# The Technical Application of Blockchain in the Field of Cold Chain Logistics

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#### Keywords: Blockchain, Cold Chain Logistics, Information Traceability.

Abstract: While cold chain logistics is not a brand-new technology, it does have certain drawbacks, such as insufficient product security, limited digitalization in related processes, and high costs. However, the utilization of blockchain technology in cold chain logistics is a comparatively recent development that offers numerous benefits. Three fields of applications have been identified based on pertinent research literature: fresh food, medicine, and food. The precise application methods of merging blockchain with other technologies were introduced separately. If an emergency blood trading plan is offered, the information monitoring, disclosure, and traceability functions of fresh items, and the efficient resource allocation plan for food trading are proposed to obtain maximum benefits. Research has shown that the use of blockchain in conjunction with other technologies makes information on the chain publicly available, allowing for effective information querying and monitoring across a range of processes and emphasizing the benefits of lower logistics costs. Additionally, weaknesses and opportunities were mentioned at the same time.

# **1 INTRODUCTION**

Wang, Y.

As a special supply chain system, cold chain plays an important part in many areas like food safety, medical product preservation and economic trade. A special kind of logistics is called cold chain logistics, which is defined as "a systematic project in which refrigerated and frozen foods are kept in a specified low-temperature environment at all stages of production, storage, transportation, sales, and consumption to ensure food quality and reduce food loss (Dong et al. 2021)." By keeping an environment at a low temperature, it tries to preserve the safety and quality of perishable foods and short-term medications. Cold Chain Logistics (CCL) has a number of traits, including high implementation costs, demanding technical support and challenging monitoring in transportation process. As a result, perfecting the cold chain presents a significant difficulty. However, if substantial progress is made, the advancement of cold chain logistics will have a profound positive impact on economic trade and the quality of life in modern society. In terms of the traditional cold chain logistics, there are some limitations. For example, because CCL is at an inadequate level of digitalization, so real-time access

to a wealth of information is impeded, and product quality and safety are tightly under control (Han et al. 2021). At the same time, in the absence of digital cold chain logistics, temperature monitoring and adjustment are delayed, posing a risk to logistics and subsequently compromising business performance (Ali et al. 2018).

Blockchain was first proposed by Satoshi Nakamoto in 2008, since then it has progressively grown to become a widely recognized technology that now is being continuously developed, studied and used in a variety of industries (Sarmah 2018). These days, cold chain logistics and blockchain are combined in a lot of technologies. Combining cold chain logistics with blockchain technology has many benefits. For example, it can lower transaction costs by reducing the number of middlemen involved in the transaction process and streamlining operations (Mendonça et al. 2021). This not only makes decentralized and quick public transactions possible, but it also minimizes costs, saves time on products transit, and keeps the environment at the proper temperature while guaranteeing the quality of the items. Blockchain increases the transparency and public availability of supply chain data, which encourages medical facilities to share blood supplies and optimizes resource use (Kim et al. 2020).

The Technical Application of Blockchain in the Field of Cold Chain Logistics. DOI: 10.5220/001333800004558 Paper published under CC license (CC BY-NC-ND 4.0) In Proceedings of the 1st International Conference on Modern Logistics and Supply Chain Management (MLSCM 2024), pages 461-466 ISBN: 978-989-758-738-2 Proceedings Copyright © 2025 by SCITEPRESS – Science and Technology Publications, Lda. Utilizing blockchain technology can also lead to onchain data traceability and monitoring, which makes it be able to efficiently construct an effective cold chain logistics and satisfy the needs of several parties in terms of services (Tian 2017), it can also minimizing transaction errors and the spread of fake goods (Agarwal et al. 2022). It is evident that the use of blockchain technology is crucial for cold chain logistics, and cold chain logistics can be greatly improved.

However, these innovations are still in the early stages of development, and before they can be used, more must be proposed, tested, and refined. Therefore, it is necessary to provide a comprehensive review on how blockchain has been applied in cold chain logistics. The rest sections of this paper will make a detailed analysis on how blockchain technology is being used in cold chain logistics and offer pertinent potential problems and future development opportunities.

## 2 METHODS

#### 2.1 Introduction of Blockchain Technology

Blockchain creates a distributed database by using encryption methods to connect a number of chronologically ordered data blocks. Users start transactions on the blockchain, broadcast transaction information publicly, and the network verifies it. This is the fundamental way the blockchain operates. Through consensus processes, nodes validate transactions and matching blocks; if the verification is successful, the transactions and accompanying blocks are appended to the blockchain (Puthal et al. 2018). The information is kept open and united thanks to blockchain's decentralization, consensus process, and transparency. By joining the transaction data contained in the block together with their hash values, it creates a chain that makes it simple to follow any step in the transaction chain. The data is encrypted for security and to prevent tampering. This essentially stops fraudulent transactions because all nodes must come to a consensus before making any modifications to the data. However, there are still a lot of blockchain-related areas that need to be developed and improved, like how to scale up, improve information anonymity, efficiently minimize energy consumption, and further safeguard data security (Yli-Huumo et al. 2016).

#### 2.2 Blockchain in Medical Cold Chain Logistics

The application of blockchain in medical cold chain logistics is an important direction. Kim et al. proposed a system based on the Hyperledger Fabric private blockchain technology in the study. It involves the design and development of a novel blood cold chain system that facilitates emergency blood transactions between hospitals and records blood information via a distributed ledger. The transaction contains nodes in the blockchain made of participants and validators, who validate each link of the transaction, record consensus information on the state of blood and transaction content, and update blood inventory information in various hospitals (Kim et al. 2020).

of pharmaceutical cold The use chain management is the second application. Using blockchain technology and the Internet of Things to control the pharmaceutical cold chain is one way to find a solution. The cloud storage module stores the pertinent data signatures for registering medications. The generated drug information will be added to the blockchain and the registration request will be verified by the next blockchain platform. Based on the medicine information in the blockchain, the cold chain warehouse simultaneously asks the IoT monitoring module for a data storage address. The blockchain platform will also authenticate the drug related information provided by the cold chain warehouse and write it into the blockchain. Another strategy is to figure out the ideal level of cold chain inventory and manage it based on drug storage data stored in blockchain (Zhang et al. 2021).

#### 2.3 Blockchain in Fresh Agricultural Cold Chain Logistics

One application addresses the issues of data storage and transaction permissions in cold chain logistics by putting forth a multi-mode agricultural cold chain logistics model based on blockchain data model. In order to save the file index hash value, Si proposed a method that first creates a dual structure consisting of a private chain and an alliance chain. Alliance chains are used to search and share information, while private chains are used to collect and store information. Smart contracts were later created independently for each of the two chains. Upon completion of the transaction, the endorsing node on the smart contract executes the transaction request that was started by the client and returns the transaction outcome. After that, the transaction data package is distributed to every node for validation and is updated in the blockchain copy (Si 2022).

Blockchain is also employed in the traceability system of cold chain logistics for agricultural products. Tracing the information flow inside the system is the most essential step. All information pertaining to the planting, processing, storing, shipping, and selling procedures is included in this information flow, including standard product data, temperature of the surrounding environment, product quality, intervals of time, and other pertinent information. The QR code on the box will store these streams of information. A dual chain structure is also used by the traceability system. This structure consists of operation layer, data acquisition layer, data layer, consensus and network layer, presentation layer, and user layer. Key blockchain technologies, like peer-to-peer networks, propagation and authentication procedures, PoW and PoS consensus techniques, etc., are included in the consensus and network layers. It uses two different methods of data storage: full data is kept in a relational database and data summaries are kept on the blockchain network (Zhang et al. 2022).

#### 2.4 Blockchain in Food Cold Chain Logistics

Zhang et al. suggested a blockchain-based distributed cold chain logistics system and allocated resources using the Stackelberg game model. A decentralized cold chain logistics alliance is formed, bringing together all the institutions and users involved in transactions, based on the Hyperledger Fabric idea. The traceability function can be attained by this model, and in the end, game theory can be used to identify the best resource price and quantity that maximizes gains for all stakeholders (Zhang et al. 2023).

Another application is suggested that it is a blockchain-based cold chain supply chain system. There are four layers in this structure: the application layer, platform layer, data layer, and physical layer. In addition to the B/S structure and web front-end interface utilized in the application layer, all foodrelated data connected to all operations will be stored in the chain for simple one-click viewing. This will give users access to data interfaces that facilitate information exchange and traceability (Fu & Dong 2023).

#### **3 DISCUSSION**

#### 3.1 Advantages of Blockchain Technology in Different Scenarios

The benefits of blockchain technology in various industries can be summed up by looking at the study mentioned above. First, information disclosure can be achieved by directly storing the status information of traded products in linked fields in the chain, which is made possible by the structure and features of blockchain technology. Consensus methods are employed by blockchain technology to ensure data consistency and prevent malicious attacks that alter data. Data can be swiftly synchronized to the blockchain, decreasing the likelihood of fraud, when multiple technologies, such as GPS positioning systems, are combined to locate the transportation process and real-time information monitoring is accomplished through various technologies in the Internet of Things (IoT). By simply scanning the relevant QR code, customers can quickly grasp the details of each product link and subsequently purchase the item with confidence, all while having faith in the product's transaction process based on publicly accessible information. It can increase cold chain logistics efficiency in addition to stimulating economic growth and consumption. This is a thorough examination of the technology.

In terms of the medical field, Kim et al.'s proposed blockchain-based emergency blood supply cold chain system design efficiently reduces the time required for verification and transportation across several links in accordance with the overall state of the blood supply, freeing up critical time for patient rescue (Kim et al. 2020). For patients, blood type matching and status information are crucial. Physicians can use donated blood from other hospitals with confidence thanks to real-time information sharing and disclosure enabled by IoT and Hyperledger Fabric technology. Additionally, it raises the pace at which blood is utilized.

Store drug lifecycle data on the blockchain so that consumers can utilize timestamps to trace back depending on certain time points. It is much less expensive and takes up less room to store hash values simultaneously rather than the entire original piece of data.

In terms of the agricultural field, when real-time data from IOT is coupled with agricultural or transportation processes, items can be checked promptly based on quality standards. This allows for the early use of resources to cultivate the next batch of products, saving time and money on unqualified products. Users' purchases of products will rise as a result, significantly raising the qualification rate of products exchanged in the market. Consumption is encouraged by this.

The dual chain structure of blockchain is used in the process of implementing data traceability. Enterprises use the private chain for private purposes, which can achieve information concealment, while the consortium chain stores hash values for viewing shared information for simple traceability. The enterprise's anonymity is further safeguarded by the difficulty of deciphering the hash value, even in cases where the information is publicly accessible. Additionally, the two chains operate separately, have no effect on one another, and inspire confidence in the system's security in users.

In terms of the food field, the blockchain's public data disclosure leverages pre-existing decision models for thorough analysis, shortens the time spent by both parties negotiating their objectives , effectively maximizing revenues and minimizing disputes between participants. Additionally, due to the disclosure of information, it can stop one party from committing transaction fraud. In addition, it can guarantee food safety and lower the possibility of mishaps for both sides.

Analyzing a research model that can be applied to assess the cost analysis of BC technology at various application levels in the food cold chain is the following part. It is a study conducted by Zixuan L et al. regarding the impact of blockchain and Radio Frequency Identification (RFID) technologies on cold chain logistics costs (Liu et al. 2022). They developed a cost calculation model, and the Fig. 1 displays the final results derived from the data.

It can be concluded that the use of blockchain technology may successfully cut the cost of cold chain logistics because the table makes it evident that the more the percentage of blockchain and RFID technology applications, the cheaper the cost compared to not applying them.

#### 3.2 Challenges and Future Work

But as of right now, there are still certain challenges and restrictions with this technology. For example, there might be a greater need for computer processing power. Each link needs computer power sufficient to meet the requirements for chain data in order to obtain complete information about the chain. As the number of links in various cold chain domains increases, so does the number of verification nodes. As a result, there is a greater need for processing power to update and store data nodes.

Secondly, it is found from the entire procedure that the cold chain needs to store a massive amount of data. A significant quantity of storage space is undoubtedly needed if different product kinds and transaction chain data are saved on the blockchain. Additional development is necessary to expand the storage space.

There must be chances and directions for future development because the current state of affairs presents obstacles and restrictions. For instance, conquering current obstacles, overcoming constraints, and taking on challenges head-on.



Figure 1: Costs in different situation (Liu et al. 2022).

There are now no defined regulations in this area due to the ongoing development of blockchain applications in big cold chain systems; therefore, industry guidelines and pertinent regulatory constraints must be harmonized. For instance, to place restrictions on integrity, utilizing information transparency to support hierarchical management is a good method.

At the same time new technological integrations to automate specific workflows can be added. To automatically verify the quality of products in terms of cold and fresh food after monitoring data and uploading it, CCL based on BC can also utilize machines or internal programs. If it is practical, the next future work is to find ways to enhance the utilization rate of cold chain resources for products by promptly providing feedback to product responsible personnel. Or, when paired with AI, robots can take the place of people in order to do tasks. By doing this, tasks can be done more accurately and efficiently while reducing human mistake.

In conclusion, the use of blockchain technology in cold chain logistics remains relatively new, hence potentially expanding the technology's potential applications. For example, expanding application mode in financial sector.

### 4 CONCLUSION

of blockchain-related The implementation technologies in cold chain logistics for pharmaceuticals, fresh agricultural items, and food is detailed in this paper, which also introduces blockchain technology and cold chain logistics. It is clear from the study of technology applications that cold chain logistics has benefited greatly from the use of blockchain technology. Improving the quality of real life is the ultimate goal, starting with streamlining and regulating the logistics process, cutting costs, and effectively meeting the fundamental needs of cold chain logistics throughout the entire process, like environmental temperature. All information is then integrated into the blockchain to achieve information disclosure and security maintenance. Furthermore, blockchain still has a lot of issues. Being a relatively new technology, there are evident problems that need to be resolved, like the lack of pertinent laws and industry regulations. If there are weaknesses, there are certain areas that require improvement. Based on current research and market analysis, cold chain logistics supported by blockchain offers high development potential because the technology is still

in its early stages of research and development and has not yet reached a large enough user base.

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