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Original Paper

Research on Application Solutions of Blockchain Technology in Multi-Party Collaborative Emergency Logistics System

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Abstract

With the continuous development of global trade and logistics business, the construction of emergency logistics system has become an important part to ensure the efficient operation of logistics chain. However, in the face of emergencies, such as natural disasters, traffic accidents or public health crises, the traditional emergency logistics system is vulnerable to information asymmetry, data tampering and other problems, resulting in low emergency response efficiency. Blockchain technology, with its decentralized, immutable, transparent and traceable characteristics, offers new possibilities for solving these problems. This paper aims to discuss the solution of blockchain technology applied in the field of emergency logistics from the perspective of supply chain, in order to build a multi-agent collaborative emergency logistics "digital platform" network, and improve the response ability and toughness of the urban emergency logistics system that "combines emergency and peace".

Keywords

emergency logistics, blockchain, architecture design, multi-party collaborative, intelligent logistics

1. Introduction

Due to China's vast territory, floods, mudslides, typhoons, earthquakes and other natural disasters frequent, environmental pollution, ecological damage, traffic accidents, epidemics, food safety and other social emergencies are still more frequent, in order to maintain the national economy and people's lives and property, the stability of the logistics system also put forward higher requirements. In 2022, The State Council issued the 14th Five-Year Plan for National Emergency Response System, the first

five-year plan in the field of emergency management in China, which clearly states that by 2025, “an emergency management system with Chinese characteristics featuring unified command, both specialized and regular operations, sensitive response, and linkage between the top and the lower levels will be formed, and a national emergency response capability system featuring unified leadership, consistent powers and responsibilities, authority and efficiency will be established.” Emergency logistics, in particular, requires cross-departmental coordination. The plan also clearly proposes to “form a new pattern of emergency management featuring joint construction, joint governance and shared benefits” by 2035, and proposes to “deepen the emergency transportation linkage mechanism and implement emergency transportation support measures for railways, highways and aviation.”

For a long time in the future, we will face severe tests brought by public emergencies. How to ensure that goods can reach the disaster relief site in a timely and safe manner with the fastest speed, the least casualties and the lowest cost is a major issue in emergency rescue. In the past, research in the field of emergency logistics mostly focused on cost optimization and route selection. Based on emergency management theory, supply chain theory and coordination theory, this study builds an emergency supplies supply chain coordination platform, applies information technology such as blockchain and big data to the coordination platform, improves the response efficiency and resilience of the logistics system in emergencies, and provides reference for the development of emergency logistics at the present stage.

2. Current Situation and Problems of Emergency Management Development in China

2.1 Development Status

2.2.1 Favorable Policies Are Frequently Adopted by the State

In September 2023, five departments, including the Ministry of Industry and Information Technology, the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Finance and the Ministry of Emergency Management, jointly issued the Action Plan for the Development of Key Areas of Safety Emergency Equipment (2023-2025). The action Plan focuses on key safety emergency equipment used in ten scenarios, including earthquake and geological disasters, flood disasters, urban waterlogging disasters and family emergency response, strengthens core technology research and promotion and application, and improves disaster prevention and control, emergency rescue and disposal capabilities.

2.2.2 The Scale of the Industry Continues to Grow

China’s safety emergency response industry will develop rapidly in 2022. The total output value for the year exceeded 1.9 trillion yuan, up about 13 percent from 2021. In addition, among the enterprises engaged in the safety emergency response industry in China, manufacturing production enterprises accounted for about 60 percent, and service enterprises accounted for about 40 percent. From the regional point of view, the safety emergency industry in the eastern coastal areas is relatively large, with steady growth in sales, lucrative profits and strong competitiveness, leading the rapid development

of the regional safety emergency industry.

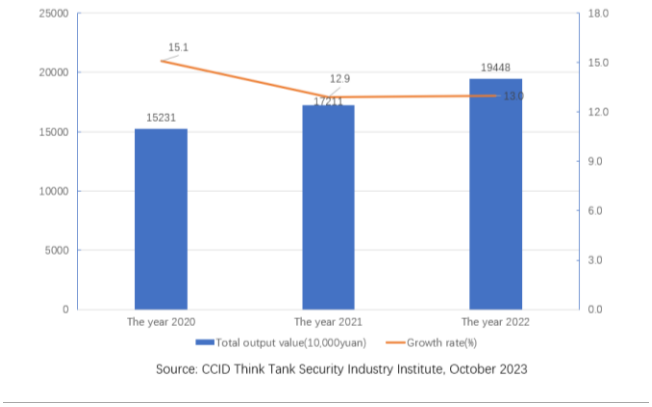

Figure 1. The Scale and Growth Rate of China's Security Emergency Industry from 2020 to 2022

2.2.3 The Application of Data Is more Monitoring and Less Early Warning

Although China has constantly improved the disaster risk assessment and early warning mechanism, timely release of disaster early warning information, and improve the response speed and accuracy of emergency logistics. However, in terms of depth, the current digital application mainly focuses on replacing manual investigation with video surveillance, but the data amount, granularity, coverage and fineness of the basic information required for hidden danger investigation, monitoring and early warning are not enough to support in-depth analysis and mining. In terms of breadth, due to the uneven level of information construction of emergency management departments across the country, the earthquake, geology, meteorology, flood and drought, fire and other disaster monitoring network is not perfect, the daily use of business systems mostly stay at the level of data statistics and work process digitization, and focus on the underlying basic governance work, lack of business application orientation.

To sum up, China's emergency logistics management has made some progress in terms of policy support, material reserves, industrial scale, etc., but there are still many obstacles. Strengthen cooperation among all parties and improve the ability to cope with emergencies and disasters.

2.2 Existing Problems

In emergencies such as flood fighting and rescue, emergency logistics, as the "lifeline", provides a solid guarantee for the protection of people's lives and property. However, there are still some weak links in China's emergency logistics system in terms of coordination mechanism, resource support and service capacity, etc. It is urgent to accelerate the construction of a modern logistics emergency response system to provide efficient, convenient and reliable emergency logistics service support for all kinds of emergencies in the future.

2.2.1 The Structure and Layout of Emergency Materials Reserve is Unreasonable

At present, the state and industry associations have not established the emergency materials reserve

catalog, although some specialties have a catalog list, but the update cycle is long, resulting in the emergency demand and materials reserve categories do not match, the quantity is not enough, the distribution is not convenient, and the storage is not matching. The reserve level of emergency materials in some regions is relatively insufficient, especially for specific types of emergencies, such as anti-epidemic materials and disaster relief materials in response to natural disasters.

2.2.2 Local Emergency Materials Warehouses Fail to Form a Storage Network System, and the Deployment and Implementation Are not Timely and Uneven

The planning of emergency logistics sites in provinces, cities and counties across the country does not fully consider the overall warehouse network layout, and the regional linkage between emergency materials warehouses fails to form. When emergency materials increase sharply to exceed the logistics carrying capacity in the plan, it is difficult for the demand side to quickly find a professional logistics operator in the first time. In the process of emergency materials deployment, there are situations where the deployment is not timely and unbalanced. On the one hand, in some areas, the allocation of materials is not timely enough, resulting in inefficient emergency response; On the other hand, some regions have excess material reserves, while others have shortages, resulting in a waste of resources and unbalanced distribution.

2.2.3 Information Asymmetry and Data Silos

At present, no integrated information sharing platform integrating military, police and civilian has been formed, and information related to emergency logistics is not transparent. There is “fog” in the demand, resources and process of emergency materials, and there is information asymmetry and data island among different departments and regions, resulting in the lack of timely and inaccurate information acquisition in the emergency response process, and it is impossible to fully grasp the demand and circulation status of allocated and donated materials. Not only is it easy to cause huge waste, but also aggravates the difficulty of emergency logistics operation. Information sharing and cooperation among governments at all levels, industry departments and enterprises need to be further strengthened.

2.2.4 The Relative Absence of Professional Strength

The ability of various functional modules of emergency logistics is obviously insufficient, especially the lack of professional forces such as rapid transceiver, sorting and distribution under emergency environment, mainly relying on manual management, and the operation efficiency is insufficient in the face of rapid turnover and a large surge in demand; The emergency logistics force does not match the professional rescue force, and it is difficult to meet the needs of professional distribution. Due to traffic, road network and other factors, logistics and transportation efficiency is low in some areas, and materials transportation time is long, which cannot meet the timeliness requirements of emergency response.

2.2.5 The Level of Standardization and Informatization Needs to Be Improved

At present, China’s emergency logistics management system is not perfect enough, the lack of unified norms and standards, there are differences in the emergency logistics management of various regions

and departments, and the degree of cooperation and information sharing needs to be improved. Some regions and enterprises in the emergency logistics information construction there is still a big gap, insufficient technical support level, resulting in limited emergency response ability, unable to fully grasp the allocation and donation of materials demand and circulation status. At present, the existing emergency management platform at all levels mainly connects the system of various functional departments of the government, and it is difficult to get through the information of all nodes and links of emergency materials management, resulting in information islands and affecting the efficiency of emergency materials scheduling and management.

The improvement and perfection of the emergency logistics system requires the joint efforts of the government, enterprises and society to strengthen the construction of material reserve, optimize the allocation of materials, improve the level of information sharing and technical support, so as to cope with various emergencies and disasters.

3. Relevant Theoretical Basis

3.1 Emergency Logistics

Emergency logistics refers to the logistics generated by the supply of emergency materials in the event of disasters and other emergencies. It faces more difficult situations than ordinary social logistics. First, it requires high timeliness and agility, emergencies are often difficult to predict, and the preparation and response time of emergency logistics is short, which requires the emergency logistics system to improve its rapid response ability; Second, it is highly professional. In response to emergencies, not only the rescue force should be professional, but also the emergency logistics force should carry out accompanying support. No matter from the independent adaptation of the rescue environment to the storage and distribution of relief materials, professional emergency logistics forces are needed to support; Third, high sensitivity, emergencies related to the safety of people's lives, the whole process of emergency logistics is likely to be exposed to the public media, the slightest mistake may cause international adverse impact and public opinion; Fourth, the subjectivity is strong. Emergency rescue often takes emergency material support as the core, and emergency logistics operations become the main body of rescue operations to drive other actions to be carried out simultaneously.

Emergency logistics is an emergency state of the social logistics system. Therefore, it is unscientific and unrealistic to set up a separate emergency logistics system when building an emergency logistics system. The correct approach should be to use information technology to efficiently integrate the resources in the social logistics system, and realize the coordination and intelligent management of multi-agents such as the government and third-party logistics. In order to build an emergency logistics system of "leveling and combining with emergencies", it can efficiently rescue when emergencies occur.

3.2 Technical Characteristics of Blockchain

3.2.1 Decentralization

Blockchain technology uses a decentralized distributed ledger where each participant owns the same information and the data is guaranteed to be immutable through encryption and consensus mechanisms. Compared with traditional data storage methods, blockchain is immune to hacking attacks targeting a small number of network nodes (less than 50%), and also has a higher level of disaster tolerance. Since there is no centralized operating body to maintain the database, blockchain may also be technically free from the market centralization of intermediary platforms.

3.2.2 Asymmetric Encryption Mechanism

Blockchain technology can realize the real-time sharing of information, ensuring that all participants have access to the latest data and avoiding the problem of information asymmetry. Through asymmetric encryption and whole-process record based on time stamp, blockchain gets rid of the traditional trust mode, and can realize information verification under the premise of privacy protection. Therefore, all participants (even if they have different market positions and asymmetric information) are easier to reach a consensus of trust at low cost. Under the guarantee of asymmetric encryption mechanism, blockchain can verify the authenticity of stored information at a low cost, so as to form a continuous and jointly recognized record of all kinds, and realize the information sharing and full traceability of the transaction process and data changes in each link.

3.2.3 Smart Contract

On the basis of the consensus mechanism, multi-party contracts of participants can be automatically executed by the program under the premise of meeting the consensus conditions, forming a smart contract supported by the blockchain. Smart contracts can transform “multi-party consensus” into “automatically realized” contract execution results. Smart contracts, an important feature of blockchain, automatically execute contract terms through preset conditions, increasing the automation of emergency logistics systems.

4. Analysis of the Advantages of Blockchain Application in Multi-Party Coordination of Emergency Logistics

Blockchain technology has a high degree of fit with multi-party coordination of emergency logistics, mainly reflected in the following aspects:

4.1 Data Transparency and Immutability

Blockchain technology ensures the transparency and immutability of data through the characteristics of decentralization and distribution. In emergency logistics management, the data involved by all parties include material reserves, transportation routes, delivery records, etc. The authenticity and integrity of these data is crucial for emergency response. Recording and sharing such data through blockchain technology can effectively prevent data tampering and falsification, and improve the credibility of emergency logistics.

4.2 Application of Smart Contracts

In contrast to other contract mechanisms, blockchain smart contracts can be automatically executed when preset conditions are met. In emergency logistics, smart contracts can be used to achieve automated logistics management processes, such as automatically triggering the allocation of materials according to the disaster situation and automatically settling transportation costs, which improves the efficiency and response speed of logistics management.

4.3 Information Sharing and Cooperation

Blockchain technology can establish a decentralized information sharing platform, and all participants can share information in real time on the same platform to achieve multi-party cooperation. In emergency logistics management, government departments at all levels, logistics enterprises and volunteer organizations can share information such as material reserves, transportation needs and traffic conditions through the blockchain platform to achieve efficient allocation of resources and coordinated response to emergencies.

4.4 Traceability and Management of Supply Chain

Blockchain technology can realize the full traceability of the supply chain, ensuring that the source, flow direction and quality of materials can be traced. In emergency logistics management, blockchain technology can be used to trace the flow path and production process of materials, ensure the safety and quality of materials, and improve the controllability and credibility of emergency logistics management.

4.5 Establishment of Trust Mechanism

Blockchain technology through the characteristics of decentralization, the establishment of a trust mechanism, the participants do not need to trust each other, still can achieve a safe and reliable data exchange and transaction. In emergency logistics management, there may be trust barriers between the parties, and a mutual trust data exchange and cooperation mechanism can be established through blockchain technology to promote multi-party coordination to deal with emergencies.

To sum up, blockchain technology has a high degree of compatibility with multi-party coordination of emergency logistics, which can effectively improve the efficiency, transparency and credibility of logistics management, and provide technical support and guarantee for emergency response.

5. Construction of Emergency Logistics System Based on Blockchain Technology

Because of its distributed ledger, consensus algorithm, time stamp, smart contract and other characteristics, blockchain naturally meets the needs of multi-agent collaborative emergency management. Based on the basic structure model of blockchain, this study proposes a possible way for blockchain to be embedded in multi-agent collaborative emergency management.

5.1 System Architecture Design

The multi-party coordinated emergency supply chain system consists of government, emergency material suppliers, third-party logistics providers and other social groups and even individuals, which

form a relatively complex supply and demand relationship and management relationship among each other, as shown in the following Figure.

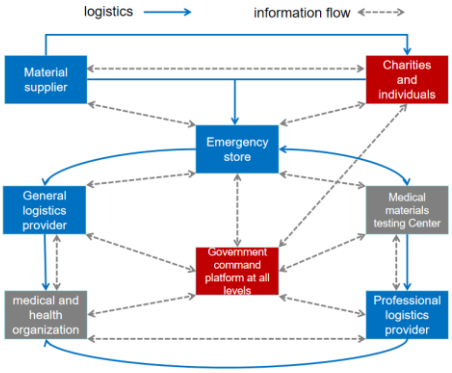

Figure 2. Structure Diagram of the Emergency Logistics Supply Chain

The system of blockchain applied in emergency logistics is a complex and organic system, which should integrate the above-mentioned multi-party participants in one system, aiming to realize the resource integration, intelligent decision-making and efficient supply of the entire emergency material allocation process. The architecture of the emergency logistics supply chain collaboration platform designed in this paper based on blockchain and other technologies is as follows, including the technology layer, data layer, application layer and collaboration layer.

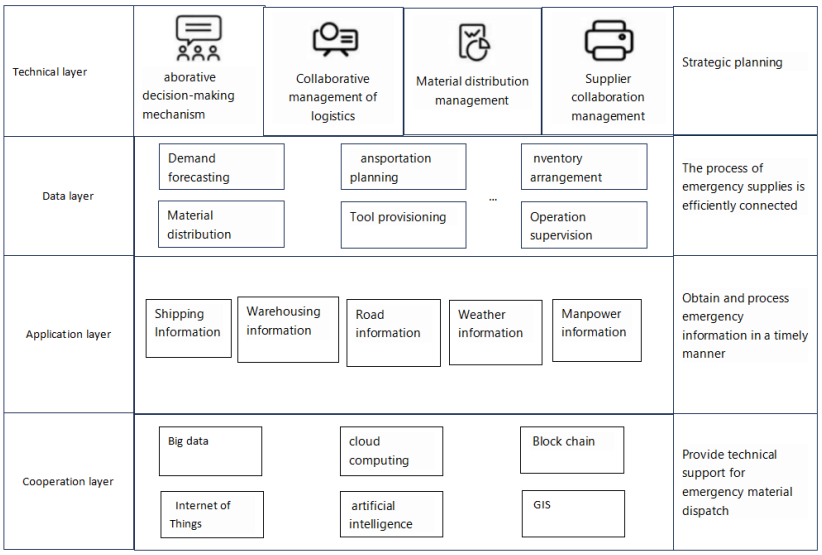

Figure 3. Blockchain-Based Collaborative System Architecture for Emergency Supplies

Figure 1. Emergency supplies supply chain system architecture based on blockchain (sample diagram, need to be modified) 1

5.1.1 Technical Layer

The technical layer is the base layer of the emergency supplies supply chain cooperation platform, and the information technology used in the emergency supplies supply chain cooperation system is defined in this layer. The blockchain is used as the basic technology to ensure the security and immutability of data. Every node in the logistics system has access to the blockchain and can communicate and exchange information with other nodes. Ensure the stability and security of the network with appropriate consensus algorithms, such as Pow or Pos. Deploy smart contracts to manage various operations in the logistics process, such as order creation, distribution, delivery, payment, etc., ensuring transparency and immolability. It is used to process, analyze and display emergency material data.

5.1.2 Data Layer

The data layer of the emergency supplies supply chain collaboration platform, which is used to collect, store and manage various information data, including material data, logistics data, road data, etc., which will be stored on the blockchain in a structured manner, ensuring that all participants can access and understand the data. The data layer is critical to the efficient operation of the emergency materials dispatching subsystem and provides scientific support for business execution.

5.1.3 Application Layer

Application layer and business execution layer, including demand forecasting, material distribution, route planning and other businesses, when there is an emergency situation, the logistics system will automatically start the emergency response mechanism. This may include operations such as redistributing materials, adjusting distribution routes and notifying relevant participants to ensure that goods can arrive at the disaster relief site on time. The logistics collaborative system tracks the location and status of goods in real time through Internet of Things technology, so that participants can check the real-time location and transportation status of goods at any time. The logistics collaborative system enables automated payment of goods after delivery through smart contracts.

5.1.4 Collaboration Layer

The coordination layer is also the core layer of the coordination platform of the supply chain of emergency materials, including the deployment of various intelligent materials and the integration of resources and needs of various participants, effectively connecting various subjects in the emergency logistics system, opening up the direct communication channel between the government and enterprises, and realizing the decentralization of enterprises. Under the role of the sharing mechanism, The information in the system can be shared in real time. Through the coordination layer, participants in the supply chain of emergency materials jointly determine the principles and norms of material scheduling to ensure that strategic emergency material scheduling objectives can be achieved and emergency rescue efficiency can be improved.

5.2 System Operation Process

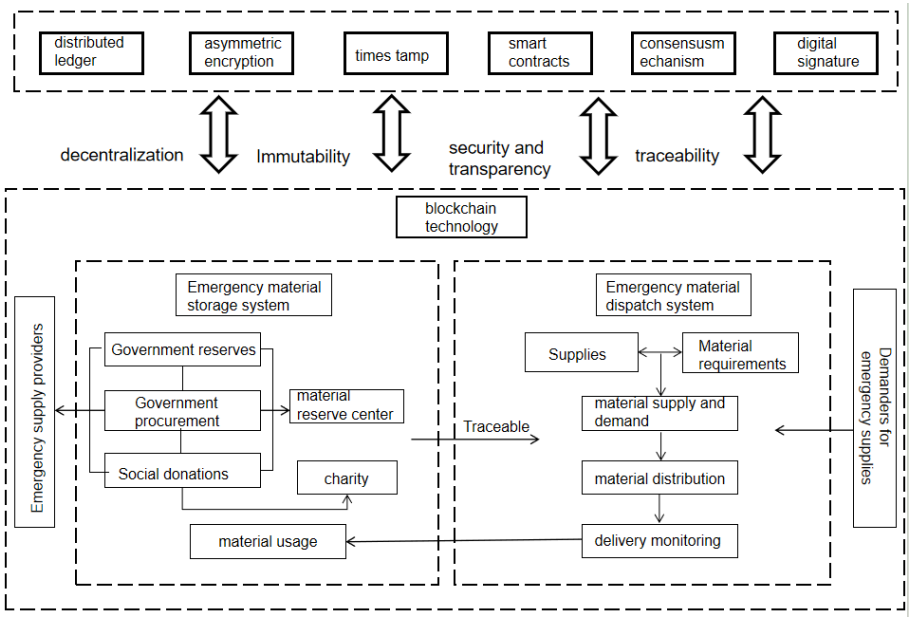

Figure 4. Blockchain-Based Emergency Supplies Collaborative System Operation Flow Chart

The operation process of the emergency materials supply chain coordination system based on blockchain technology can be divided into the following main steps:

First of all, the supply information provided by national and local reserves, government procurement and social donations is entered into the emergency materials information storage subsystem, including the basic information of the supplier and the type, quantity, specifications and other information of the purchased or donated materials. At the same time, the State Food and Drug Administration and other government departments are supervised. Using the consensus mechanism, the data information on the blockchain cannot be tampered with, and a safe and reliable trust environment is provided for the allocation of emergency materials.

Secondly, when emergencies occur (such as natural disasters, traffic accidents, etc.), the monitoring system will collect and analyze relevant data in order to issue early warnings in time. The early warning information will trigger the emergency logistics supply chain coordination system and initiate the emergency response mechanism. The collaborative system will collect and analyze demand information in the affected areas, including demand for materials and transportation needs. Based on the results of the demand assessment, the system will dispatch logistics resources, including vehicles, manpower, warehousing, etc., to meet the needs of the affected areas. At the same time, the material information required by the demand side is entered into the material demand module, and the supply and demand sides can achieve a more reasonable material matching through the smart contract, improving the safety and reliability of the supply and demand matching process. According to the demand assessment results, the collaborative system will reasonably arrange material matching,

logistics center location and route optimization according to the traffic situation and the urgency of the destination.

During the emergency material transportation phase, the collaborative system will monitor the transportation process of goods, including real-time tracking of the location of goods and monitoring the transportation status. Logistics companies or carriers will use the tools and information provided by the system to ensure that goods arrive at their destinations on time and safely.

The collaborative system will provide an information sharing platform for participants to communicate and share information resources in real time. This includes information on the needs of disaster-affected areas, information on supplies, and progress of transportation. Various participants can post updates, offer help, request support and so on through the system. The recipients in the affected areas will receive the goods as they arrive, store them and distribute them. The collaborative system will monitor the process of receiving and distributing the goods and record relevant data for subsequent analysis and evaluation.

Finally, after the shipment is completed, the collaborative system will collect transportation data and related feedback information. Based on the evaluation results, the collaborative system will be optimized and adjusted accordingly to improve the system's emergency response capability and efficiency. Individual participants will also improve their own emergency preparedness and response capabilities based on lessons learned.

The above process is the basic process of the operation of the emergency logistics supply chain collaborative system, which realizes the efficient allocation and transportation of materials in emergencies by integrating the resources of all parties and optimizing the logistics and transportation process.

6. Conclusion and Prospect

In this paper, we delve into the application solutions of blockchain technology in emergency logistics collaborative system and resource integration. As blockchain technology has great potential, it can effectively solve the problems of information asymmetry and data tampering in the traditional emergency logistics system, and improve the transparency, security and efficiency of logistics operation, so this paper presents the architecture of emergency logistics collaborative system based on blockchain, and carries out in-depth analysis and design for the key links. We designed an information sharing mechanism based on blockchain to realize real-time data sharing and interaction between participants, and ensure the transparency and traceability of the logistics process.

Limitations

Although blockchain technology has greatly improved the development of emergency logistics, the operability and practical effects of its practical application still need to be further verified. In conclusion, the research results of this paper provide important theoretical and practical support for

promoting the application of blockchain technology in the field of emergency logistics, and provide useful inspiration and reference for the construction and improvement of emergency logistics system. It is expected that further research can be conducted in the future to promote the deep integration of blockchain technology and emergency logistics, and contribute to the construction of a safer and more efficient emergency logistics system.

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