BLOCKCHAIN-ENABLED CAPABILITIES IN TRANSPORT OPERATIONS: AN OVERVIEW OF THE LITERATURE

Mario Henrique Bueno Moreira Callefi
Federal University of São Carlos, Brazil
E-mail: mariocallefi@gmail.com

Thais Moreira Tavares
Federal University of São Carlos, Brazil
E-mail: thaism0405@gmail.com

Gilberto Miller Devós Ganga
Federal University of São Carlos, Brazil
E-mail: ganga@dep.ufscar.br

Moacir Godinho Filho
Federal University of São Carlos, Brazil
E-mail: moacir@dep.ufscar.br

ABSTRACT

The blockchain was initially developed for use in the banking sector. However, over time, different areas of knowledge have adopted these technologies, including transportation operations. This use of blockchain in the transport sector is mainly due to the ability of this technology to enable the data generated by these activities to be reliable. In addition to aspects related to data immutability, blockchain enables greater data privacy, as well as making it possible for the data control process to be decentralized. In this sense, it was carried out a systematic literature review (RSL) to identify the general publications panorama on the topic, and to identify the capabilities enabled by the blockchain in the context of transportation operations. RSL has great potential to make it possible to deepen the literature on a given topic. The analysis of the RSL results included the realization of two stages. The first step consisted of a quantitative analysis of data from a sample of 50 articles, to identify this research field about the distribution by journal, year, and author. This first step enabled a general analysis of the field of study on the use of blockchain in transportation. The second stage consisted of a qualitative analysis of the ten most relevant articles in this field of study.

s728

In this way, it was possible to understand more about the use of blockchain in transport operations, as well as to identify seven capabilities enabled by the blockchain. These capabilities represent abilities that blockchain technology allows the transport sector today, demonstrating the importance of its use, as well as of study.

Keywords: Blockchain; Capability; Transport; Systematic Review

1. INTRODUCTION

In 2008, blockchain technology emerged as a great tool for the security of distributed records related to bitcoin cryptocurrency. Its importance was mainly due to its characteristics since blockchain allows the records to be immutable, enabling data reliability (Nakamoto, 2008).

Initially, blockchain was applied only in the financial area, but as time passed, this reality changed. Currently, the use of blockchain has expanded to several fields of study, including transport operations (Balasubramaniam et al., 2020). As highlighted by Maesa and Mori (2020), the development of blockchain is now in a phase known as landmark 3.0, which is marked by the development of applications related to smart contracts.

This interest in blockchain can be explained by its great ability to enable tracking, immutability, security, transparency in the registration, and data sharing. Besides, with the blockchain is possible to meet regulatory demands, since several laws impose the need to ensure data reliability (Al-Jaroodi & Mohamed, 2019). Another essential blockchain feature is the ability to allow data control decentralization, mainly using smart contracts and consensus mechanisms (Koh, Dolgui & Sarkis, 2020).

Knowing the characteristics and advantages of using blockchain, it is necessary to emphasize its importance in the transport sector, since several authors have been studying the topic today (Dorri et al., 2017; Lei et al., 2018; Zhe Yang et al ., 2019). However, to the best of our knowledge, no research identifies the capabilities made possible by blockchain in transport operations. These capabilities refer to the skills that blockchain makes possible in the transport sector.

Because of these characteristics and advantages of using blockchain, it is necessary to emphasize its importance in the transport sector, since several authors have been studying the topic today (Dorri et al., 2017; Lei et al., 2018; Zhe Yang et al., 2019). However, to the best of

our knowledge, no research identifies the capabilities made possible by blockchain in transport operations. These capabilities refer to the blockchain skills in the transport sector.

Knowing this, this article aims to understand the stage of scientific production regarding blockchain technology use in transport operations, as well as the identification of blockchain-enabled capabilities in transport operations. To achieve this objective, a systematic literature review (SLR) was carried out.

2.   THE IMPORTANCE OF BLOCKCHAIN IN THE TRANSPORT SECTOR

In the transport sector, the use of blockchain is quite expansive, since it is being used for many activities. For example, Wang et al. (2020) highlight that blockchain is of great importance for the safety of connected autonomous vehicles (CAVs). The author points out the increase in the number of CAVs, allows a greater occurrence of problems of large scales in the roads, as these vehicles can be invaded by hacker attacks, putting people's safety at risk.

Several authors point to the potential of using blockchain to make the transport sector safer (Tan, Zhao & Halliday, 2018; Li et al., 2020). This need arises from the fact that the traditional transport system has a centralized data structure, which brings great difficulties in privacy and security. A decentralized structure allows a greater data security since, in the centralized pattern, the attacker simply attacks the central node of the data network. (Wang & Zhang, 2020).

In this sense, the blockchain allows all data related to traffic and vehicles to be registered in a distributed ledger. This registration makes it impossible for any user to modify the data. If there is an invasion or attempted modification, the system will automatically block any action. Therefore, with more reliable and immutable data, it is possible to guarantee greater safety for road users (Li et al., 2020).

Currently, there are intelligent transportation systems (ITS), which are systems that integrate different technologies types (communication technologies, computational technologies, automatic control technologies, and artificial intelligence) (Baldini et al., 2018; Zhu et al., 2018). The combined use of blockchain with ITS enables greater efficiency for the management and control of the cities' transport system (Du et al., 2020).

In addition to the field related to traffic operations control, blockchain is being applied to enable greater communication security between vehicles (V2V). This is due to the blockchain's ability to allow greater security and privacy in the communication process between vehicles (Jabbar et al., 2020).

s730

3.   THE IMPORTANCE OF BLOCKCHAIN IN THE TRANSPORT SECTOR

The Systematic Literature Review (SLR) is widely used today. The Systematic Literature Review (SLR) is widely used today. This methodology covers a robust literature review process, allowing the researcher to achieve more reliable and in-depth results (Thomé, Scavarda & Scavarda, 2016). In general, Levy and Ellis (2006) point out that the SLR allows research questions to be answered based on an analysis of the current literature study topic, adopting an approach for evaluating and sintering the literature found.

In this paper, an SLR will be carried out based on the recommendations highlighted by Denyer and Tranfield (2009). These authors emphasize SLR can be defined in five main stages: development of the research question; location of studies; selection and evaluation of studies; analysis and synthesis of study results; and report of studies. The details of each of these five stages are presented below.

The first stage covers the process of defining the scope of the research, and the research question is determined to enable the beginning of the realization of the SLR. Therefore, the following research questions were asked:

- (Q1) - What is the panorama of work related to the application of blockchain technology in transport operations?
- (Q2) - What are the blockchain-enabled capabilities in transport operations?

The second stage of the SLR consists of locating the works related to the studied topic, to answer the defined research question. For that, following the guidelines of Denyer and Tranfield (2009), the Web of Science (WoS), Scopus, and Engineering Village databases were selected. These bases cover topics related to the areas of operations and transport management. Besides, the string was defined by consulting the keywords of works related to the topic of interest. Therefore, the following search string was defined: ("transport *" OR "road *" OR "highway *") AND ("blockchain" OR "block chain").

With the search in each of the databases, a total of 586 journal articles were found, written in English, of which 257 came from the Scopus database, 239 came from the Web of Science database and 90 came from the Engineering Village database.

The third step consists of evaluating the found articles considering the research question. To carry out the process of selecting and evaluating studies consistently, it was defined the inclusion and exclusion criteria (Denyer & Tranfield, 2009), as shown in Table1.

s731

It should be noted that articles in journals and in the English language have already been selected in the database itself, and there is no need to filter again.

Table 1: Inclusion and exclusion criteria

	Inclusion
I-1	The study addresses the application of blockchain in the transportation sector
	Exclusion
E - 1	The article is not a peer-reviewed journal article
E - 2	The article is not entirely written in the English language
E - 3	The article is from a journal without JCR
E - 4	An article without full text to be evaluated.
E - 5	Abstract or/and title points out the article is not related to the application of blockchain in the transport sector

Fonte: Authors (2020)

With the removal of duplicate articles, 308 papers remained. Subsequently, filtering was performed from reading the article's abstract (E-5) and identifying the journal JCR (E-3). With this filtering, a sample of 50 papers was reached. Given the number of articles, the analysis of the results was divided into two stages. The first covers the bibliometric analysis of these 50 papers, the second and third stages consist of a qualitative content analysis of the ten most relevant articles, according to the values from the Methodi Ordinatio (Pagani, Resende & Kovaleski, 2015).

The Methodi Ordinatio was proposed by Pagani, Resende, and Kovaleski (2015) and aims to calculate the degree of importance of articles (equation 1), which is represented by the InOrdinatio index. To calculate this InOrdinatio value, the following information is required: impact factor of the journal (If); the number of papers citations (Npc); the year of the present research (ypr); the year of publication of the evaluated paper (ypev). Besides, it must be considered the variable α, which represents the degree of importance given by the researcher to the year of publication. It values 10, according to recommendations by Pagani, Resende, and Kovaleski (2015).

$$InOrdinatio = \left(\frac{If}{100}\right) + \alpha * [10 - (ypr - ypev)] + Npc \qquad [1]$$

Based on the ten articles best classified according to the Methodi Ordinatio, a qualitative content analysis will be carried out, in an attempt to answer the research questions Q1 and Q2.

4.   RESULTS AND DISCUSSIONS

This section will present the SLR results. First, it is presented the bibliometric analysis of the 50 papers identified. Later, it is presented the content analysis of the 10 articles best evaluated by Methodi Ordinatio.

4.1.   Bibliometric analysis

Based on the inclusion and exclusion criteria presented in Chart 1, a sample of 50 articles from journals that were aligned with the research topic was identified. Thus, this sample of articles was considered for the bibliometric analysis.

The first analysis carried out was the analysis of the number of articles by journals. In total, the sample of 50 articles covered 22 different journals. The journals with the most articles were IEEE Access (12 articles), Sensors (9 articles), IEEE Internet of Things Journal (4 articles). 14 out of 22 journals presented only one article in the analyzed sample.
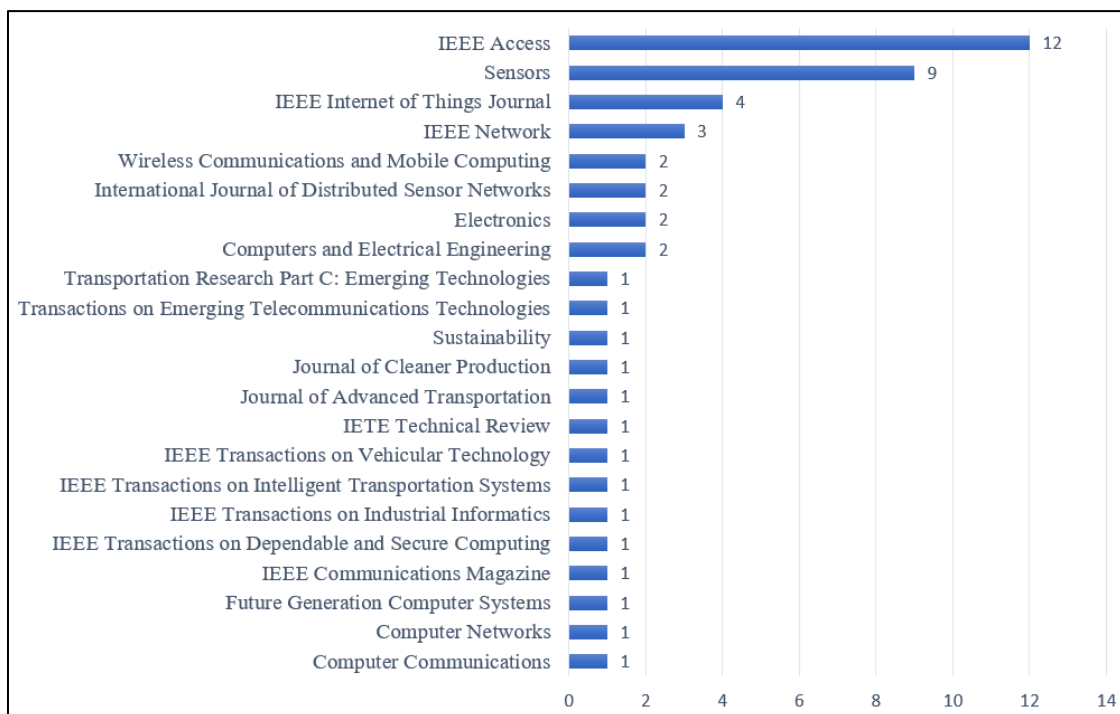

Figure 1: Number of articles per journal
Fonte: Authors (2020)

The first analysis carried out was the analysis of the number of articles by journals. In total, the sample of 50 articles covered 22 different journals. The journals with the most articles were IEEE Access (12 articles), Sensors (9 articles), IEEE Internet of Things Journal (4 articles). 14 out of 22 journals presented only one article in the analyzed sample.

The second analysis identified 209 different authors. Of this total number, only 12 were authors of more than one article. The author with the most published articles was Xiaohong

Zhang, with three published articles. Thus, it appears the production related to the application of blockchain in transport operations is quite diverse about the authors.

The third analysis identified the keywords of the papers. The keywords with the most occurrence are: "blockchain" (37 occurrences), "privacy" (7 occurrences), "security" (6 occurrences), internet of vehicles (5 occurrences). In total, there were 177 different keywords. Also, the Vosviewer 1.6.15 software (Figure 2) created a cloud of words.
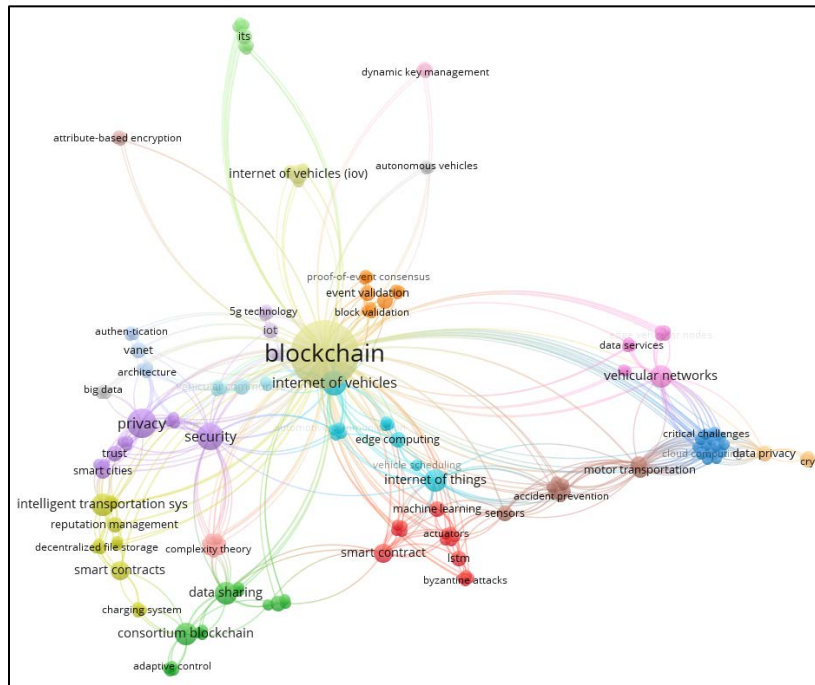

Figure 2: Keyword frequency cloud
Fonte: Authors (2020)

From Figure 2, the term "blockchain" is the central keyword, and the keywords "security", "privacy", "5g technology", "block validation", "IoT", and "internet of vehicles" are close to that central term. This means the studies on the blockchain are directly related to the concepts close to the central term.

The fourth analysis was about the number of publications by year. This type of analysis is extremely important, as it makes it possible to understand the evolution of the theme over time. In this sense, Figure 3 shows the distribution of publications by year.
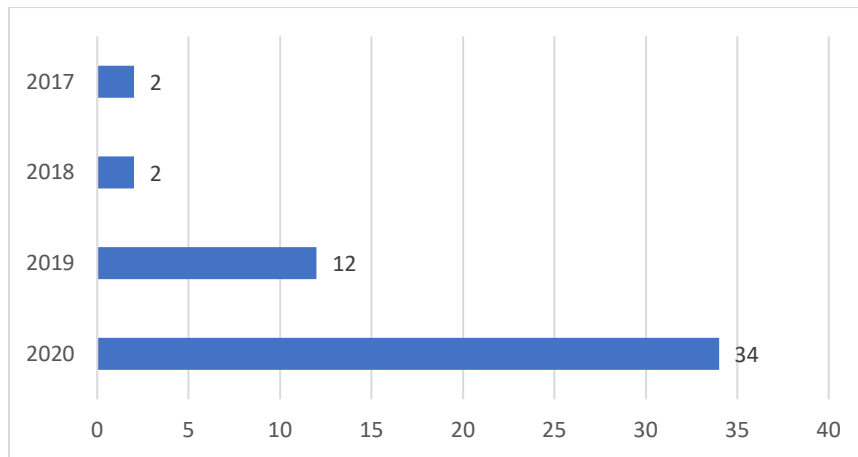
Figure 3: Number of articles per year
Fonte: Authors (2020)

From Figure 3, it can be seen that the first article was published in 2017, showing that publications on the use of blockchain in the context of transport operations are recent. Besides, in the year 2020, twice as many previously published articles were published, revealing that the topic is in evidence.

4.2.   Quantitative analysis

To carry out the quantitative analysis, the ten articles with the highest value for InOrdinatio were considered, so that these publications are considered those with the greatest academic importance according to the principles proposed by Pagani, Resende, and Kovaleski (2015). In this sense, Table 2 presents these 10 articles.

In the first position is the work of Dorri et al. (2019). These authors developed a blockchain-based system to ensure users' privacy and enable vehicle security. This system makes private the data that may put the user at risk, enabling greater security in the context of transportation.

In the second position is the work of Zhe Yang et al. (2019). These authors developed a system that makes it possible for vehicle network data to be managed in a more appropriate and decentralized manner. For that, blockchain technology was used, as this technology allows transactions and data storage to be reliable.

s735

Table 2: Overview of the analyzed sample

#	IO	Authors	keywords
1	450,01	Dorri et al. (2019)	-
2	376,01	Zhe Yang et al. (2019)	Blockchain; trust management; vehicular networks; data credibility.
3	335,01	Lei et al. (2017)	Dynamic key management; blockchain; handover; its.
4	254,01	Li et al. (2018)	Smart transportation; blockchain; vehicular communication; incentive mechanism; threshold authentication; privacy.
5	247,01	Kang et al. (2019)	Blockchain; reputation management; security and privacy; smart contracts; vehicular edge computing.
6	214,01	Jiang, Fang, and Wang (2019)	Blockchain; Internet of Things (IoT); Internet of Vehicles (IoV).
7	180,00	Singh and Kim (2018)	Blockchain technology; communication; intelligent vehicles; privacy; security; trust.
8	138,00	Zhang and Chen (2019)	Consortium blockchain; data sharing; data storage; signature verification; vehicular ad-hoc network.
9	127,00	Rathee et al. (2019)	Blockchain; connected vehicles; internet of vehicles; IoT; security; vehicular ad-hoc network.
10	125,00	Tsung Yang et al. (2019)	Blockchain; event validation; proof-of-event consensus; trust verification; vehicular ad-hoc networks.

Fonte: Authors (2020)

In the third position is the work of Lei et al. (2017). These authors developed a system to dynamically manage keys in ITS through the blockchain. These keys are used to identify each user in the transactions related to the blockchain.

In the fourth position is the work of Li et al. (2018). These authors developed a blockchain-based system called CreditCoin. This system allows user privacy when exchanging V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) messages.

In the fifth position is the work of Kang et al. (2019). These authors studied the application of consortium blockchain and smart contract technologies in the context of vehicular networks. These technologies were used to ensure the correct storage of data and the privacy of shared messages.

In the sixth position is the work of Jiang, Fang, and Wang (2019). These authors developed a blockchain-based system related to the Internet of Vehicles (IoV). The main focus of the blockchain application was the quest to guarantee the reliability of the stored data.

In the seventh position is the work of Singh and Kim (2020). These authors studied the potential of applying blockchain technology concerning smart vehicles. In this context, the use of blockchain technology allows vehicle communication to be performed reliably.

In the eighth is the work of Zhang and Chen (2019). These authors address the use of blockchain technology in the context of the security of the vehicular ad-hoc network. This system used the Consortium-type blockchain, which allows for greater savings in terms of financial aspects.

In the ninth position is the work of Rathee et al. (2019). These authors studied the benefits of using blockchain in the security of Connected and Autonomous Vehicles. The authors point out that the blockchain has great potential to enable the reliability and immutability of data from sensors of this type of vehicle.

In the tenth position is the work of Kang et al. (2019). The authors developed a blockchain-based application to ensure the validation of traffic-related events. This data is essential for users of transport routes to have a better understanding of what is happening on the highways.

With the analysis of the objective and characteristics of each of the ten selected publications, the next step is the presentation of blockchain-enabled capabilities in transport operations.

4.2.1. *Blockchain-enabled capabilities*

Seven blockchain-enabled capabilities were identified in the ten articles analyzed qualitatively. These capabilities represent skills that blockchain enables in the context of transportation operations. In this sense, Chart 3 presents these seven capabilities identified in the literature.

Table 3 shows that blockchain is used in the context of transport operations to enable data immutability, data privacy, decentralization of data control, key management, vehicular communication reliability, traffic data validation, and trust verification.

s737

Table 3: Blockchain-enabled capabilities

Capability	Description	Source
Data immutability	Ability to enable data relating to vehicular communication not to be modified	Dorri et al. (2019); Kang et al. (2019); Jiang, Fang and Wang (2019); Rathee et al. (2019); Zhang and Chen (2019); Zhe Yang et al. (2019)
Data privacy	Ability to make data available only to specific users.	Dorri et al. (2019); Kang et al. (2019); Lei et al. (2017); Li et al. (2018)
Decentralization of data control	Ability to allow data to be controlled in a decentralized manner, that is, without depending on a central trust broker.	Dorri et al. (2019); Jiang, Fang and Wang (2019); Li et al. (2018); Tsung Yang et al. (2019); Zhang and Chen (2019); Zhe Yang et al. (2019)
Key management	Ability to enable management of dynamic keys that are used to make sure that the blockchain registry is reliable.	Lei et al. (2017)
Vehicular communication Reliability	Ability to enable vehicle communication to be reliable in transmitting and receiving data.	Jiang, Fang, and Wang (2019); Singh and Kim (2018); Zhang and Chen (2019)
Traffic data validation	Ability to enable data passed on a given traffic-related event to be validated.	Tsung Yang et al. (2019)
Trust verification	Ability to enable vehicle systems to check the trust level of the node requesting a connection for data exchange.	Li et al. (2018); Kang et al. (2019); Tsung Yang et al. (2019); Zhe Yang et al. (2019)

Fonte: Authors (2020)

5. CONCLUSIONS

In the systematic review, it was possible to answer the two research questions initially proposed, identifying the panorama of works related to the theme and identifying the blockchain-enabled capabilities in the context of transport operations.

In general, the analysis of the results covered two stages. The first involved a quantitative analysis of a sample of 50 articles. it was possible to identify that the study area on the use of blockchain technology in transport operations is recent since the first selected publication was published in the year 2017. However, over the years there has been a strong growth trend in the number of publications. In 2020, twice as many researches were published about the sum of previously published papers.

The second stage of analysis included a quantitative analysis of the content involving the ten most relevant papers in the literature, according to the principles proposed by Pagani,

Resende, and Kovaleski (2015). From this, it was possible to understand in general about the research field and identify seven blockchain-enabled capabilities.

For future research in the context of transport operations, it is highlighted the need to validate the identified capabilities with experts, as well as to understand how these capabilities are applied in the practical context through empirical research. Besides, future research could verify whether there are more capabilities in the literature, considering a sample in addition to those ten identified by the Methodi Ordinatio.

6. ACKNOWLEDGMENT

REFERENCES

Al-Jaroodi, J., & Mohamed, N. (2019). Blockchain in industries: A survey. **IEEE Access**, 7, 36500-36515.

Arora, A., & Sharma, M, & Bhaskaran, S. (2019). Blockchain Technology Transforms E-Commerce for Enterprises. In: International Conference on Recent Developments in Science, Engineering and Technology, Singapore, **Proceedings…** Singapore, 2019, 26-34.

Balasubramaniam, A. et al. (2020). Blockchain For Intelligent Transport System. **IETE Technical Review**, 1-12.

Baldini, G. et al. (2018). Regulated applications for the road transportation infrastructure: The case study of the smart tachograph in the European Union. **International Journal of Critical Infrastructure Protection**, 21, 3-21.

Denyer, D, & Tranfield, D. (2009). Producing a Systematic Review. In: Buchanan, D, & Bryman, A. **The Sage Handbook of Organizational Research Methods**. Londres: Sage, 671–689.

Dorri, A. et al. (2017). BlockChain: a distributed solution to automotive security and privacy. **IEEE Communications Magazine**, 55(12), 119–125.

Du, X. et al. (2020). Blockchain-Based Intelligent Transportation: A Sustainable GCU Application System. **Journal of Advanced Transportation**, 2020.

Kang, J. et al. (2019). Blockchain for secure and efficient data sharing in vehicular edge computing and networks. **IEEE Internet of Things Journal**, 6(3), 4660–4670.

Jabbar, R. et al. (2020). Blockchain for the internet of vehicles: A decentralized IoT solution for vehicles communication using ethereum. **Sensors** (Switzerland)., 20(14), 1–27, jul.

Jiang, T., Fang, H., & Wang, H. (2019). Blockchain-based internet of vehicles: Distributed network architecture and performance analysis. IEEE Internet of Things Journal, 6(3), 4640–4649, jun.

Koh, L., Dolgui, A., & Sarkis, J. (2020). Blockchain in transport and logistics–paradigms and transitions. **International Journal of Production Research**, 58(7), 2054–2062.

s739

Lei, A. et al. (2017). Blockchain-Based Dynamic Key Management for Heterogeneous Intelligent Transportation Systems. **IEEE Internet of Things Journal**, 4(6), 1832–1843.

Levy, Y., & Ellis, T. J. (2006). A systems approach to conduct an effective literature review in support of information systems research. **Informing Science**, 9.

Li, L. et al. (2018). CreditCoin: A Privacy-Preserving Blockchain-Based Incentive Announcement Network for Communications of Smart Vehicles. **IEEE Transactions on Intelligent Transportation Systems**, 19(7), 2204–2220, jul.

Maesa, D. D. F., & Mori, P. (2020). Blockchain 3.0 applications survey. **Journal of Parallel and Distributed Computing**, 138, 99-114.

Nakamoto, S. (2008). **Bitcoin:** a peer-to-peer electronic cash system.

Pagani, R. N., Kovaleski, J. L., & Resende, L. M. (2015). Methodi Ordinatio: a proposed methodology to select and rank relevant scientific papers encompassing the impact factor, number of citation, and year of publication. **Scientometrics**, 105(3), 2109-2135.

Rathee, G. et al. (2019). A blockchain framework for securing connected and autonomous vehicles. **Sensors** (Switzerland)., 19(14).

Singh, M., & Kim, S. (2018). Branch based blockchain technology in intelligent vehicle. **Computer Networks**, 145, 219–231.

Tan, A. W. K., Zhao, Y. F., & Halliday, T. (2018). A blockchain model for less container load operations in China. **International Journal of Information Systems and Supply Chain Management**, 11(2), 39–53.

Thomé, A. M. T, Scavarda, L. F, & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. **Production Planning & Control**, 27(5), 408-420.

Tsung Yang, Y. et al. (2019). Blockchain-Based Traffic Event Validation and Trust Verification for VANETs. **IEEE Access**, 7, 30868–30877.

Wang, D., & Zhang, X. (2020). Secure data sharing and customized services for intelligent transportation based on a consortium blockchain. **IEEE Access**, 8, 56045–56059.

Wang, Y. et al. (2020). Challenges and solutions in autonomous driving: A blockchain approach. **IEEE Network**, 34(4), 218–226.

Zhang, X., & Chen, X. (2019). Data Security Sharing and Storage Based on a Consortium Blockchain in a Vehicular Ad-hoc Network. **IEEE Access**, 7, 58241–58254.

Zhe Yang. et al. (2019). Blockchain-based decentralized trust management in vehicular networks. **IEEE Internet of Things Journal**, 6(2), 1495–1505.

Zhu, Li. et al. (2018). Big data analytics in intelligent transportation systems: A survey. **IEEE Transactions on Intelligent Transportation Systems**, 20(1), 383-398.