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Logistics in a Green Era, a Blockchain-Based Framework

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Abstract: With the promotion of sustainable models, increased attention is being given to ecological logistics and the application of GSCM in an increasing number of industries. Ecological logistics as a concept is viewed as a sustainable model in specialized studies, however, a consistent obstacle is observed in terms of real-time data collection and sharing. This article aims to highlight how the implementation of blockchain technology in logistics can provide a solution to this challenge, through the well-known specific characteristics of blockchain technology, which have already been successfully applied in various fields of activity.

Keywords: blockchain; GSCM; green logistic

1. Introduction

Logistics is the process of managing material procurement, movement, storage, and information flow. It's vital for businesses to stay competitive and improve cost and quality. The logistics industry has grown worldwide. To stay competitive, companies prioritize cost control for profitability in challenging markets. As more and more negative effects on the environment are observed due to the logistics industry, the development of GSCM becomes a crucial necessity, especially in the context of resource depletion. This involves incorporating modern techniques to minimize environmental hazards during planning, control, and implementation - known as green supply chain management. Logistics firms aim to reduce costs and their impact on the environment by implementing green logistics. Logistics involves many stakeholders and requires collaboration to reduce costs and improve efficiency, while

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promoting green practices. Electrical appliance manufacturers manually match operations and logistics objects to orders on paper forms, hindering real-time data collection and sustainable solutions. Data sharing is crucial for efficient logistics operations, but it remains a challenge among stakeholders. Without shared data, collaboration is impossible. Logistics data leakage threatens customers as personal information is easily accessible through paper-based records. Mistrust among stakeholders hinders cooperation. Blockchain can impact logistics management. Blockchain was created in 2008 for Bitcoin and now used for other areas like manufacturing and smart cities. Using blockchain for logistics ensures reliable and immutable data. It's a topical research field, with industries like telecommunications benefiting from increased transparency in sharing network traffic and economic compensation. Blockchain's impacts on aviation operations & sustainability in supply chain have been studied. There's no network to ensure optimal effectiveness, efficiency, and sustainability in applying blockchain to logistics. Research mainly explores policies, opportunities, and barriers rather than implementation.

2. Literature Review

In regards to the Literature Review, we focused on Green Supply Chain Management and the application of blockchain technology in logistics.

2.1. Green Supply Chain Management (GSCM)

In the last years, there has been increasing attention paid to supply chain management, and this aspect has also been influenced by the Covid-19 pandemic, when SCM resilience was put to the test (Ishida, 2020). On the other hand, strategies for green logistics are becoming increasingly important to researchers and governments, as there is a need to combat the ever-increasing consumption of the 21st century through the use of green logistics.

Dekker et al. (Dekker, 2012) propose the integration of environmental aspects into logistics to achieve a sustainable balance that can bring financial benefits through improved operations and cost reduction Ahi and Searcy (2013) have established the existence of a plurality of definitions of sustainable supply chain management (SSCM) and green supply chain management (GSCM). Specifically, their study highlighted the presence of twelve definitions of SSCM and twenty-two definitions of GSCM. The authors underscored the dearth of a universally accepted definition for either SSCM or GSCM and propose a new definition for sustainable supply chain management. De Oliviera et al. (de Oliviera, 2018) proposed a bibliometric analysis of GCSM articles published between 2006-2016 and identified that financial impact and implementation motivations were the most common research contexts for GSCM.

Several theories on sustainable supply chain management, together with a global map based on the frequency of these theories, are proposed by Touboulic et al. (Touboulic, 2015). Green logistics schemes that are applied or can be applied in metropolises worldwide were analyzed (Geroliminis, 2005), and small transport vehicles are included in several studies, with Cirovic proposing routes for them in urban areas using the neuro-fuzzy model (Cirovic, 2014). Karaman investigates the association between green logistics and sustainability in a study applied to 117 countries over a 10-year period, proposing a composite index of logistics performance (Karaman, 2020).

More and more countries are paying increased attention to GSCM, with Chinese companies focusing on improving the entire supply chain and making progress in adopting GSCM practices (Zhu 2004), with the aim of demonstrating opportunities for improving financial and environmental performance. The US Environmental Protection Agency issued a practical guide called "The Lean and Green Supply Chain" in 2000 (US EPA 2000), while the EU introduced the concept of "Green corridors" in 2007 (European Commission, 2007), paying increased attention to routes for the development of green logistics at the European level. Koreans have proposed green logistics platforms that provide information about goods, and in 2016, over 20% of trucks transporting goods in Korea used these platforms. On Korean green logistics platforms, shippers, carriers, warehouse operators, service providers, platform operators, and service users all have access (Kwak, 2020).

2.2. Blockchain Technology Applied in Logistics

Blockchain technology, known as the technology behind the digital currency Bitcoin (Nakamoto 2008), is applicable in most domains, 15 years after its emergence. Experts appreciate the technology for its decentralization, immutability, transparency, confidentiality, disruptive character, speed in processing transactions, traceability, real-time updating, and unique updating for all network members (Abou Jaoude, 2019; Gorkhali, 2020; Conoscenti, 2016).

The blockchain technology can be very helpful for companies that want to collaborate horizontally, by offering them an organized framework where transparency and security are a priority. Peer-to-peer networks provide each member with equal rights and responsibilities, and the encryption technology ensures the security of each user's data. (Li, 2022)

Through the Smart Contract feature of blockchain technology, contractual terms regarding rights and obligations are automatically generated by algorithms, eliminating the need for a third party to be involved in the process of introducing them. The use of smart contracts facilitates the development of e-commerce in the Internet of Things (Zheng, 2020).

In the context of the Internet of Things (IoT), security represents a major challenge that can be addressed through blockchain technology. This technology provides a secure framework for identifying and managing the trust of different devices, through authentication mechanisms, access control, information tracking, and responsibility in IoT applications (Perboli, 2018).

The blockchain technology can increase reliability and transparency, optimize input processes, streamline operations, and reduce logistics costs, becoming the backbone of digital supply chains (Perboli, 2018)

Although there are studies in the specialized literature on the benefits of applying blockchain technology in logistics, we have noticed a limitation in studies regarding the benefits of blockchain technology in GSCM. Therefore, this paper proposes the design of a framework based on blockchain technology for the sustainable logistics.

3. Logistics in Supply Chains

Logistic means managing how things get from where they start to where they need to go in order to meet people's needs. The illustration depicted in Appendix A elucidates a prototypical supply chain configuration comprising various functional entities such as manufacturers, suppliers, customers, and end distributors. An upstream stakeholder could potentially be perceived as a supplier of goods or services to its downstream stakeholders. Hence, within the context of business operations, it is possible to consider upstream stakeholders as a vendor, while downstream stakeholders can be classified as purchasers or buyers. As an illustration, manufacturers can be characterized as vendors to distributors.

When engaging in commercial transactions, purchasers employ a series of processes, encompassing procurement and distribution, in order to acquire goods or services from vendors. Upon successful placement of an order, vendors shall proceed to enlist the services of a third-party logistics in the conveyance of merchandise. Multimodal transportation is commonly employed in the majority of instances. The domain of transportation encompasses the domains of long-haul transportation, warehousing, and short-haul transportation. Ultimately, the requisite products are conveyed to the buyers and, thereby, the act of trade is consummated. Efficient completion of transportation tasks within the logistics process necessitates a collaborative and coordinated effort amongst the various stakeholders. In order to effectively achieve collaboration and coordination, it is paramount that stakeholders make use of real-time data and information to facilitate the realization of optimal solutions and decisions in attaining green logistics.

It should be noted that stakeholders may possess their own proprietary databases, consequently impeding the exchange of information among them. While certain digital platforms have been created with the intention of streamlining the sharing of data and information, it is not uncommon for delays to be encountered when attempting to update this content. Such delays may arise from the manual nature of data and information collection or from the time-consuming process of disseminating updates throughout the system. Insufficient real-time information and data may lead to suboptimal utilization of logistics resources, culminating in the dissipation of energy. Moreover, this inadequacy impairs prompt, informed decisions that are otherwise essential, including meeting receiving dates or leveraging transport capacity information. As of present, the field of logistics is confronted with a formidable challenge, namely the establishment of robust interconnections among stakeholders. The collection and sharing of real-time data and information are crucial elements that merit significant attention.

Blockchain technology can facilitate the process presented above, efficiently neutralizing the challenges. Through IoT and big data, this article will explore the application of blockchain technology in logistics.

4. Utilizing Blockchain Technology for Green Logistics

To attain the objective of multi-party data sharing and prompt decision-making, the utilization of IoT technology is essential. Nevertheless, the utilization of this technology frequently engenders challenges concerning data privacy and security. The underlying principle of Blockchain technology is rooted in a systematic approach that enables previously unidentified entities to collaboratively create and sustain virtually any form of database through a fully decentralized framework.

The following segment presents a blockchain-oriented structure for eco-friendly logistics, imbued with the purpose of attaining optimized and sustainable operations in logistics. This structure assimilates the Internet of Things and big data, which collectively contributes to the framework’s effectiveness and proficiency. The principal objective is to provide an introduction to the utilization of IoT technology in transforming conventional items into intelligent entities, alongside highlighting essential logistics applications.

4.1. Overview of the Framework

The proposed framework, comprising seven distinct levels, is represented in APPENDIX B. These levels include the physical level, perception level, network level, blockchain level, management level, application level, and user level.

The first level is the physical level. This level comprises of all sorts of coordinations assets that are included within the logistics process and are the essential assets to back the operation of logistics. These assets are categorized into three sorts. The primary sort is goods that got to be transported from venders to buyers. The moment sort is Cargo handler who are mindful for the development of merchandise. The third sort is coordinations gear, such as trucks, forklifts and distribution centers.

The perception level constitutes the second tier of the analytical framework. The present tier offers the capacity to supervise and discern the condition of logistics resources with the aid of a diverse array of sensing devices, encompassing the employment of radio frequency identification (RFID) technology. RFID readers, tags, scanners, and barcodes serve as crucial tools for unique identification of various goods. Webcams are utilized for the purposes of monitoring the work environment and safeguarding the security of goods. Trucks are installed with global positioning systems (GPS) to enable the capture of the real-time location of these vehicles. The logistics industry has embraced the utilization of wearable technology due to its ability to substantially enhance operational efficiency and mitigate the workload of logistics personnel. This phenomenon is commonly acknowledged as sustainable development from a societal standpoint. Advanced sensors, such as those integrated in intelligent electricity, water, and gas meters, possess the capability to detect resource depletion.

Communication channels are facilitated through the network level. The transmission of data from the perception level to the blockchain level is enabled by various communication channels, including but not limited to 4G/5G networks, LoRa, Bluetooth, TCP/IP, ultra-wideband, and so on. This level facilitates the rapid, secure transmission of live data.

The blockchain level refers to the storage mechanism of accumulated information which is organized into a sequence of interconnected blocks, assembled in successive order, to create a cohesive blockchain. A blockchain comprises a header and a body, delineating its fundamental structure. The former entity is comprised of metadata, whereas the latter entity is responsible for preserving a hashed and authenticated dataset in the form of a Merkle tree (Yuan, 2018). A Merkle tree is comprised of distinct sets of data pertaining to order information, shipment and receipt dates, product information, operating details, and related data. To establish a blockchain, it is imperative to have three fundamental components. The initial component pertains to the consensus mechanism, which involves the utilization of consensus algorithms to ensure data consistency and enable all nodes in the blockchain network to attain a unanimity regarding the data. The second aspect pertains to the incentive mechanism, which functions as a mode of stimulating every node to record data. The third constituent pertains to the employment of cryptography, which strives to encipher and shield information.

The management level is reinforced by a diverse array of operational management tools. The aforementioned resources embody a multifaceted skill-set, inclusive of overseeing and administering blockchain systems, user management, network governance, and large-scale data analysis. The objective of managing blockchain technology is to successfully oversee and uphold the different tiers within the blockchain framework. The oversight of logistics process analysis in the context of supply chain management, as well as the identification and resolution of user-related issues, including the generation of both public and private keys, are encompassed within the purview of user management. The process of network management involves the regulation of communication channels. The utilization of big data analytics is employed in the processing of data that is stored in blockchain for diverse applications.

At the user level, a diverse array of applications can be accessed via the application layer, encompassing functionality related to logistics traceability, emissions analysis, sophisticated transactional capabilities, and information-sharing within collaborative logistics arrangements. The participants involved in logistics operations within a supply chain are frequently denoted as users.

4.2. Key Applications

Traceability

The notion of traceability holds significant implications for logistics, particularly in light of the integration of blockchain technology, which enables the comprehensive monitoring and tracing of goods across the complete supply chain. This application offers remarkable benefits that encompass the augmentation of efficacy in the supply chain by facilitating prompt delivery of goods, along with affording swift and unimpeded access to pertinent information for all parties involved, that is indispensable for streamlining logistics procedures. The utilization of this application plays a pivotal role in the attainment of reverse green logistics by eliminating losses incurred during the manufacturing of commodities and promoting efficient material usage. Moreover, governmental authorities may efficiently manage both domestic and foreign logistics with the utilization of this technology.

Vehicle routing

This application has the potential to function as a foundational element in the facilitation of streamlined routing and the advancement of ideal logistics and supply chain management strategies. The present application affords the creation of an efficient itinerary for visiting several buyers, resulting in reduced costs and improved customer satisfaction. Furthermore, this particular application has the potential to mitigate environmental impacts by decreasing energy usage, circumventing obstructions, and minimizing carbon dioxide discharges. The vast majority of the gathered data is viable for immediate use, culminating in the development of an ecologically and energetically proficient logistics framework.

Energy saving management

Energy-saving management is a crucial instrument for the supervision, regulation, and administration of energy consumption (Yang, 2009), thus emphasizing the need for its efficient implementation. Conventional energy management and control practices are hampered by the unavailability of dependable energy consumption data, thereby making it difficult for logistics companies to perform comprehensive evaluations of their environmental performance. The integration of smart sensors into physical objects facilitates the real-time collection and storage of energy consumption data in the blockchain. By leveraging this data, logistics companies can perform energy analysis without the need for manual data manipulation, adopt energy-saving solutions, and implement big data analytics to develop a comprehensive energy-saving strategy. The adoption of energy-saving management practices has the potential to mitigate environmental pollution and address the concerns that challenge enterprise managers. Furthermore, these practices provide a crucial foundation for the establishment of green supply chains.

Collaborative logistics.

This software solution facilitates logistical partnerships between companies to jointly serve a shared customer base, resulting in decreased expenses related to freight logistics and optimal utilization of available facility capacity. The act of collaborating among logistics enterprises exhibits the potential to curtail energy consumption and carbon emissions, alongside the capacity to augment revenue generation. In the logistics industry, there exists a cooperative market comprised of numerous entities seeking to exchange their logistics resources or tasks. The allocation of logistics resources and tasks within traditional collaborative logistics markets is proven to be a challenging endeavor, owing to the dynamic nature of demand and supply. The implementation of blockchain technology presents an opportunity to create a peer-to-peer collaborative logistics marketplace that enables unencumbered trading.

5. Discussions

5.1. Benefits

Blockchain benefits logistics with transparency, trust, and collaboration. "Using blockchain technology, this framework enhances transparency by providing dependable, uniform, and unalterable information to stakeholders." With blockchain, stakeholders can access real-time logistics data. It's hard to build trust with stakeholders. With blockchain, logistics firms can assess historical on-time deliveries and pickups. They can also track customer contract fulfillment. Smart contracts can automate payment processes when conditions are met. Establishing trust among stakeholders enhances collaboration and cooperation. In logistics, stakeholders can find optimal solutions to cut costs and boost profits. Real-time data sharing allows them to adjust plans based on reality. Competitors can benefit from collaboration, such as using logistics together to cut costs and increase capacity.

5.2. Challenges

Challenges for logistics adopting blockchain: incentives, data and cost, incl. storage/transmission. The amount of data in the world is growing rapidly. The data collected daily could represent a danger to the use of blockchain technology in the logistics field. Data collection in blockchain requires nodes with large storage capacities, but this leads to storage wasted due to duplicated data in each node. Electricity use goes against green development goals. IoT devices cause network congestion and reduce service quality. The instability of blockchain affects data transmission in logistics. Logistics companies face a series of high costs, including operating, maintenance, training, and equipment acquisition costs. In addition, if logistics companies want to implement blockchain technology in their activity, additional costs will be added to achieve green logistics. Despite potential benefits, companies may choose not to adopt blockchain to avoid heavy investment. High risk is an issue and blockchain’s usage is still being explored. Logistics companies are vulnerable to disruption due to technical issues, thus requiring incentive mechanisms. In crypto, miners get rewarded, but logistics companies don’t when recording data. Without logistics companies, blockchain cannot be established and used for logistics operations. Incentives are necessary.

6. Conclusions

Blockchain can revolutionize industries and businesses. Our paper introduces a sustainable logistics framework using blockchain, IoT, and big data. This study analyzes blockchain in logistics and offers a triple contribution. This paper analyzes supply chain logistics issues hindering green logistics and proposes a seven-level blockchain framework. This framework allows logistics to shift to blockchain operation mode, with applications to cut costs, boost profitability.

Future research directions include answering research questions like: How to connect physical and perception level for logistics data collection? How to incentivize participation of logistics companies in blockchain construction? How to tackle costs and risks of adopting blockchain?

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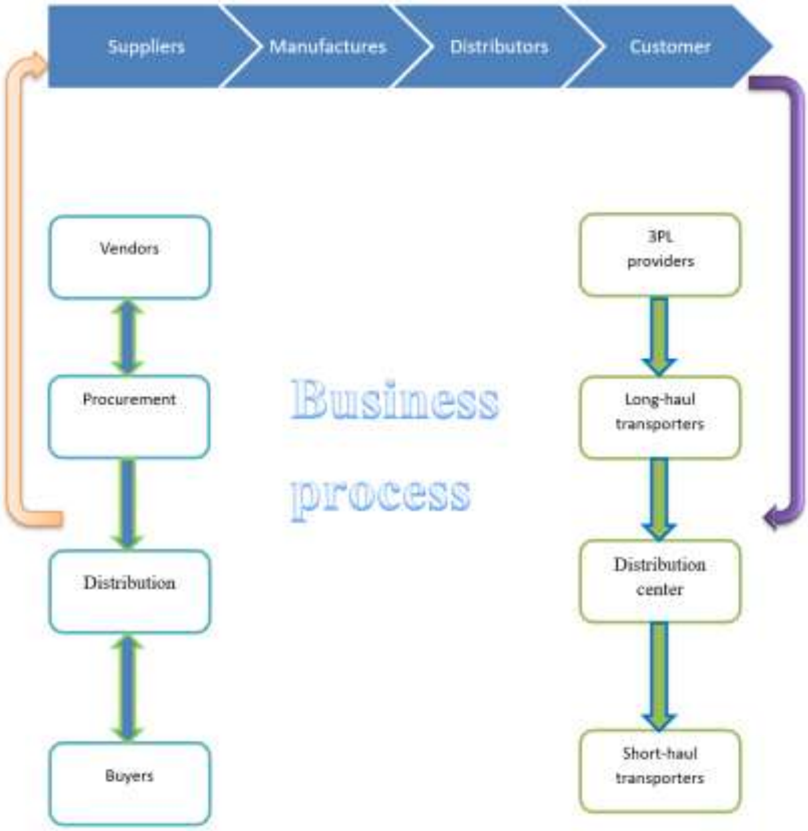
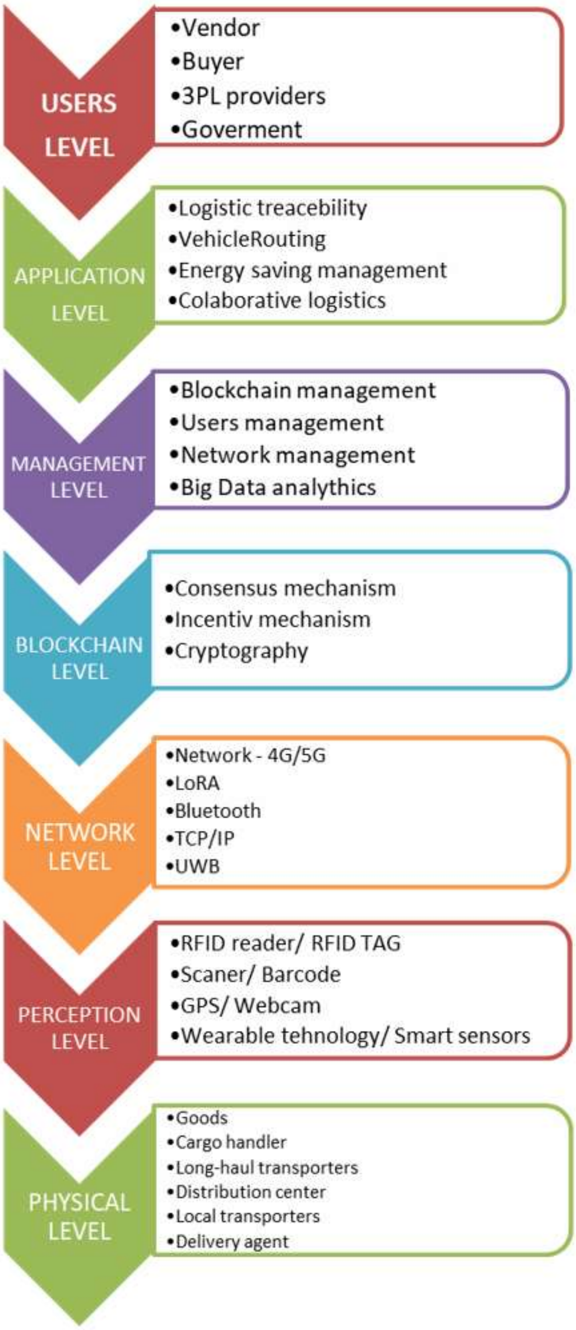
Appendix A



Appendix B


USERS LEVEL
•Vendor
•Buyer
•3PL providers
•Goverment
APPLICATION LEVEL
•Logistic treacebility
•VehicleRouting
•Energy saving management
•Colaborative logistics
MANAGEMENT LEVEL
•Blockchain management
•Users management
•Network management
•Big Data analythics
BLOCKCHAIN LEVEL
•Consensus mechanism
•Incentiv mechanism
•Cryptography
NETWORK LEVEL
•Network - 4G/5G
•LoRA
•Bluetooth
•TCP/IP
•UWB
PERCEPTION LEVEL
•RFID reader/ RFID TAG
•Scaner/ Barcode
•GPS/ Webcam
•Wearable tehnology/ Smart sensors
PHYSICAL LEVEL
•Goods
•Cargo handler
•Long-haul transporters
•Distribution center
•Local transporters
•Delivery agent