MEST Journal
DOI 10.12709/mest.12.12.01.02

A REVIEW OF BLOCKCHAIN APPLICATION IN LOGISTICS AND LAST-MILE DELIVERY

Zoran Cekerevac
MESTE, Belgrade, Serbia
https://orcid.org/0000-0003-2972-2472

Milanka Bogavac
Faculty of Business and Law, MB University, Belgrade, Serbia
https://orcid.org/0000-0003-4252-6919

Lyudmila Prigoda
Maykop State Technological University, Maykop, Russian Federation
https://orcid.org/0000-0002-4762-3892

JEL Category: **M15, O32**

We dedicate this article to our late friend and colleague, Professor Sergey Kirsanov, who left us too soon.

Abstract

Due to the ongoing arrival of individuals, large urban areas are expanding while the daily life within them becomes increasingly demanding. These cities' authorities confronted many challenges in providing necessities for their citizens, such as water and food supply, energy, public transportation, road infrastructure, healthcare services, waste management, recycling, and storage facilities. Cities embrace novel technologies and innovative approaches to cope with these evolving circumstances. Cyber-physical systems, digitization, networking, cloud computing, the Internet of Things, and blockchains are valuable tools that enable the efficient functioning of smart cities. The subject matter of this article is very complex and covers several disciplines, such as management, transport, and information technologies. Few have mastered the necessary knowledge in all these areas. The authors wish that this multi-dimensional presentation of the current situation will be helpful to those who deal with the organization of life in cities, logistics, or the application of information technologies in business organizations, but also ordinary citizens who are not yet familiar with these problems. The article should allow the reader to see the complexity of last-mile delivery and encourage it to use its potential to get involved in solving this problem.

Keywords: Supply chain, blockchain, logistics, city logistics, last-mile delivery, fraud.

Address of the corresponding author:
Zoran Čekerevac
zoran@cekerevac.eu

1 INTRODUCTION

In recent years, blockchain technology has been of great interest to a wide range of people interested in cryptocurrencies. Not knowing what technology is, many have tried to make money by trading cryptocurrencies. When cryptocurrency trading declined, enough people had already acquired the necessary knowledge to be inspired and able to try to find new possibilities for the practical application of this technology.

How blockchains work and how SMEs can create and use them are shown in (Cekerevac & Cekerevac, 2022). In (Cekerevac & Cekerevac, 2023) (Cekerevac, Prigoda, & Cekerevac, 2022, May 25), and in (Cekerevac, Prigoda, & Maletic, 2018), the authors discussed different blockchain applications. There is considered synergy between blockchains and the Internet of Things. Therefore, we will not discuss the details of blockchain technology here. We want to point out that blockchains are decentralized platforms where each stakeholder participates by adding data to the chain and can see all changes in the chain. Blockchain is very reliable and resistant to external disturbances. Each blockchain has its ledger, a system that keeps records. Blockchain ledger contains a chronology of all transactions in the form of cryptographically verifiable parts called blocks and linked together (see Fig. 1) (Cekerevac, Prigoda, & Maletic, 2018)

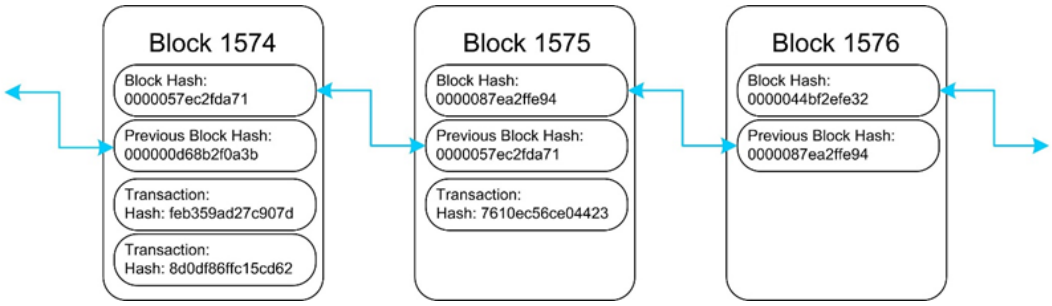

Fig. 1 An example of three consecutive blocks in the blockchain
Source: (Gupta, 2017)

Blockchains can be public, private, or consortium. In what category specific blockchain will be classified depends on who can participate in the network, validate blockchain entries, and keep the decentralized register.

Public blockchains are fully decentralized. Anyone can participate in the network. They are suitable for applications that value the benefits of an open system. Ethereum is an example of an open-source blockchain. It combines the advantages of the public blockchain with "programmable action chains" so-called smart contracts.

Private blockchains are different. They are accessible to selected participants exclusively and managed by network administrators. Only participants in the chain can see transaction information. Only participants in the chain can see transaction information. The network administrator assigns privileges to participants. The network operator, or a selected group of participants, performs validations. Formally speaking, a private blockchain is not decentralized. It is essentially a cryptographically secured distributed ledger.

Principally, both public and private blockchains can be used in logistics, and the type can be chosen depending on its purpose and the number of participants in the logistics chain.

This article analyzes the possibilities and justification of applying blockchain technology in logistics, especially last-mile delivery. The paper has five chapters.

Chapter 2 describes used materials and methods.

Chapter 3 presents a summarized literature review and an analysis of collected information. That chapter has two subsections. The first one gives some examples of blockchain technology applications and its application in logistics. The following subchapter discusses the relationships between blockchain and city logistics, particularly last-mile delivery.

In Chapter 4, Conclusions, the authors discuss and summarize obtained results. Based on the analysis and their pieces of knowledge, the authors give several recommendations for last-mile delivery improvement.

The last chapter, Works Cited, presents a list of literature sources used in the writing of this paper.

2 MATERIALS AND METHODS

The study is based on the system-functional approach. The researchers used commonly utilized scientific methods and techniques, including deduction, induction, comparison, scientific abstraction, generalization, and methodological development tools like graphical interpretations. The authors used high-quality literature to support their theoretical positions and argumentation of conclusions. They ensured proper and complete citation of all utilized sources, promoting high reproducibility of the research findings. The used sources encompass publicly available literature referenced in the Works Cited section and the authors' previous research published in scientific papers and presented at conferences.

Before the research, a research question arose: Is there any correlation between logistics service quality and blockchain technologies, and if yes, can blockchain improve last-mile delivery?

For the research question resolving the null hypothesis can be set up as:

H_0: There is no correlation between blockchain and the quality of logistics, so blockchain technology is not suitable for last-mile delivery and logistics processes improving at all.

Because of the research question and null hypothesis, two alternative hypotheses can be set:

$H_{a,1}$: There is a correlation between logistic quality improvement and blockchain technologies application.

$H_{a,2}$: There is a correlation between the last-mile delivery quality and blockchain technologies application.

3 LITERATURE REVIEW AND ANALYSIS

Logistics is an indispensable component of every business process. Given that international trade accounts for approximately 90% of total trade (Ziggurat, 2019) and absolute values grow every year, increasing the efficiency of logistics processes has a significant impact on the world economy. We should know that efficiency significantly depends on the various barriers removal and the organization's improvement.

Here, we will pay attention to blockchain applications in logistics, particularly city logistics, and last-mile delivery.

3.1 Potentials of blockchain technology use in logistics

The classic organization of logistics processes has its advantages, primarily in that the entire organization is centralized on one server and runs by one company. At the same time, it is also a significant disadvantage because that company suffers a great burden and carries a great responsibility in every respect. In case of any error of employees or the company servers' failures, problems arise in the entire logistics chain. The larger the company is, the heavier the challenges are.

Blockchain technology appears as an alternative that can help in logistics process optimization. In supply chains, blockchains enable product tracking during production and through whole delivery to the customer. That can help a lot in preventing fraud, especially Internet fraud. The origin of each product is known, and it cannot happen that the product appears from nowhere. By tracking the shipment movement, recipients can prepare for their receipt timely.

Blockchain has the potential to prevent errors from appearing in supporting documentation. Over 10% of freight invoices contain inaccurate data (Ziggurat, 2019). That affects the effectiveness of the process.

One of the potentials of blockchain technology is the ability to monitor the quality of goods. Since the origin of each product is known, in case of detection of any imperfection, it is possible to remove only the imperfect product from the store shelves. That is especially important in the case of food products.

Blockchain also allows the returned product to be tracked to the seller or recycling center, depending on whether it is a defective shipment or an old, already used but expired product. Until recently, only a dedicated industry practiced it, but now it is available to everyone.

Till now, many companies, startups, and researchers have dealt with this topic and shown interest in applying blockchain technology for last-mile delivery solutions. Some of them are:

- **Walmart** – patented and implemented a blockchain-based delivery "Smart package" system. The system uses a blockchain-based tool intended for use in autonomous vehicles and drones to track shipments, environmental conditions, locations, and other details. The application records the key addresses along the chain, including a "seller private-key address, a courier private-key address, and a buyer private-key address." (Partz, 2018) The "Smart Package" is not the first blockchain technology application at Walmart. Previously, in partnership with IBM, it used blockchain to detect and remove food recalls from the sales list.
- **The U.S. Postal Service** – analyzed different possibilities for its services. The analysis found potential postal blockchain applications in financial services, device management, identity services, and supply chain management. Blockchains can be used for identifying shipments and ensuring effective coordination of stakeholders in supply chain management. The Postal Service coordinates the work of many participants and tracks shipments throughout the delivery process. Blockchain use can speed up shipment delivery in domestic postal traffic, but the best results are in international shipment delivery. (RARC-WP-16-011, 2016) Each shipment can be marked so that the blockchain can identify it. Blockchain can then create transactions and share information promptly. The blockchain surveillance system can execute smart contracts for payment and customs clearance.

  Currently, tagging every piece of mail with a sensor is still expensive. In the beginning, the company can use the blockchain approach for high-value shipments. Tags can have additional information about the shipment so that the application can facilitate customs clearance and faster delivery. Also, the application can integrate payment processing into the shipping process. If payments are in digital currency, costs are reduced, and online trading is facilitated. The private sector tested this approach using the Ethereum blockchain. The applicant pays the invoice automatically when a shipment arrives. The great potential of the application is in drop-shipping, work-sharing, and international terminal fee settlement. Also, Citibank and Australia Post were beginning to research and experiment with this technology to provide new and more efficient services. (RARC-WP-16-011, 2016)
- **Carrefour** – implemented blockchain as part of its supply chain transformation. It launched its 'Carrefour 2022', a four-year transformation plan with a massive investment in digitalization with other costs slashing. Using blockchain technology is a crucial step in meeting this aim. Carrefour was the first in Europe to provide consumers with complete transparency in the traceability of their products. (Mouncer, 2020)

  The first step was the "Carrefour Bio" application for the own-brand organic products program, whose use started in April 2022. Carrefour thus became the first company that used blockchain technology in commerce and provided evidence of the actual quality of organic products. Consumers got transparent access to up-to-date information about the products' histories - from their production to their shipping to stores. Blockchain technology Carrefour first applied to a dessert orange of Spanish origin.

  Consumers can access product information by scanning the product's QR code. Product life cycle data that the customer can see are (n.d., 2022):
  - The product's origin, the route it took, the producer's name, the geographic location, the place of packing, and the means of transport.
  - Product quality: harvest date, analysis results, variety, and seasonality.
  - Organic certificate: date of conversion, official certificate, and additional initiatives carried out by the producer.

There are a lot of platforms based on blockchains and used in supply chains and logistics. Daley and Urvin (Daley & Urvin, 2023) briefly discussed several solutions (Daley & Urvin, 2023).

In logistics, it turned out that the concept of the transaction as it was in the original blockchain idea is often not enough. Often, business operations depend on many interactions. Therefore, the blockchain must be supplemented with smart contracts, programs that blockchain users can instantiate and use. Ethereum Virtual Machine (EVM) can translate contracts into bytecode language and execute them on all network nodes. That makes it possible to ensure the integrity of the database permanently. The execution of smart contracts is integrated with the ETH cryptocurrency that underlies the Ethereum blockchain. The Ethereum Solidity programming language enables myriad complex distributed applications (Dapps). (Kretzschmar & Eckardt, 2019)

Blockchain can serve both vertical and horizontal coordination. In the first case, a chain is formed from the producer to the end user. In the second, participants of the same level are linked, e.g., the carriers' fleets that carry out the logistics operations.

We believe that consortium or private blockchains are a good solution for logistics chains, especially in cooperation with the IoT. We expect a modern supply chain to provide end-to-end visibility, flexibility, trust, and process control. With its transparency, the Internet of Things brought revolutionary changes to supply chains. At the same time, it provides operational efficiency and the possibility of income. (Čekerevac & Bogavac, 2022)

The cited examples of successful application of blockchain technology in logistics proven savings show that the application of blockchain technology can contribute to improving the quality of logistics services.

3.2 Blockchain technology in last-mile deliveries

By reviewing the literature, one can determine that many works deal with the application of blockchain in last-mile delivery, but, unfortunately, most are only related to this topic by title. That could mean that, in principle, there is not much difference between what is related to logistics and what is related to last-mile delivery. But there are differences. Last-mile delivery has its specificities due to the specific task it performs and the conditions under which it is performed. Due to the influence on the total cost of transportation, it is highly significant how it is organized, how much it costs, and above all, how satisfied the customer will be with the delivery.

To simplify and speed up the whole process, it is advantageous if there are fewer participants. For these purposes, Kretzschmar and Eckardt (Kretzschmar & Eckardt, 2019) proposed peer-to-peer (P2P) networks and blockchains because there is no need for a proprietary central operator, and there will be no bottlenecks. The cryptographic ability with signature procedures can ensure that only authorized parties can access data, although the blockchain is accessible publicly.

What sets last-mile delivery apart from the rest of the logistics chain are the criteria it must meet. These are primarily the number of participants, accuracy, and sustainability.

For the client's satisfaction, the most important thing is to fulfill the condition that he receives the goods on time and in the correct state. He is (most often) not very interested in the part of the logistics chain that precedes sending his order to his address[1]. It is interesting for the buyer to follow the goods from the seller to his address. Therefore, in the case of last-mile delivery, the blockchain can work simplified to focus only on the immediate participants in the last stage of delivery, on the micro-hub, and on the carrier in the last stage. For the previous part of the goods' journey, it is enough for the customer to receive only rough information. That way, the blockchain can be private, shorter, and require fewer resources.

Last-mile delivery needs to be sustainable. That is emphasized in smart cities especially. It is significant to what extent it will impact the environment, how big the source of pollution will be, and how it will affect the already overloaded city traffic. An optimized choice of means of delivery can influence last-mile delivery's sustainability. The optimized selection here primarily means the vehicle selection from the

[1] The exception can be, e.g., organic food, although what constitutes organic food is debatable.

group of unengaged vehicles to deliver parcels. When optimizing the choice of means of transport, the transporter must consider many factors, and the aggravating circumstance is that these factors change over time. For example, in previous years, states stimulated the use of electric-powered vehicles, provided subsidies for their purchase, and emphasized that electric drive is the solution for the future and ensures zero emissions. Recent events in the energy markets have changed that drastically. Now a large part of electricity is obtained by burning coal, which is the most unfavorable and significantly more harmful than gaseous and liquid fuels.

Blockchains and good horizontal coordination can be very successful here if a successful selection model based on criteria relevant to smart cities is established. IoT and smart city technologies can help to automate processes and reduce the involvement of human work. The possibilities are great, and it's just a matter of the system designer's imagination and success in choosing the selection criteria.

Last-mile delivery encompasses the most efficient route selection, vehicle and human resource management, delay management, and troubleshooting. The most common parameters for the last-mile delivery efficiency evaluation are total cost, delivery time, accuracy, reliability, environmental impact, flexibility, traceability, and customer satisfaction (Francescangeli, 2023). When one creates a model for last-mile delivery, data from several areas should be collected and processed.

The first group consists of data related to micro-hub capacities and carrier capacities. Micro-hub data includes:

- The position and size of the micro-hub.
- The size of the territory for which the micro-hub is planned.
- Access road capacities.
- Means of internal transport by types and capacities.
- Human resources micro-hub.
- Data on available funds of micro-hab.
- Data on carrier capacities include:
- Number and type of delivery vehicles.
- The capacity of each delivery vehicle.
- Up-to-date data on the readiness of delivery vehicles.
- Data on planned asset maintenance.
- The carrier's human resources are always up to date on qualifications and availability.
- Always up-to-date data on roads, including city streets.
- Data on fuel consumption and
- Refueling organization.

The second group of data consists of data for the achieved results assessment. They should show how successful the business is and where the weak points are. This group includes data on:

- How many shipments were delivered on time, how many were late, and how many were not delivered and why?
- Proof of delivery.
- How long the vehicle was active and with what load it was loaded?
- How long did the vehicle wait within the delivery parked near the delivery point?
- How long was the vehicle unused?
- How much fuel did the vehicle use?
- The other costs associated with the vehicle and drivers.

The third group of data refers to transactions that may be different. When implementing smart contracts, it is necessary to include the goal of implementation, consideration of system sustainability, token mechanism, and consensus mechanism. That is necessary for the traceability, efficiency, and security of the process when there are several participants. Because of transactions, the model should also contain the following (Lobo, Wicaksono, & Valilai, 2022):

- Token System
- Collaterals (payment for service + delivery assurance)
- Rewards (efficient planning, saved energy, on-time delivery)
- Fines (Tardy delivery, inefficient planning)

Blockchains are already in use in last-mile delivery and will increasingly impact it. They can increase traceability and transparency – giving carriers greater visibility in the last mile and across the entire supply chain. The reasons are (Fidelitone, 2022):

- Blockchain prevents any disputed transaction or unwanted transaction manipulation from taking place in the supply chain.

- Blockchain increases security and prevents hacking. It is especially true when there are many links in the chain.
- Blockchain increases efficiency, as it can reduce manual processes.

Blockchain will show its strength in synergy with automated delivery systems and self-driving vehicles. It will improve the user experience. Drones[2] have been developing for the past ten years. They came into the public spotlight, especially in 2022 with the beginning of the Russian special operation in Ukraine. It is not expected that drones will deliver commercial packages across the city anytime soon, but logistics leaders have made significant progress. Experimenting with ground-based unmanned vehicles in urban environments showed higher potential than with unmanned aerial vehicles (UAVs) due to fewer regulations that need to be met. One of the main questions remains, who is to blame in a car accident involving a drone? In the future, these types of innovative technologies will be front and center in the supply chain, and companies will need to evaluate and adopt the right innovations to remain competitive (Montgomery, 2022). Unmanned aerial vehicles can come to the fore in sparsely populated areas due to the lower risk of damage caused by falling UAVs than in cities.

4 CONCLUSIONS

This study looks at the effects of using blockchain in supply chains, focused on last-mile deliveries. In principle, blockchain provides positive effects and enables many benefits for stakeholders in terms of more efficient and effective management of operations while increasing the satisfaction of users of logistics services.

The results of the analysis from subchapter 3.1 reject the null hypothesis H_0 that “Blockchain technology cannot be used in logistics processes improving” and confirm the alternative hypothesis $H_{a,1}$, according to which there are cases where “there is a correlation between the city-logistic quality and blockchain technologies”.

The results from subchapter 3.2 also reject the null hypothesis H_0 and confirm the alternative hypothesis $H_{a,2}$: There is a correlation between the last-mile delivery quality and blockchain technologies.

Finally, we cannot avoid pointing out that the bigger the city, the bigger the problems of living in it. It would be much more favorable if countries developed evenly, and the population might progress in their territory and not feel the need to seek happiness in big cities. If the current pace continues, a huge part of the territory will be uninhabited, and the population will be concentrated in bulky and dysfunctional cities.

WORKS CITED

Cekerevac, Z., & Cekerevac, P. (2022, 07 15). Blockchain and the application of blockchain technology. (Z. Cekerevac, Ed.) *MEST Journal, 10*(2), 14-25. doi:10.12709/mest.10.10.02.02

Cekerevac, Z., & Cekerevac, P. (2023). Blockchain Technology and Application – SMEs Aspect. *MEST Journal, 11*(2), 12. Retrieved from https://www.meste.org/mest/MEST_Najava/XXII_Cekerevac.pdf

Cekerevac, Z., Prigoda, L., & Cekerevac, P. (2022, May 25). Application of Blockchain Technology. *The National Scientific and Practical Conference with international participation in "Innovative Educational Technologies as a Tool for Developing the Intellectual Potential of the Region". 1*, pp. 278-286. Nalchik: IKC Ekspert.

Cekerevac, Z., Prigoda, L., & Maletic, J. (2018, July 15). Blockchain Technology and Industrial Internet of Things in the Supply Chains. (Z. Cekerevac, Ed.) *MEST Journal, 6*(2), 39-47. doi:10.12709/mest.06.06.02.05

[2] A drone is another name for all unmanned aerial vehicles, an aircraft that operates without a human pilot on board (Robarts, 2019), although the term drone can refer to anything from remote-controlled toy cars to military weapons.

Čekerevac, Z., & Bogavac, M. (2022). Impact of the pandemic on blockchain and the IoT application in supply chains from the SME aspect. *Mechanics Transport Communications, 20*(3/3), 11-17.

Daley, S., & Urvin, M. (2023, Feb 24). *Blockchain and Logistics: 19 Examples of the Technology*. (builtin) Retrieved from https://builtin.com/blockchain/blockchain-supply-chain-logistics-uses

Fidelitone. (2022, Aug 30). *Last Mile Logistics Tech Took Center Stage at Home Delivery World.* Retrieved from Fidelitone: https://www.fidelitone.com/last-mile-delivery/last-mile-logistics-tech-took-center-stage-at-home-delivery-world

Francescangeli, V. (2023). *Blockchain technology and Last Mile delivery.* Rome, Italy: LUISS. doi:10.13140/RG.2.2.16679.62883

Gupta, M. (2017). *Blockchain For Dummies* (IBM Limited Edition ed.). Hoboken, NJ: John Wiley & Sons, Inc. Retrieved from https://public.dhe.ibm.com/common/ssi/ecm/xi/en/xim12354usen/XIM12354USEN.PDF

Kretzschmar, J., & Eckardt, F. (2019). A Blockchain Approach towards Cargo Sharing in Last Mile Logistics. *VEHICULAR 2019 : The Eighth International Conference on Advances in Vehicular Systems, Technologies and Applications*, (pp. 11-15). Rome.

Lobo, C. R., Wicaksono, H., & Valilai, O. F. (2022). Implementation of Blockchain Technology to Enhance Last Mile Delivery Models with Sustainability Perspectives. *IFAC PapersOnLine, 55*(10), 3304-3309. doi:10.1016/j.ifacol.2022.10.123

Montgomery, K. (2022, Feb 28). *3 Ways to Improve Your Last-Mile Delivery Strategy.* Retrieved from Kenco: https://blog.kencogroup.com/3-ways-to-improve-your-last-mile-delivery-strategy

Mouncer, B. (2020, May 17). *Carrefour implements blockchain as part of supply chain transformation.* Retrieved from Digital Supply Chain: https://supplychaindigital.com/digital-supply-chain/carrefour-implements-blockchain-part-supply-chain-transformation

n.d. (2022, Apr 13). *Carrefour is the first retailer to use blockchain technology with its own-brand organic products, providing consumers with more transparency*. (Carrefour) Retrieved from https://www.carrefour.com/en/news/2022/carrefourbioblockchain

Partz, H. (2018, Mar 02). *Walmart To Implement Blockchain-Based Delivery System.* Retrieved from Cointelegraph: https://cointelegraph.com/news/walmart-to-implement-blockchain-based-delivery-system

RARC-WP-16-011. (2016). *Blockchain Technology: Possibilities for the U.S. Postal Service.* United States Postal Service Office of Inspector General. Retrieved from https://www.uspsoig.gov/sites/default/files/reports/2023-02/rarc-wp-16-011.pdf

Robarts, K. (2019, Oct 18). *Difference between Drones, UAVs, and Quadcopters.* Retrieved from Difference Between: https://differencebetweenz.com/difference-between-drones-uavs-and-quadcopters/

Ziggurat, G. I. (2019, Feb 12). *Blockchain success cases: Supply chain and logistics*. Retrieved from Ziguart Institute of Technology: https://www.e-zigurat.com/innovation-school/blog/blockchain-success-cases/

Received for publication: 21.07.2023
Revision received: 30.08.2023
Accepted for publication: 08.01.2024.

How to cite this article?

Style – **APA** *Sixth Edition:*

Cekerevac, Z., Bogavac, M., & Prigoda, L. (2024, 01 15). A Review of Blockchain Application in Logistics and Last-Mile Delivery. (Z. Cekerevac, Ed.) *MEST Journal, 12*(1), 4-12. doi:10.12709/mest.12.12.01.02

Style – **Chicago** *Sixteenth Edition:*

Cekerevac, Zoran, Milanka Bogavac, and Lyudmila Prigoda. "A Review of Blockchain Application in Logistics and Last-Mile Delivery." Edited by Zoran Cekerevac. *MEST Journal* (MESTE) 12, no. 1 (01 2024): 4-12.

Style – **GOST** *Name Sort:*

Cekerevac Zoran, Bogavac Milanka and Prigoda Lyudmila A Review of Blockchain Application in Logistics and Last-Mile Delivery [Journal] // MEST Journal / ed. Cekerevac Zoran. - Belgrade – Toronto : MESTE, 01 15, 2024. - 1 : Vol. 12. - pp. 4-12.

Style – **Harvard** *Anglia:*

Cekerevac, Z., Bogavac, M. & Prigoda, L., 2024. A Review of Blockchain Application in Logistics and Last-Mile Delivery. *MEST Journal,* 15 01, 12(1), pp. 4-12.

Style – **ISO 690** *Numerical Reference:*

A Review of Blockchain Application in Logistics and Last-Mile Delivery. **Cekerevac, Zoran, Bogavac, Milanka and Prigoda, Lyudmila.** [ed.] Zoran Cekerevac. 1, Belgrade – Toronto : MESTE, 01 15, 2024, MEST Journal, Vol. 12, pp. 4-12.