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Smart Integration of Blockchain in Air Cargo Handling for Profit Maximization

Rosalin Sahoo¹ [0000-0002-1571-1206], Bhaskar Bhowmick² and

Manoj Kumar Tiwari³ [0000-0001-8564-1402]

¹ Indian Institute of Technology, Kharagpur, 721302, India

² Indian Institute of Technology, Kharagpur, 721302, India

³ National Institute of Industrial Engineering (NITIE), Mumbai, 400087, India
rosalinsahoo73@gmail.com

Abstract. Transportation and logistics management are critical to the economic growth of a country. Smart transportation is becoming possible thanks to the advancement of digital technology implementation. To decrease the vulnerability of digitized systems from cyber-attacks, Blockchain has recently become one of the most commonly adopted technologies for free, decentralized, and trustworthy intelligent transportation networks. By analyzing the potential application of Blockchain technologies in the smart transportation of cargo by air, this study hopes to contribute to the area of logistics management. For efficient and safe air cargo movement, we propose a distributed blockchain layered framework that helps in transforming air logistics operations in national and international trades and we validated our framework by mathematically comparing the cost with and without the implementation of Blockchain.

Keywords: Air cargo, Blockchain, Layered Framework

1 Introduction

The air cargo industry has become an indispensable part of the global economy holding an important niche in the transport of high valued commodities. World logistics has turned upside down by the COVID-19 pandemic where countries have stopped their import/export and closed the doors of their Industries and Manufacturing sectors. A sudden disruption in supply and demand causes the need for establishing the vital connections of world trade and logistics together [1]. Maximum goods shipped by air cargo include perishable items, pharmaceuticals, medical protective equipments, and food supplies. Therefore, today the rapidly growing global trade requires cost-efficient, reliable, and highly secured air cargo operations and logistics management [2].

Blockchain is a decentralized transaction and data storage technology that helps individuals and businesses to store and share value without the use of conventional middlemen [3]. It's a cutting-edge technology with the ability to upend traditional economic and social structures and replace them with systems that are more accessible, reliable, and stable. Blockchain technology is based on a globally distributed ledger that verifies and approves transactions using the properties of a massive peer-to-peer network [4]. The Blockchain database is a permanent archive of transactions that occur between individuals or between customers and businesses. There are a variety of Blockchain implementations that are still under development. A transaction value is available to any network user with access privileges, making the Blockchain-enabled transaction system extremely transparent [5]. It makes it very difficult to carry out fraudulent transactions. However, when making a transaction, a network user will select what information about their identity they want to share with the rest of the network, resulting in pseudonymity. Digital technologies have the potential to break down these barriers, allowing the supply chain to become a truly interconnected marketplace that is fully open to all stakeholders - from raw material, product, and portion manufacturers to trans-porters of those suppliers' finished products, and eventually to end-users [6].

The purpose of this research is to compare and analyze the traditional air cargo operations with digitized cargo management systems implementing blockchain. We have created a layered and structured framework to address the future role of air freight operations and services in transforming. This research would aid in identifying the latent opportunities presented by blockchain today, as well as the obstacles that come with these future opportunities. It will aid in comprehending the key factors of mainstream Blockchain acceptance in the logistics supply chain, as well as potential market models and competitive considerations.

The following sections are as follows: Section 2 explains an overview of the Concept of smart transportation in cargo logistics and challenges followed by the integration of blockchain in the air cargo logistics sector. Section 3 provides a comparison between the traditional model and our proposed layered framework and the applications that were derived from the literature and discussed potential business models and strategic considerations. Section 4 highlights the validation of the proposed model by considering the implementation of Blockchain. Section 5 summarizes the findings and conclusions drawn from the research.

2 Literature Review:

The role of smart transportation and logistics will be described first, followed by a discussion of the issues and challenges that the logistics industry is facing. After that, we will study how Blockchain can help with transportation and logistics.

2.1 Concept of smart transportation in air cargo logistics and challenges

Air cargo is the most energy-intensive and inefficient mode of freight transport. As a result, the majority of freight shipped by air is both perishable and time-sensitive in the context of a broader manufacturing chain, or high value and low density. There has been very little contribution in air cargo-specific innovations using cutting-edge technologies to digitize the supply chain. A parallel transportation management system was developed by [3] for real-time ride-sharing services using blockchain. A methodology intelligent software agents can be used to monitor the activity of stakeholders in the blockchain networks to detect anomalies was proposed by [7]. Few researchers such as [8], [9], and [10] conducted a comprehensive survey on blockchain technology adoption by discussing its influences as well as the opportunities and challenges. Some of the challenges include Traceability and visibility across the value chain, Lack of trust among the stakeholders, and Unsustainable and inefficient use of resources in cargo handling.

2.2 Integration of digitization and Blockchain in cargo logistics

Blockchains are an immutable set of records that are cryptographically linked together for audit. The activities and decisions of stakeholders participating in air freight operations will have a direct impact on the whole transport chain management process. As a result, digitization technology will assist freight staff in developing new business logic and economic models, resulting in a variety of innovations and increased competitiveness by stimulating consumer demand. A container stacking and dispatching problem was studied by [11] using blockchain management. Implementation of blockchain using machine learning has been researched by many authors to design a decentralized, privacy-preserving, and secured network [12],[13],[14], and [15]. To highlight more on the application part of the blockchain and the cost-saving perspective, we developed a layer-based framework. The position of logistics is critical for the growth of civilization and the development of new frameworks, as these would open up new avenues for inquiry. As a result, the proposed model offers a simple and dependable architecture that is suitable for both transportation and logistics. Given the importance of logistics and transportation, it is essential to provide a comprehensive and consistent model/framework. To bridge this void, we have proposed a layered

infrastructure that better addresses the need for smart transportation and logistics via blockchain.

3 Comparison of the proposed model with Traditional model

3.1 Traditional Model

Traditional air freight includes the flow of physical goods, information, and financial transactions involving the key stakeholders such as shipper/buyer, Freight forwarders, and airlines. Often it is difficult to track the province of goods and the shipment status when the process relies on manual and paper-based transactions causing friction in global trade. Block chain can potentially help overcoming the frictions enabling data transparency and access among the potential stakeholders, creating single source of truth as shown in Figure 1.

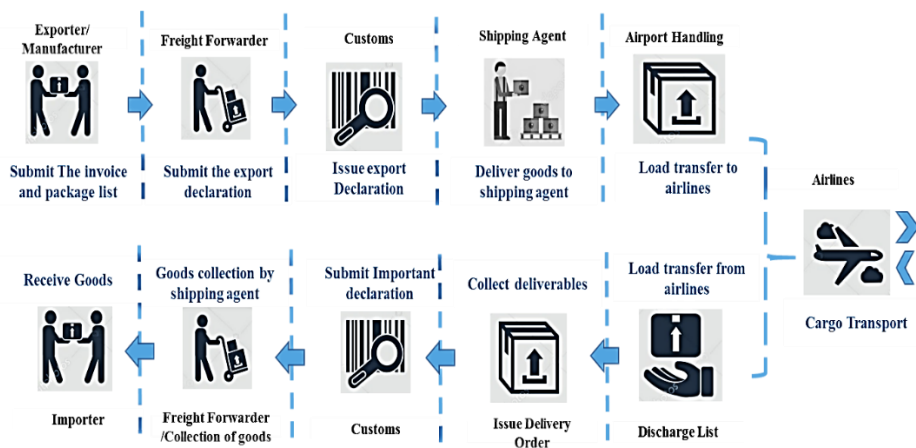


Fig.1. Traditional air cargo supply chain frameworks

In traditional model, the most common challenges airline freight forwarders face are usage of defunct technologies, unstructured data and no transparent information sharing. There exists difficulties in inability to track cargo consignments in real time once outside the carrier network and lack of integration throughout the supply chain leading to higher costs and lower efficiency.

3.2 Proposed Framework

To make the transportation and logistics system secure and efficient, the proposed framework combines Blockchain technology with IoT to make the system efficient and resilient against all the disruptions in freight handling.

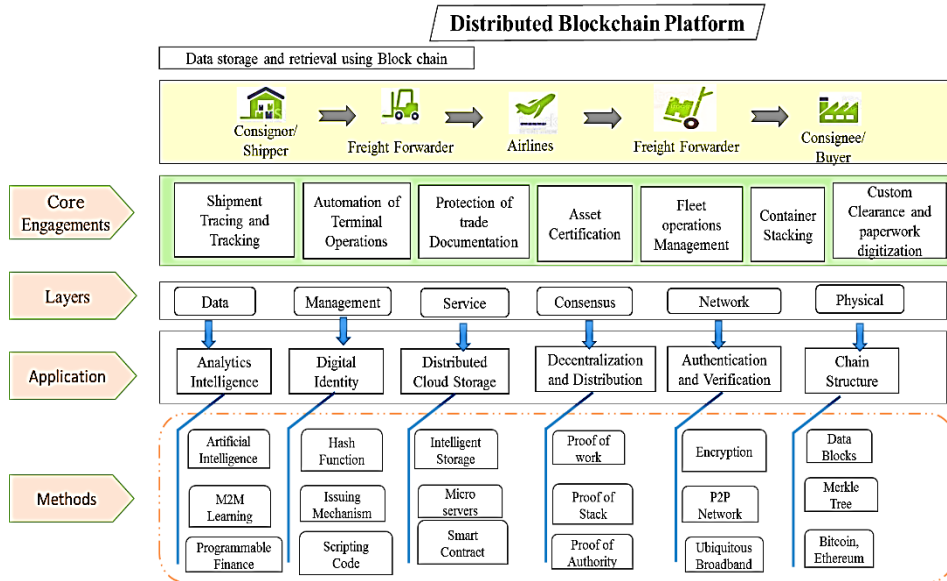


Fig.2. Blockchain in air cargo framework

In this section, we propose a layered framework that signifies the prominent application of blockchain in handling global air freight logistics, supply chain transparency, and traceability. These frameworks useful to alleviate global trade managing procurement, transportation, trace and track, collaboration, customs, and trade finance depicted in Figure 3. The layers of the blockchain manage the different architectures of the freight movement process.

Data Layer: This layer refers to the process of data masking providing the reproduction of data in a nonproduction environment to support the test and development process without exposing sensitive data. It eliminates all the identifiable features in sensitive data and enables data anonymization to remain available, thereby eliminating the risk of leaking sensitive information This layer provides the chained data blocks, together with the related techniques including asymmetric encryption, time-stamping, hash algorithms and merkle trees.

Management layer: This layer refers to different functions of managing data using hash function, issuing code and cryptic framework. In Blockchain architecture, all the client nodes are connected with peer-to-peer networks. Once data is sent, it is received and encrypted using various hashing techniques and is broadcast. Only the legitimate

person will receive the broadcast transaction, and this is only possible due to Blockchain enabled IoT sensors. In logistics, Blockchain technology not only maintains the integrity of transported products, but it keeps a complete record of the overall shipping process.

Service layer: The service layer specifies the mechanisms of distributed networking, data forwarding and verification. Most models, systems and application scenarios are composed of large numbers of distributed, autonomous, dynamic decision-making devices or vehicles.

Consensus layer: The consensus layer determines which the consensus algorithm is adopted to achieve consensus on some information among untrusted parties in decentralized systems. Currently, there are a lot of consensus protocols being applied in blockchain systems, which could be roughly divided into consensus protocols with proof of concept (e.g., Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS) and Proof of Authority (PoA)). According to the different types of blockchains, consensus protocols are selected differently. For example, due to the loose control and poor synchronization, the consensus protocol in permissionless blockchain(public blockchain) widely selects the incentive- based consensus schemes, such as PoW and PoS.

Network Layer: This layer is responsible for transferring data. Blockchain uses a P2P network of devices instead of a middleman and transmits blocks through consensus. Once a block is created, it is broadcast on the P2P network and is verified by each node according to the predefined specifications. Each node discards invalid data and passes the valid data to its neighboring node. Thus, Blockchain data is verified by multiple nodes and then finally appended into a Blockchain. If a node forwards invalid data to its neighboring node, it is disconnected from the P2P network for a specific period of time. Therefore, only valid data are transmitted over the network.

Physical Layer: The physical layer encapsulates various kinds of physical entities (e.g., devices, vehicles, assets and other environmental objects) involved in ITSs, such as traffic lights, digital cameras, cars, and so on. The devices in this layer collect data and forward it to the upper layer for validation. IoT plays the main role in this layer by providing massive interconnectivity of devices. Sensors at this layer provide various functions, including temperature monitoring, traffic data collection, light, pressure monitoring, etc. Further, Blockchain-based sensor devices enhance data security and privacy. A large amount of data is collected through these sensors and is stored in decentralized blockchain ledgers.

4 Validation of Proposed model- Consideration of Blockchain Implementation:

By enabling a more learner, streamlined, and error-free operation, blockchain will save money. It will accelerate the physical movement of commodities by increasing the visibility and predictability of logistics operations. The ability to trace the provenance of products will allow responsible and sustainable supply chains at scale, as well as aid in the fight against product counterfeiting. Our proposed framework is validated by providing an adequate mathematical explanation in this section. The model is tested by applying the blockchain concept in the profit maximization problem of a freight forwarding firm.

$$Max_{q^a, T_B} \pi_B = v \cdot \underbrace{\min [D_B, q_B^a]}_{\text{Revenue}} - \underbrace{\left[r^a + (s^a + w)(1 - T_B) + (s_B^a + w_B)T_B \right]}_{\text{Total cost of air shipping}} - \underbrace{\left[I_B + c(q_B^a) \right] T_B}_{\text{Cost savings due to Blockchain}} \quad (1)$$

Where,

$$D_B \sim N(\mu_B, \sigma_B^2), \quad \text{where } \sigma_B > 0 \quad (2)$$

$$s_B^a = s^a - g(\tau^a)^a > 0, \quad \text{where } g(\tau^a)^a > 0 \quad (3)$$

$$w_B = w - g(\tau^a)^w > 0, \quad \text{where } g(\tau^a)^w > 0 \quad (4)$$

$$T_B \in \{0, 1\} \quad (5)$$

Notations:

| | |
|---------|--|
| q^a | Quantity shipped over Air |
| T_B | Binary decision variable |
| π_B | Expected Profit |
| v | Unit Revenue |
| D_B | Demand |
| q_B^a | Shipped quantity tracked and traced using Blockchain |
| r^a | Revenue cost by air shipment |
| s^a | Shipping cost |
| w | Waiting time translated into monetary value |
| s_B^a | Shipping cost traced using Blockchain |
| w_B | Waiting time tracked via Blockchain |
| I_B | Implementation of Blockchain |
| c | Variable cost |

| | |
|------------|---|
| μ_B | Std. Deviation of normally distributed products are being shipped |
| σ_B | Variance of demand |
| τ | Saved time |
| A | Shipments through Air |
| B | Blockchain Integration |

Equation (1) depicts the profit obtained through the implementation of Blockchain. The first term represents total revenue, the second term is the total cost of air shipping and the third term represents the cost savings due to the implementation of Blockchain. Equation (2) represents the demand function and Equation (3)-(4) is the decrease storage cost of air shipping. Equation (5) represents the binary decision variable, if 1 then Blockchain is implemented, if 0, then otherwise. To the best of our knowledge, there is a scarcity of publicly available datasets of Blockchain cost implementation, therefore we assumed the objective function to be non-linear and we tried to solve the problem by random data generation of cost concerning demand variability. Figure 3 depicts the decrease in total cost with the implementation of blockchain technologies in handling air cargo system.

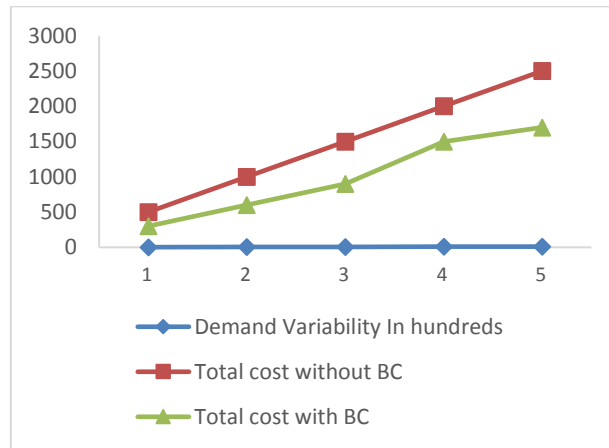


Fig.3. Total air transport cost

Blockchain technology brings down the total cost improving efficiency in air cargo shipping and logistics operations preventing damage to cargo. It helps to automate the payments process that are repetitive most of the time so as to improve the customer service. Thus, with these contributions, the current study makes an effort to provide practical insights and also introduce a new channel for further study in fulfilling the voids regarding the adoption of blockchain technologies in the freight logistics industry.

5 Conclusion

Transportation and logistics management are critical for the growth of country. Smart transportation is now a possibility thanks to the advancement of IoT products. This study suggests a layered structure for integrating Blockchain into air freight shipping and logistics to make it more effective and resistant to security attacks. Blockchain, on the other hand, is a decentralized mechanism that operates on a peer-to-peer network. It is made up of chain blocks, each of which documents a series of transactions while still keeping track of previous blocks and their hashing. Smart pay, improved fault tolerance, real-time knowledge sharing, privacy, and protection are just a few of the benefits that convergence brings to transportation and logistics. This post has aided research in a variety of areas. First, it gives a thorough description of smart transportation and logistics, as well as their significance in today's growth age. Second, using Blockchain-enabled air freight movement offers a robust platform for smart shipping and logistics. Third, the proposed structure is further tested using statistical modeling by examining profit maximization by blockchain implementation. This study can be extended by developing a system-level model in the future to assess the scalability and interoperability of different platforms used in smart transportation and logistics using more real-world case studies.

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