing agreements where there are several vendors. All of these vendors are interdepend-able and accountable to drive a certain result [26].

Using the BCT, a supply chain may cascade invoices, invoices, receipts modify orders, shipment alerts, and other transit or origin-related records, by going beyond simple matching, programmes for aggregation, replenishment, and more are triggered, as well as payments depending on thresholds. These features can assist businesses in planning more precise demand projections and in making better judgements. [27]. Especially in the context of cross-border activities, efficiency may be increased by digitising document transfers and accelerating the flow of data [25].

III. Economic Benefits

With new technology, comes numerous opportunities for any country to capitalise on it and to become the pedestal for the industry to set up. As it is evident by Taiwan's example. In 1987, the Taiwanese government and Morris Chang founded one of the most influential companies of this digital era called the Taiwan Semiconductor Manufacturing Company Limited (TSMC), which manufactures chips used in everyday products, from laptops and desktops to televisions and remote controllers. TSMC has become both a world and market leader in terms of supplying chips. It caters to 92% of a global market worth USD 580.88 billion [28]. In just five years the company's yearly revenue reached USD 245 billion, employing 250 process engineers and in 2022, TSMC contributed 15% to Taiwan's GDP [29]. With, TSMC achieving such importance at both economic and technological levels, it has sparked both China's and the world's interest in the small island.

A similar case is also available in India though not much exclusive as TSMC, i.e., the Information Technology or IT industry. India offered a large cache of skilled labour, with English language capability with demand for low salaries which resulted in the success of the IT industry in the country [30]. Apart from the highly attractive qualities offered by the country, friendly policies along with the desire for infrastructure and restructuring in education were adopted which ensured an endless supply of skilled labour and the creation of an industry worth USD 227 billion supporting the Indian GDP by 7.14% in 2022 [31]. As per the data provided by the Indian government, it is estimated that 5.1 million people are directly employed in the Indian IT industry with an additional 12 million people employed indirectly [32].

Blockchain is a novel technology that has immense capability and offers a lot of potential applications in supply chain management [33]. By laying the foundation for BCT's adoption, especially in SCM India can enhance its economy significantly and capitalise on the global blockchain market which was valued at USD 4.67 billion in 2021 [34][35]. Drawing a parallel from the IT industry, blockchain also possesses similar capabilities in terms of generating jobs in India. Koh et al, suggest that if BCT is adopted in SCM it can give rise to other companies which offer BCT as a service to serve both private and public users [36]. E.g., if a small company is willing to adopt BCT but is reluctant to invest heavy capital in terms of computing power it can do so by entering into a partnership with such a firm offering BCT as a service. And with India offering cheap skilled labour, MNCs which have adopted BCT as a service model business can outsource their projects to India resulting in an inflow of revenue and the creation of jobs.

Apart from the potential aspect of job creation, inherent properties of BCT such as instantaneous information sharing, cyber-security, transparency, reliability, traceability, and visibility can improve trade resulting in a reduction in delays, faster movement of goods and greater efficiency [37] [38]. India takes anywhere between 24-48 hours for air cargo and 72 hours for seaport cargo clearance and is aiming to speed up the process by reducing the time to an hour [39]. This reduction will significantly increase the efficiency of both trade and the economy in the process.

Any, transaction on the blockchain network is visible to all the participants in the network and is immutable. E.g., a separate block could be created for each and every one transaction of both information and finance between all the members of the supply chain. Necessary documents such as permits, clearance, etc can be uploaded on the network. With visibility to everyone in the network, the paperwork could be accessed with ease without worrying about its authenticity [40]. Integration with "Industry 4.0" technology like radio frequency identification (RFID) tags and GPS can give the added advantage of real-time tracking, a necessity to ensure both safety and adequate resource [13].

Such enhanced visibility will provide a better auditable trail of the footprint of a product, which is especially charming to various industries such as the food industry and pharmaceutical, where details about the origination of a product are crucial [27]. If provenance information is available then both the intensity and integrity of assets involving any product or technical equipment can be ensured. This could enforce responsible sourcing on the part of producers and manufacturers, allowing detection and even counterfeiting of products and other fraudulent activity [41]. In 2019 alone the counterfeiting market was worth USD 449 billion. China accounts for almost 80% of the volume and 90% of the value of trade with fakes [42]. With India and China sharing borders and India being the fifth largest economy globally, serves as the nearest market to this ill practice. Almost 25-30% of all the commodities sold in India are spurious. Counterfeiting is most widespread in the apparel and FMCG industry with 31% and 28% of all the goods being fake respectively. In pharmaceuticals, fraudulent goods count for 20% of the total trade, which poses a serious health threat to Indians [43]. Counterfeiting also dwindles the economy by weakening the local industry, reducing legal imports, and severely hurting the government revenue collection in form of duties and levies. The revenue of a brand or company also diminishes as counterfeiting can have a multiplier

effect on the economy in a manifestation of fewer jobs as manufacturers of authentic products may become financially fragile also disseminating to less recruitment of fresh talent.

With such constant menaces to both SCM and the Indian economy, it becomes crucial to extensively investigate the possible remedy at hand which is BCT. The Indian government, however, has addressed the benefits offered by BCT and running many pilot projects in the country. One such pilot project is discussed and its subsequent impact is studied below [44].

3.1 Fertiliser Subsidy in India

3.1.1 Background

In 2018, National Institution Transforming India Aayog or NITI Aayog (Indian Government’s think tank) in collaboration with PricewaterhouseCoopers (PwC) and Intel, commence a pilot program to optimise the subsidy supply chain for fertiliser using a blockchain-based solution [45]. The Indian government provides farmers access to fertilisers at subsidised rates which is decided by the Depart of Fertilizers (DoF). Manufacturers receive the subsidy post-sale. Fertiliser is one of the most significant outflows of revenue in the Indian budget. Between 2022-23, India paid INR 518.75 billion equivalent to USD 6.25 billion for fertiliser subsidies [46].

Fertiliser manufacturer claims subsidy from the Indian government in two ways (i) subsidy claim and (ii) freight claim. For subsidy claims, the difference between production cost and subsidised sale price is claimed is based on the record of the product to the farmers. The sales record is collected using invoices generated by the retailers in the Point of Sales (PoS) machines. While, for freight claims, the cost incurred due to transportation and logistics is paid to the manufacturer. These are generated by accumulating the received quantity by warehouses and the invoices are sent to DoF monthly [47].

For this entire process, multiple systems of record-keeping run parallelly. Apart from that, before subsidy claims are passed, multiple authority checks are necessary including that by chartered accountants (CAs). The supply chain has multiple stakeholders and due to the complexities of bureaucracy and finance, there was a dire need for a permanent trusted digital record. The invested members used the framework shown in figure 1.

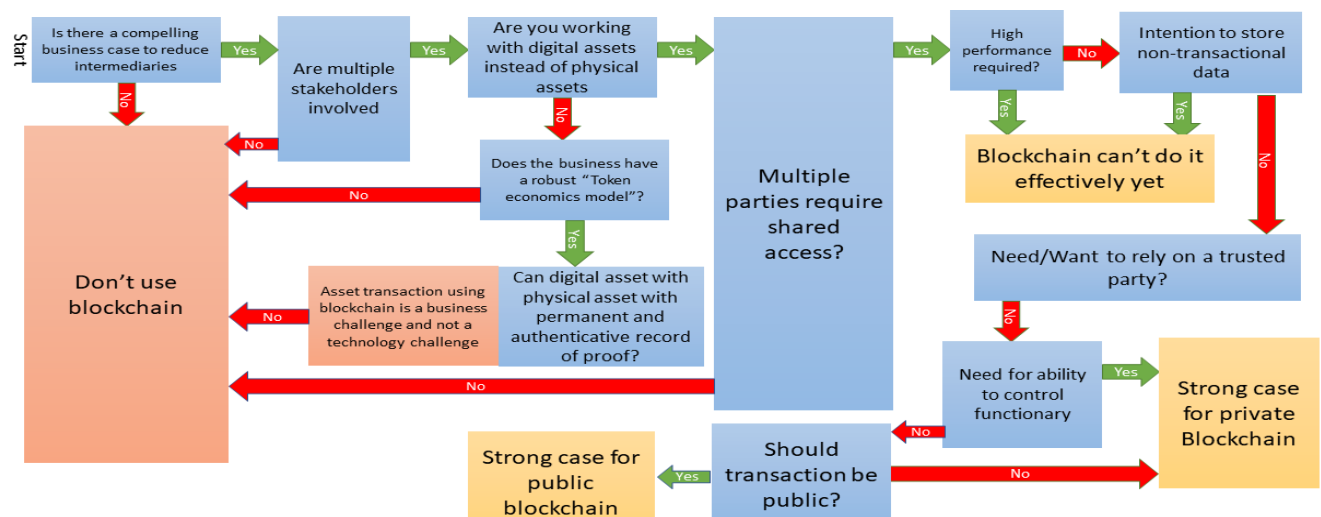


Fig.1: framework adopted by niti aayog, pwc & intel [47]

3.1.2 Advantages

The application of the pilot project yielded numerous benefits. The productivity was increased significantly by enabling shipment acknowledgements to the manufacturer in minutes. Near real-time verification of documents instead of weeks was achieved. The implementation also eliminated paper trails and the need for paper beneficial for both efficiency and the environment. The applied solution was also integrated with Enterprise Resource Planning (ERP) software which ensured that officials were available with pre-filled forms and a reduction of inputs from users [47]. The blockchain-based business flow of fertilizer is shown in figure 2.

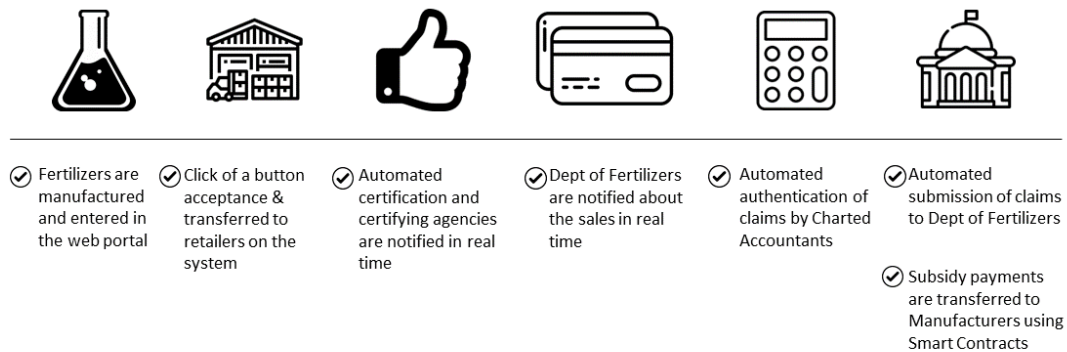


Fig.2: manufacturer blockchain-based business flow [47]

3.1.3 Disadvantages

The pilot project uncovered some problems. Despite, many advancements in blockchain it offered limited processing power resulting in low volume of transactions. E.g., one of the most commonly used blockchain platforms Ethereum was striving to reach 3,000 transactions while Visa, a third-party platform was capable of performing 50,000 transactions per second. Blockchain was also not suited to store any private or proprietary information, it is best suited for storing transaction information. If a process flow required the involvement of a third party it became complicated to deploy blockchain [47].

3.1.4 Economical Impact

While the disadvantages seem significant for the pilot project, the benefits outweighed them. The government was able to save significantly in terms of time and resources post the deployment of the pilot project. With the integration of blockchain with the ERP, better resource planning was achieved. Speedy clearance of claims also led to a streamlined process of subsidy payment to manufacturers. If similar widescale changes in SCM are adopted both by government and private players then the discussed economic benefits can be potentially achieved by India.

IV. Environmental and social sustainability in SCM

To establish inter-generational equity for the coming generation to equally be able to enjoy the benefits of the planet's resources and ecological facilities, environmental sustainability becomes key. To do that a sustainable supply chain management decision framework is put out by Sarkis [48], who emphasises the dynamic character of enterprises and their connection to the environment. Due to its dynamic nature, a system where continuous real-time monitoring is performed becomes necessary which synchronises the process of updating data regarding each supply chain participant. A superior supply chain is a desirable replacement for common company standards and practices to boost sustainability practices due to the properties of BCT-synchronised exchange procedure, dependability, traceability as well as efficiency in terms of cost [49]. Blockchain technology, in particular, can help in:

Environmental emission abatement - Participants in the supply chain can pinpoint the exact amount of emission happening from which locations, specifically, carbon emissions, hazardous pollutants, or wastewater, from each stage and, as a result, respond appropriately to adhere to emission regulations. Each participant is also responsible for ensuring that their partners sitting on the upstream value chain adhere strictly to laws or standards regarding emission. The whole supply chain will reduce its environmental emissions conscientiously in response to this demand.

Resource management - Exact location from where raw material has originated is monitored with the help of blockchain technology which subsequently helps in managing the utilisation level and avoiding over-extraction of natural resources, helping in preventing issues like deforestation and salinization. Yet, no factual study has been recorded that depicts if and to what extent BCT can ensure sustainable resource usage.

Waste Management - Businesses may track their garbage using blockchain technology [50], making it feasible to recycle, repurpose, or handle those materials responsibly. The IBM Food Trust, for instance, is a modular food traceability solution which helps in monitoring the food wastage happening in the whole food chain [51].

The blockchain-based supply chain has an influence on social sustainability as well [49]. In particular, Blockchain technology allows supply chains to keep data secure, and the "immutable" component of blockchain protects all parties involved in supply chains against corruption, whether they be people, governments, or organisations. This is only feasible because the blockchain-based supply chain only allows authorised participants to

update the information. Exploring the social challenges in the precious metal (Gem) business [52] from the perspective of blockchain-based supply chains. Particularly in the area of sourcing, this industry's supply chain is expanding. In the diamond business, there is much discussion about unethical sourcing practices that can violate human rights. Moreover, they emphasise how the blockchain-based supply chain facilitates the creation of an open process by confirming the supplier's activities and averting any possible problems with unethical sourcing. Also, from a societal standpoint, the topic of unethical sourcing in the fashion industry is addressed [53]. This sector has a large number of multi-tier suppliers, and some of them lack incentives to seek social sustainability. Hence, unethical concerns from the suppliers would result in harm to the shareholder wealth, sales, and reputations of all pertinent supply chain players [54]. So, by having a more transparent supply chain built on blockchain technology, we can boost visibility and stop such unethical sourcing.

4.1 Maersk and IBM (TradeLens)

4.1.1 TradeLens: Maersk and IBM's Blockchain-Based Supply Chain

Maersk, An integrated logistics company which is active in both inland and ocean transportation services, has shifted its focus to improving supply chain flow transparency globally with the increased adoption of blockchain technology. In conjunction with IBM, they developed "TradeLens," a blockchain-based logistics platform, in December 2018. This logistical shipping sector is very fragmented and involves lots of players who use manual processes at each step of their supply chain which lengthens the value chain [55]. Maersk has pushed to boost the visibility in its global supply chain by facilitating international trade through the "TradeLens" platform, which makes use of BCT to permit entities to transact in a "simple, secure, and real-time environment" [56].

According to their published sustainability report, Maersk examined the trade patterns at their Indian terminal, where they found out that the system's blockchain-based transaction processing system had simplified their overall operating costs. Mumbai's export-import companies in particular were able to increase their topline by 15% overall after implementing blockchain technology.

4.1.2 Objectives met by TradeLens regarding Supply Chain Sustainability

- Cost-effective reduction of paperwork- For instance, it costs \$300 to send avocados from Mombasa to Rotterdam, or about 15% of the delivery fee. Depending on the specific supply chain and its list of participants, TradeLens reduced these costs by 70–90%.
- operators of ports and terminals- increases the effectiveness of all processes, minimising vessel and equipment downtime. gives more information about each ship, container, and load, which lowers the number of mistakes and fraud cases.
- Shorter shipping durations- The amount of goods transported within the United States decreased by 40% primarily as a result of shorter lines and faster workflow. On lengthy supply chains, there is less time gain.
- Reducing the process from 5–10 steps to 1–2 in order to respond to simple operational queries like "Where's my container?"

V. Conclusion

This study systematically analyses the potential economic, social, and environmental benefits of BCT adoption in SCM in India through an empirical study of various applications and pilot programmes. Successful adoption can lead to the creation of a new industry and job creation and serve as a hub for outsourcing from MNCs resulting in an influx of foreign currency, especially US dollars. The success of the IT industry can serve as a testament and help in establishing the BCT industry catering to the SCM MNCs. This can help India become a global leader and a central hub of the industry if it capitalises on first-mover advantage.

Many threats faced by the Indian economy can also be eradicated by BCT adoption primarily being the counterfeiting industry. Socially, many industries employ unethical means or practices. The gem industry is a prime example of such malpractice. The visibility offered by BCT can help eradicate malpractices and exploitation. People can refuse to buy gem-laded jewellery from jewellers who conduct businesses with ill-reputed companies. The food product on the table can be traced to its original source through increased visibility thus, increasing accountability in the supply chain.

The supply chains of a company or organisation account for 90% of its greenhouse gas emissions [57]. Environmentally, BCT can help companies manage their resources efficiently. This will help reduce greenhouse gas emissions through various means such as efficient route mapping, loading, unloading schedules etc.

This research is exploratory in nature, thus, further research diving into the barriers, scope and feasibility in the Indian context is required. Most Indian supply chains rely on local players new BCT paradigms and solutions are required to be researched and suggested. To comprehend the blockchain phenomena, especially in the Indian context, several theoretical frameworks and multi-methodological strategies should be used. The current estimated

benefits of blockchains and BCT's adoption in the industry are highly conjectural with very few examples in the real world. More pilot programmes and trial runs are required to determine the BCT's potential in the Indian SCM industry. Disruptions in these pilot programs could additionally enhance our awareness of blockchains and the integration of the technology within supply chains. Finally, other factors such as ethical, legal and security issues must also be investigated.

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