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Blockchain in supply chain management in automotive industry: systematic literature review

Vuk Vuković
University of Novi Sad, Faculty of Economics in Subotica, Subotica, Serbia
https://orcid.org/0000-0002-0040-9936
Duc Tran Anh
Titus-Research GmbH, Wildau, Germany
https://orcid.org/0000-0001-5012-3736
Radenko Marić
University of Novi Sad, Faculty of Economics in Subotica, Subotica, Serbia
https://orcid.org/0000-0002-8870-8702
Abdalla Rashwan
Titus-Research, GmbH, Wildau, Germany
https://orcid.org/0000-0002-0330-8348
Sebastian Henningsen
Titus-Research, Wildau, Germany
https://orcid.org/0000-0001-5963-5834
Malgorzata Sliwa
University of Zielona Góra, Institute of Mechanical Engineering, Zielona Góra, Poland
https://orcid.org/0000-0001-6453-5758
Bogdan Ubiparipović
Atos Banka, Republic of Srpska, Bosnia and Hercegovina
https://orcid.org/0000-0002-2462-610X

Abstract
Background: Although Blockchain Technology (BT) is one of the innovations that has considerable potential to improve business processes and enable new services for potential users, its implementation in supply chain management (SCM) of the automotive industry is only at its beginnings. From the growing number of publications focused on this issue, it is evident that the application of BT would significantly contribute to the development of the automotive industry and improve the supply chain of automotive components.
Purpose: In this regard, the paper aims to analyze the challenges to the implementation of BT in SCM in the automotive industry sector through a systematic review of the literature and precise definition of the advantages and limitations that appear in supply chains after the application of BT.
Study design/methodology/approach: The research is based on the application of systematic literature review methods. The paper presents the results and conclusions of 21 studies based on the search criteria outlined by the Web of Science, Scopus, and SpringerLink index databases.
Findings/conclusions: The results suggest that insufficiently developed technology, lack of clear guidelines for implementation, incomplete standardization, legislative ambiguity, conflicts and insufficient cooperation between chain members appear as the biggest challenges for BT implementation. On the other hand, BT has great potential in reducing costs, providing higher quality products and services, and improving chain visibility in the automotive industry.
Limitations/future research: The analysis of the papers in the above mentioned databases exclusively in English and the absence of empirical research stand out as the most prominent shortcomings. However, the obtained results of this study represent a quality basis for future research, which, judging by the popularity of the issue, will increase in frequency.

Keywords
Blockchain Technology (BT), Supply Chain Management (SCM), automotive industry, systematic literature review, digitalization.

Introduction

In their 2021 study, Raj Kumar Reddy, Gunasekaran, Kalpana, Sreedharan, & Kumar provide a complete view of Blockchain Technology (BT), which they view as a distributed ledger technology (DLT) that stores transaction records in a tamper-proof manner. Shahbazi, & Byun (2021), Aich, Chakraborty, Sain, Lee, & Kim (2019), Anand, Seetharaman, & Maddulety (2022) and Dursun, Birinci, Alptekin, Sertkaya, Hasekioglu, Tunaboylu & Zaim follow this view (2022) and believe that BT is a solution that contributes to the incorporation of flexibility, transparency, and traceability in traditional supply chains.

In recent years, academic research (Xu, Tatge, Xu, & Liu, 2022; Patro, Ahmad, Yaqoob, Salah, & Jayaraman, 2021; Surjandy, Meyliana, H. L. H. Spits Warnars & E. Abdurachman, 2020; Alabi, & Telukdarie, 2021) offers the dominant view that supply chain participants should be more encouraged to implement BT in their business processes. The authors (Yuksel, Bolat, Bozkurt, & Yucekaya, 2021; Upadhyay, Ayodele, Kumar, & Garza-Reyes, 2020; Raj Kumur Reddy, Gunasekaran, Kalpana, Sreedharan, & Kumar, 2021) emphasize that the application of BT is still in its infancy, especially in complex sectors like the automotive industry. Xu et al. (2022) indicate that the automotive industry is particularly suitable for the implementation of BT-based applications. The authors' opinion is that such modern technology would simplify the procurement processes of automotive components, improve the chain flexibility and provide various additional services to existing and potential customers (Fernández-Caramés, Blanco-Novoa, Froiz-Míguez, Fraga-Lamas, 2019; Cichosz, 2018). A similar belief is shared by Chung (2021), who considers the implementation of modern information and communication technologies based on the Internet of Things (IoT) and BT to be crucial for increasing efficiency and effectiveness in logistics and transport systems. Erol, Ar, Ozdemir, Peker, Asgary, Medeni, & Medeni, T. (2020) state that the flexibility of blockchain platforms and their ability to adapt and respond to different user needs makes them suitable for application in agricultural supply chain management (SCM), and the food industry, pharmaceutical industry, energy industry, automotive industry, etc. However, despite BT being a buzzword today, its application in the automotive industry is limited, as evidenced by studies by Antônio Rufino Júnior, Sanseverino, Gallo, Koch, Schweiger, & Zanin (2022) and Surjandy, Meyliana, H. L. H. Spits Warnars & E. Abdurachman (2020). In this regard, it is necessary to instruct the supply chain participants in the automotive industry in detail about all the advantages and disadvantages that the application of this technology brings.

According to Meyliana, Fernando, Widjaja, Cassandra, & Tan (2021), the most important benefits from the application of BT in the automotive industry are reflected in the protection, accuracy, and security of data, integration of data into unique blockchain technology systems, timely exchange of information among chain participants, etc. Therefore, BT contributes to the reduction of risks that occur, particularly in the exploitation of data along the entire supply chain from the beginning of production to the production of the finished vehicle, as well as the production of spare parts for the vehicle itself. Zuksel et al. (2021) state that BT effectively solves practical problems, such as records of defective parts, contract expiration dates, recording information on the transfer of physical assets, creation of smart contracts, transparency of physical destruction of used spare parts, etc. Research results related to the German automotive industry (Xu et al., 2022) suggest a more efficient collection of product information, provision of information on transactions and establishment of a reliable supply chain, reduction of process costs, assurance of product and service quality, improved chain visibility as the most important benefits of BT implementation supply and digitalization of all production and service processes. Upadhyay et al. (2020) emphasize the benefits in the form of information exchange among chain participants with minimal risks of access to the sizeable amount of data generated along the entire chain and stronger connections between the flow of information and the flow of materials. Syed, Siddique, Nadeem, Alzahrani, Jan, & Khattak (2020) see the effective application of BT in the vehicle life cycle itself, such as the creation of databases in relation to change of ownership, registration, transfer, and rental of vehicles, insurance, service, repairs, etc.

On the other hand, Xu et al. (2022) cited the lack of guidelines and clear industry standards, non-cooperation of supply chain members, technological immaturity, and legislative ambiguity as the biggest obstacles to the adoption of BT in the automotive industry. Upadhyay et al. (2020) consider that one of the challenges for BT management is the limited knowledge of BT application opportunities that most supply chain managers in the automotive industry lack. Aich et al. (2019) highlight the lack of advanced technology, lack of trust in security among chain participants, lack of flexibility for sudden demand-side gaps, fraud, code violations, illegal behavior etc. as key barriers. According to Pustokhin & Pustokhin (2019), these also include administrative and legislative barriers between countries, unfit communication infrastructure, and different customs clearance and data entry methodologies.

Based on the search results of the main index databases (Web of Science, Scopus, and SpringerLink), BT is a topic that has been increasingly present in academic research in recent years. As a time frame suitable for research, we searched works for the period from 2010-2022 by keywords: Blockchain Technology (BT), Distributed Ledger Technology (DLT), and Supply Chain Management (SCM) in the automotive/car/vehicle industry. The results of the analysis suggest that the understanding of the BT implementation process in the automotive industry began in the second half of the previous decade. The interest of researchers is particularly emphasized between 2018 and 2022, as evidenced by the hits we got with keywords.

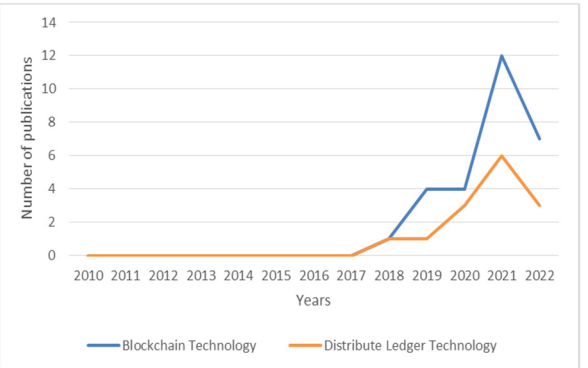

Figure 1 Number of publication – BT & DLT
Source: the authors' calculation

Only a decade after the first papers dealing with the issue of BT implementation as support for online payment were published (Nakamoto, 2008), there was an increase in academic interest in this area in the automotive industry. By detailed filtering of the search by keywords and by eliminating papers due to the irrelevance of the topic, duplication of papers, etc., this study reached 38 direct hits. An increasing trend was observed from 2018 to 2022. Two publications appeared in 2018, followed by a noticeable increase of five in 2019. In 2020 there were seven publications, and in 2021 there was an increase of over 15 publications. The year 2022 started with 10 publications. From the 38 hits obtained, this research study exclusively examines 21 papers selected for further discussion and analysis.

This paper aims to explore attitudes regarding the possibilities of implementing BT in SCM in the automotive industry and the advantages and limitations of such implementation through a systematic review of the literature. Based on the search in the index databases, we obtained a list of papers needed to define the research questions. Table 1 presents the research questions as well as the motivation.

Table 1 Research questions

No.	Research question	Motivation
RQ_1	What are the possibilities of BT implementation in SCM in the automotive industry?	The possibilities of implementing BT must be clearly defined, as well as the willingness of supply chain managers to implement BT.
RQ_2	What are the advantages and limitations to the SCM in the automotive industry after adopting BT?	All the advantages and limitations that appear in relation to the application of BT in the automotive industry must be clearly presented.

Source: the authors

The paper consists of six parts. After the introductory discussion of the research subject in the Introduction chapter, the second chapter, Methodology, describes the methodology used and the research procedure. The chapter subtitled "Conducting" the review lists the systematic review of literature, whereas the chapter "Findings" gives answers to research questions. Limitations are presented in the chapter "Threats to validity", and future research and practical implications of the work are presented in the chapter "Conclusion and future research". The last part of the work, "References", contains an overview of the literature used.

1. Methodology

With regard to the stated subject of the work and the research questions, a systematic review of the literature was chosen as the most appropriate research method. Xiao & Watson (2019) conducted a systematic literature review in eight steps grouped into three phases (Planning, Conducting, and Reporting).

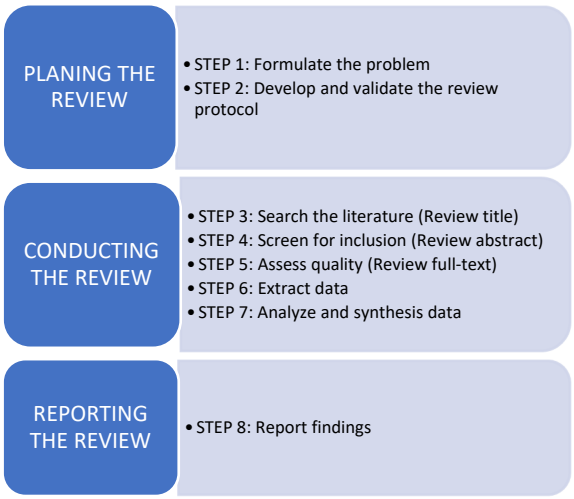

Figure 2 Process of systematic literature review.
Source: Xiao, & Watson, 2019, pp. 103

In the first phase of the research, the first two steps refer to the definition of the research subject and the development and definition of the literature review protocol. The second phase includes filtering, which begins with a review of the literature (exclusively the titles of publications), continues with a review of abstracts, and in the fifth step, a review and analysis of the entire texts. The phase ends with data extraction, analysis, and synthesis. The last stage is the reporting of the obtained findings.

Based on the protocol built by Upadhyay et al. (2020), Surjandy, Meyliana, H. L. H. Spits Warnars & E. Abdurachman (2020), and Xiao & Watson (2019), research questions were identified, and search strategy and review protocol were defined. All analyzed articles were retrieved from Web of Science, Scopus, and SpringerLink databases as the most comprehensive databases on a global level that provide the best academic information. The search process was performed using the keywords: Blockchain Technology (BT), Distributed Ledger Technology (DLT), Supply Chain Management (SCM), automotive industry, car industry, and vehicle industry. We have searched only high-quality peer-reviewed publications. In the first step, only keywords were searched individually by the database. In the second step, the titles and abstracts of the works that appeared in the hit list were reviewed. In the last step, the papers that have the potential to provide answers to the research questions were selected. This group also included those works for which the authors were unsure, based on the title, keywords, and abstract, that they were directly related to the problem of the study. The last step involved merging the works from the specified databases into a single list and then removing duplicates.

The above search methodology identified 38 papers, 21 of which were used for further in-depth analysis and the search for answers to research questions.

2. Conducting the review

The search for papers included three renowned citation databases: Web of Science, Scopus, and SpringerLink. The search was performed using keywords relevant to the research questions: Blockchain AND Supply chain management AND Automotive industry, Distributed Ledger Technology AND Supply Chain Management AND Automotive industry, Blockchain AND Supply chain management AND Car industry, Distributed Ledger Technology AND Supply Chain Management AND Car industry, Blockchain AND Supply chain management AND Vehicle industry, Distributed Ledger Technology AND Supply Chain Management AND Vehicle industry. The period covered by the search is from 2010 to June 2022. Table 2 shows the initial numbers of the papers found based on previously defined keywords.

Table 2 Number of papers based on keywords

Data base	Keywords	Number of hits
Web of science	Blockchain AND Supply chain management AND Automotive industry	19
	Distributed Ledger Technology AND Supply Chain Management AND Automotive industry	4
	Blockchain AND Supply chain management AND Car industry	4
	Distributed Ledger Technology AND Supply Chain Management AND Car industry	2
	Blockchain AND Supply chain management AND Vehicle industry	19
	Distributed Ledger Technology AND Supply Chain Management AND Vehicle industry	2

Scopus	Blockchain AND Supply chain management AND Automotive industry	15
	Distributed Ledger Technology AND Supply Chain Management AND Automotive industry	3
	Blockchain AND Supply chain management AND Car industry	3
	Distributed Ledger Technology AND Supply Chain Management AND Car industry	0
	Blockchain AND Supply chain management AND Vehicle industry	19
	Distributed Ledger Technology AND Supply Chain Management AND Vehicle industry	3
SpringerLink	Blockchain AND Supply chain management AND Automotive industry	19
	Distributed Ledger Technology AND Supply Chain Management AND Automotive industry	4
	Blockchain AND Supply chain management AND Car industry	4
	Distributed Ledger Technology AND Supply Chain Management AND Car industry	2
	Blockchain AND Supply chain management AND Vehicle industry	19
	Distributed Ledger Technology AND Supply Chain Management AND Vehicle industry	2

Source: the authors

Based on reading the title, abstract, and keywords, a total of 65 papers were selected to be the subject of further analysis since they fit in with the topic of the paper. There were 14 duplicates which were excluded from further analysis. The remaining 51 papers were read and 13 of them were discarded since they do not give answers to the research questions. Of the remaining 38 papers, 17 papers are general, that is, they include the application of Blockchain technology in SCM in various areas, while the remaining 21 papers are entirely in line with the research questions, that is, the application of Blockchain technology in SCM in the automotive industry. They are presented in Table 3. After applying exclusion and inclusion criteria 21 publications are left and are shown in Table 3.

Table 3 Papers that passed detail analysis

No	Year	Authors	Publication type	Aim(s)	Methodology	Theoretical framework
1	2020	Surjandy, Meyliana; Warnars & Abdurachman	Procceeding paper	To identify open problems in the SCM of the automotive industry where blockchain technology can help solve the problems	Systematic literature review	Not explicitly stated
2	2021	Meyliana, Fernando, Surjandy, Eka Widjaja, Cassandra, & Tan	Procceeding paper	To identify perspectives and trending topics in the application of blockchain in the automotive industry	Systematic literature review and Bibliometric analysis	Not explicitly stated
3	2021	Patro, Ahmad, Yaqoob, Salah, & Jayaraman	Journal article	To show how blockchain can effectively improve existing cars; product recall management process	Case study	Not explicitly stated
4	2021	Yuksel, Bolat, Bozkurt, & Yucekaya,	Procceeding paper	To point out the potential that blockchain technology has in providing a high degree of competitiveness, especially for automotive service providers	Case study	A distributed, blockchain-based spare parts disposal process.
5	2022	Xu, Tatge, Xu, & Liu	Journal article	To research the potential and existing challenges in the application of blockchain technology in German OEMs (original equipment manufacturers)	Collective case study and in-depth interviews	an overall framework for the impact of blockchain technology in the German automotive supply chain by evaluating supply chain management, quality control, information testing, and a comprehensive assessment of German OEMs

6	2020	Upadhyay, Ayodele, Kumar, & Garza-Reyes	Journal article	To explore the challenges and opportunities of blockchain technology from the perspective of the TOE framework (technological–organizational–environmental) for operational excellence in the UK automotive industry	Literature Review	technological and management challenges and opportunities of blockchain from the TOE framework angle for operational excellence
7	2019	Aich, Chakraborty, Sain, Lee, & Kim	Procceeding paper	To point out the differences between a conventional supply chain and a supply chain based on blockchain technology, as well as pointing out the benefits of implementing blockchain in various areas, including the automotive industry	Case study	Not explicitly stated
8	2020	Syed, Siddique, Nadeem, Alzahrani, Jan, & Khattak	Journal article	To design and develop a framework for monitoring the complete life cycle based on blockchain technology.	Exploratory Research	A blockchain-based framework for vehicle tracking
9	2022	Antônio Rufino Júnior, Sanseverino, Gallo, Koch, Schweiger, & Zanin	Journal article	To use the literature to justify the use of blockchain technology for battery tracking	Systematic Literature Review	Not explicitly stated
10	2021	Ada, N., Ethirajan, M., Kumar, A., K.E.K, V., Nadeem, S. P., Kazancoglu, Y., & Kandasamy	Journal article	To identify different problems in tracking different nodes in one supply chain of the automotive industry.	Case study	A framework for blockchain is developed for the automotive supply chain
11	2021	Kamble, Gunasekaran, Subramanian, Ghadge, B elhadi, & Venkatesh	Journal Paper	To identify the relationship between blockchain technology (BT) and sustainable supply chain performance (SSCP) Examining the direct influence of BT on supply chain integration (SCI) and SSCP; To analyze interactive effect of BT and SCI on SSCP	Survey	Blockchain technology adoption, supply chain integration, and sustainable supply chain performance
12	2017	Al-Saif, Wasim Ahmad, Salah, Yaqoob, Jayaraman, & Omar	Journal Paper	To identify the potential advantages of blockchain technology to manage energy trading operations between electric vehicles	Multiple Case study	Blockchain-based research projects and case studies to highlight the practicability of blockchain technology in electric vehicles' energy trading
13	2022	Jabbar, Dhib, Ben Said, Krichen, Fetais, Zaidan, & Barkaoui	Journal Paper	To provide a systematic review of Blockchain application to intelligent transportation systems and the Internet of Vehicles (IoV); to identify the different Blockchain applications in intelligent transport applications for IoV networks	Systematic literature review	Based on the available literature, a framework of the evolution of Blockchain, the Blockchain 1.0 phase and 2.0 phase, and the state of the art of Blockchain-based IoV solutions (BIoV)
14	2018	Kumar Sharma, Kumar, & Hyuk Park	Journal Paper	To identify a blockchain-based distributed framework for the automotive industry in the smart city; to identify a novel miner node selection algorithm for the blockchain-based distributed network architecture	Exploratory Research	Blockchain-based framework for the automotive industry in the smart city

15	2016	Debe, Hasan, Salah, Yaqoob, & Jayaraman	Journal Paper	Identifying a blockchain-based solution to enable energy trading using an auctioning and reputation scheme between EVs in a manner that is reliable, secure, and trustworthy; developing an Ethereum smart contracts which enable owners of EVs to automatically request electricity to charge their vehicles in a reliable, cost-effective, secure, and trustworthy manner; implementation of the deployed system on a test Ethereum blockchain platform	Qualitative Research	P2P energy trading schemes Energy trading between EPs and energy consumers (i.e., EVs)
16	2021	Raj Kumur Reddy, Gunasekaran, Kalpana, Sreedharan, & Kumar	Journal Paper	To analyze how to link supply chain visibility and information transparency with BCT for an efficient ASC in VUCA world Exploring the role of BCT in ASC; to analyze what kind of BCT is required to digitize ASC practices; to develop a BCT enabled framework for ASC in the VUCA world	Systematic literature review	Based on the available literature, a framework were automotive supply chain (ASC), blockchain technology (BCT), smart contracts, digitalizing the ASC, integrating BCT with digitized ASC, VUCA in the automotive industry
17	2021	Saibani, Ghania , Hassan Shamsul Akmara , Boon, Ravia, Nawawia & Mohd Asri	Journal Paper	To identify how the supply chain process can be improved with the aid of the latest technologies; to analyze the latest technologies in SCM and logistics; to analyze the latest technologies in SCM for achieving customer satisfaction	Reviewing existing literature	Supply Chain Management (SCM); latest technologies related to SCM
18	2020	Markov & Vitliemov	Proceedings Paper	To investigate the potential possibilities for implementation of Logistics 4.0 and Supply Chain 4.0 in the automotive industry plants in Bulgaria	Survey	Special feature of industry 4.0 Logistics 4.0 application model
19	2019	Miehle, Henze, Seitz, Luckow, & Bruegge	Proceedings Paper	To implement decentralized supply chain traceability mobile application called PartChain that enables the creation, monitoring, and sharing of a unique digital representation of a physical part across a supply chain network using blockchain technology (BT)	Event study	Distributed Ledger Technologies (DLTs) Smart Contracts Digital Twin
20	2021	Shahbazi & Byun	Journal Paper	To identify a real-time monitoring system based on the integration of IoT sensors, big data, and a hybrid prediction model Using the hybrid prediction model and the random forest model for classification to avoid the outlier dataset; To make the detection of the abnormal process more accurate through the steps of manufacturing; Real-time data extraction to improve the automotive industry prediction preservation	Quantitative Research	Brief review of the smart manufacturing and monitoring system literature in the automotive industry with four main topics: monitoring systems based on IoT technology, big data in manufacturing, machine learning in manufacturing, and Blockchain in manufacturing

21	2020	Hossain, Khaled, Ahamed Saju, Roy, Biswas & and Aminur Rahaman	Proceedings Paper	To propose a BC-based distributed ledger framework that is capable of maintaining a vehicle registration and information management system across platforms; To identify the required data fields to manage a vehicle registration and information management system To analyses the impact of BC-based distributed ledger in terms of managing vehicle registration	Exploratory Research	Based on the available literature, a framework were vehicle registration process, traditional paper based workflow and Blockchain impacts (BC)

Source: the authors

Figure 3 shows the works identified for analysis by year of publication. Since the search was done in June 2022, the result for 2022 does not represent complete information about the number of works published this year.

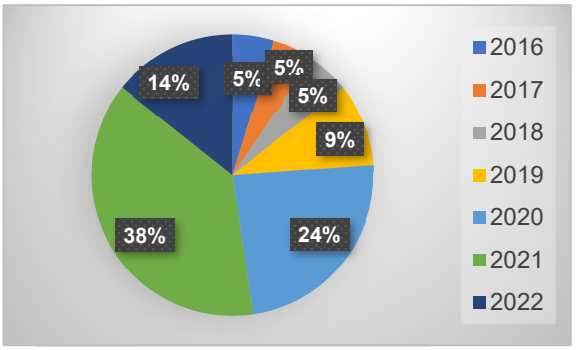

Figure 3 Number of papers per year of publication
Source: the authors

Case studies and Research articles are equally represented in the identified works for analysis at 33.33% each, Review articles at 9.52%, and Systematic literature review at 23.8%.

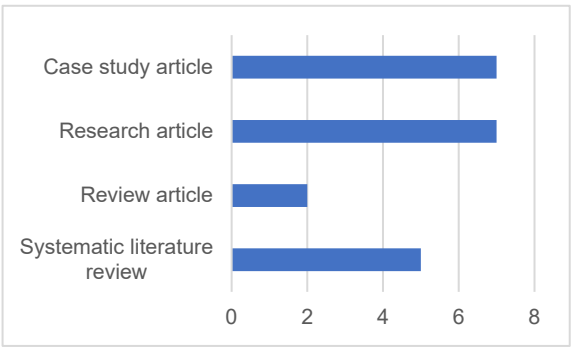

Figure 4 Distribution of paper types
Source: the authors

3. Findings

3.1. Implementation of BT in SCM in automotive industry

BT can contribute to minimizing counterfeit automotive components, monitoring and controlling logistics or distribution processes, improving the production process, improving product quality, and besides that, a more active relationship with suppliers (Surjandy, Meyliana; Warnars & Abdurachman, 2020). BT strongly influences data security, ensuring data accuracy and integrating data into the blockchain technology system for the process of information exchange between vehicles and autonomous vehicles. (Meyliana, Fernando, Surjandy, Eka Widjaja, Cassandra, & Tan, 2021). Patro, Ahmad, Yaqoob, Salah, & Jayaraman (2021) proposed a blockchain-based approach that enables a comprehensive car towing management process in a decentralized, secure, reliable, and transparent manner. It is developed, tested, and validated on the public Ethereum platform to meet the requirements of traceability, transparency, and safety of product recalls in the supply chain. They presented cost and security analyses that indicate that the proposed solution is cost-effective and sufficiently secure from cyber-attacks and is not vulnerable. Also, they compared their option with a solution that is not based on blockchain technology to show the innovation of their solution. Yuksel, Bolat, Bozkurt, and Yucekaya (2021) proposed a distributed, blockchain-based spare parts disposal process. In this way, the process is digitized and made much more secure by using intelligent contracts created with the Hyperledger Fabric infrastructure. The proposed methodology will enable more efficient monitoring of the supply process by allowing access to the system to obtain approval from partners while monitoring all transactions and parts. During the entire process, financial losses resulting from various errors in

documents as well as possible physical failures are going to be minimized.

Syed, Siddique, Nadeem, Alzahrani, Jan, & Khattak (2020) designed and developed a BT-based vehicle life cycle monitoring framework. It integrates several components related to the vehicle life cycle monitoring, starting from ordering new vehicles to the write-off (discarding) of vehicles. In addition, the solution includes features for buying and selling used vehicles, value/price estimation related to used vehicles, integration with transport authorities, maintenance of takaful insurance, verification of traffic documents, etc. Core features of the presented solution include efficiency, scalability, transparency, and modularity, and all of the above mentioned can be implemented in any country.

BT can be used for data storage which enables the execution of metric calculations to estimate greenhouse gas emissions and better management of batteries that are nearing the end of their working life. That can ensure that batteries are recycled in appropriate processes and with adequate efficiency. BT also enables the tracking of all battery materials and components in such a way that it is possible to have information on the origin of inputs, extraction of raw materials, battery production, testing and certification, first use, second use, and recycling so that all participants can make decisions based on this information. Features such as transparency, immutability, security, authenticity, and auditability justify the use of this technology to eliminate any opportunistic behavior of parties in the battery market (Antônio Rufino Júnior, Sanseverino, Gallo, Koch, Schweiger, & Zanin, 2022).

A study by Kamble et al. (2021) shows that in the automotive industry the implementation of BT in SCI improves sustainable supply chain performance (SSCP). The study supports the fact that most industrial managers are ready to invest in this technology. BT in the automotive sector can strengthen trust and cooperation between all business partners, including customers and vehicles.

Jabbar et al. (2022) confirm the necessity of BT integration in transportation systems in the automotive industry. The authors believe that blockchain implementation is necessary for the system of creating transport applications, a safe payment system, a security system, database management (big data), and energy optimization, and for the development of a transparent network of communication and information exchange between the participants of the automatic supply chain (ASC).

Kumar Sharma, Kumar, & Hyuk Park (2018) propose a distributed framework model for BT implementation in the automotive industry. This model is based on the implementation of BT in a way that interconnects the seven stages of SC, which include legislative regulation and standards, manufacturers, sellers (dealers), leasing companies, buyers (users), and the methodology of disposal of used products.

The implementation of BT in ASC is a crucial task in the modern era of digitalization. According to Kumar et al. (2021), the need to apply BT arises from the shortcomings of the traditional databases on which the functioning of ASC is based. The authors propose the adoption of IoT-based BT, which provides additional benefits such as accurate real-time information acquisition, more efficient information transfer, removal of unnecessary mediation, reliable environment, faster and more secure transactions with multi-tier suppliers, and management of critical data throughout the entire life cycle of products.

Saibania et al. (2021) suggest that SCs with integrated BT contribute to greater product transparency at all stages of the supply chain. The full implementation of BT in all IoT-based supply chain activities facilitates the planning, control, and coordination of supply chain processes. Technological advances in SCM in automotive industry and logistics include the application of machine learning (ML), autonomous vehicles/drones, advanced analytics, cloud logistics, super grid logistics, anticipatory logistics, omnichannel logistics, and additive manufacturing.

Miehle et al. (2019) advocate implementing a specific mobile application for the traceability of a decentralized supply chain in the automotive industry called PartChain. The implemented PartChain application would enable the creation, monitoring, and sharing of unique digital content of information about all products, services, processes, and activities among ASC participants by using blockchain technology (BT).

In their paper, Shahbazi & Byun (2021) conclude that the application of IoT-based BT in SCM improves the performance of the business process monitoring system in the manufacturing environment, removes errors during the production process, and similarly, prevents problems in the assembly line and final product delivery. Using IoT sensors embedded in product components, a large

amount of sensor data is collected in real-time. Owing to this technique, handling data sets and extracting appropriate information for SCM needs becomes easier and more accessible.

3.2. Advantages and disadvantages of BT in Automotive SCM

Xu, Tatge, Xu, and Liu (2022) suggest that the application of blockchain technology brings an advantage in aggregating product information, ensures the security of transaction information, and establishes a reliable supply chain. The biggest obstacles to the implementation of blockchain technology in the automotive supply chain are the immaturity of the technology, lack of guidelines and industry standards, non-cooperation of chain members, and legislative ambiguity. Based on research, BT has great potential with car manufacturers in reducing process costs, ensuring product quality and improving visibility, and digitizing the supply chain in the automotive industry.

Upadhyay, Ayodele, Kumar, and Garza-Reyes (2020) identified that blockchain as a distributed ledger technology could improve the automotive industry by eliminating many of the shortcomings of the traditional supply chain. BT would enable sustainable supply chain management, a circular economy, improved efficiency, reduced paperwork and costs, the need for man-hours, and increase customer satisfaction (e.g., customer order management). Furthermore, it would indicate the traceability of orders and increase visibility for various participants in the supply chain.

Infrastructure and expertise, technology or innovation support, technological resources and infrastructure, and innovation capacity are important organizational aspects for implementing BT. For this reason, the lack of an advanced level of technical expertise in BT, knowledge sharing, and the ability to manage the supply chain as well as the new business model enabled by BT may affect the adoption of blockchain in companies. The use of an IoT-integrated blockchain system that uses smart IoT sensors and various smart devices that can track the location of parts, quantity, and other useful information in real-time is an improvement of the system that provides numerous benefits for the manufacturing company such as planned production schedule, improvement in material flow and information, as well as improvement in the goods tracking system. On the other hand, the benefits for the suppliers are the reduction in incorrect orders, storage costs, and the optimization of stock levels. The system can also track the location of the vehicle as well as other helpful information in real-time. Such an improvement in the system for the manufacturing company provides benefits such as just-in-time logistics, reduction of damaged vehicles, and improvement in inventory control. At the same time, the benefit for the dealer and importer is the shortening of the lead time in build-to-order vehicles and the reduction of storage costs. (Aich, Chakraborty, Sain, Lee, & Kim, 2019)

The main advantages of adopting BT for battery tracking are to prevent batteries from being disposed of in inappropriate places, to ensure that they are used under the conditions prescribed by the manufacturer, and to define the battery owner. The results also indicate the ability of blockchain technology to track batteries and solve the issue of shifting responsibility in accidents and conflicts of interest that exist in the battery supply chain (Antônio Rufino Júnior, Sanseverino, Gallo, Koch, Schweiger, & Zanin, 2022).

Ada, Ethirajan, Kumar, Nadeem, Kazancoglu, & Kandasamy (2021) proposed a new blockchain architecture for the automotive supply chain. The results were obtained after optimizing the current supply chain with consideration of BT integration which enabled improved communication between partners resulting in improved inventory traceability leading to improved IQR and reduced average waiting time improving overall supply chain efficiency. It appears that the average daily costs of the entire supply chain can be reduced and the traceability of waiting times and inventory can be improved with the help of hyper ledger-based blockchain. A supply chain with applied BT is more capable of eliminating the risks and uncertainties that characterize the automotive supply chain. All of the above represents the benefits of adopting blockchain technology in the automotive supply chain.

Kamble et al. (2021) conclude that BT has a direct positive effect on three dimensions of SCM. 1) Improves external (suppliers and customers) competencies and internal integration, 2) reduces the role of intermediaries in SC networks, making the supply chain safer and more reliable, and 3) enables building SCM of the automotive industry based on trust and partnership.

Al-Saif et al. (2017) cite the lack of standards, the absence of effective guidelines, legal and regulatory frameworks, and the lack of understanding about blockchain technology as the

biggest challenges to the implementation of BT in the automotive industry. The development of high-performance quantum computers that pose a serious threat to the information security of blockchain-based energy trading systems is also some of the shortcomings of this technology. The immutability of blockchain in the electric vehicle energy trading business and ensuring the privacy of data and information that is open and available to everyone is also a disadvantage.

According to Debe, Hasan, Salah, Yaqoob, & Jayaraman (2016), the main benefits of introducing blockchain in the automotive industry relate to more efficient trading and savings in electricity intended for charging electric vehicles (EVs). The application of BT enables the efficient management of energy trade between energy suppliers and energy consumers which can meet the high demand for EV charging while reducing costs. Given that the current traditional systems, which are centralized, show deficiencies in providing transparency, reliability, auditability, security, and trust, the authors propose BT-based energy trading using auction and reputation schemes. They are developing Ethereum smart contracts that allow electric vehicle owners to automatically request electricity to charge their vehicles in a reliable, cost-effective, and secure way.

In addition to the obvious advantages of blockchain technology compared to traditional databases, Kumar et al. (2021) also warn about certain shortcomings of BT that all supply chain managers must bear in mind. These disadvantages relate, first of all, to the emergence of complications without a suitable business case and requirements, slow response time compared to traditional databases, inability to change information one time, data accumulation (creating silos in data), and challenges in managing public and private keys.

According to Saibania et al. (2021), application of modern technologies and BT in SCM improves inventory scanning and verification, tracking of goods and services, reduction of operating costs, more efficient supply of all chain participants, accuracy in delivery systems, and greater traceability of all items. Robotic machines can automate tasks in applications and systems through interaction with existing IT architectures and eliminate monotonous tasks performed by individuals. Based on this, BT in the automotive industry can provide control, connectivity, and visibility throughout the ASC and effectively link logistics operations among all ASC participants.

The results of the study by Markov & Vitliemov (2020) showed that production transparency achieved based on BT has the greatest value for SCM, while cyber security and data corruption are the main challenges. At the same time, ASC managers see autonomous vehicles as a technology that could provide the best results in reducing delivery delays in logistics processes in automotive plants. On the other hand, the main challenges facing autonomous vehicles are higher implementation costs and safety regulations.

Hossain et al. (2020) cite safer and faster vehicle registration as one of the main advantages BT brings to the automotive sector. Based on BT, the construction of a more efficient system for intelligent and secure information management through a distributed ledger is achieved, which solves the problem of the shortcomings of the traditional paper-based registration system.

4. Threats to validity

There are certain shortcomings in the conducted research that may negatively affect the results, although the research was done according to the systematic literature review protocol based on Xiao & Watson (2019). The first is the omission of some index databases of scientific papers, that is, limiting the search of papers to three index databases Web of Knowledge, Scopus, and SpringerLink. Although these are renowned databases, the quality of research would be raised to a higher level if at least two more index databases of scientific works were included. The second is the failure to conduct a backward and forward analysis of the papers, which reduced the number of studies analyzed in detail and the results presented in the Findings chapter. Also, the work would be complete if a case study was added to systematic review of the literature.

5. Conclusions and future research

Supply chain management in the automotive industry is increasingly moving towards complete digitalization through the implementation of BT. In recent years, a large number of papers have appeared in academic research that analyze the implementation possibilities, as well as all the advantages and disadvantages of BT application in SCM in the automotive industry. Based on a systematic review of the literature, which included a search of three index databases (Web of Science, Scopus, and SpringerLink) for the keywords BT,

DLT, SCM, automotive industry, car industry, and vehicle industry, a list of 21 papers were obtained for defining two research questions. What are the implementations of BT in SCM in the automotive industry? What are the benefits and limitations for the SCM in the automotive industry after adopting BT?

The conducted research found that the implementation of BT in ASC can make a significant contribution to protecting data security (Meyliana et. al., 2021), monitoring the complete vehicle life cycle (Syed et al., 2020), improving SSC performance (Kamble et al., 2021), more efficient transfer of information in real-time based on IoT (Kumar et al., 2021), integrating all phases of SC into a single whole (Kumar Sharma, et. al., 2018) and greater transparency of products through SC (Saibania et al. 2021). The most common benefits of applying BT in SCM in the automotive industry are the security of transactional information (Xu et al., 2022), improvement of efficiency and visibility of SC, reduction of paperwork, reduction of costs, and reduction of man-hours requirements (Upadhyay et al., 2020), more efficient planning of production schedule, the flow of materials and information and improvement of product tracking system (Aich et al., 2019), more efficient trading and achieving savings in electricity (Debe et al., 2016), and timely supply of all SC participants and accuracy in delivery systems (Saibania et al., 2021).

On the other hand, this research has shown that BT also has certain shortcomings. They are primarily reflected in the immaturity of the available technology, the lack of guidelines and industry standards (Xu et al., 2022), the lack of an advanced level of technical expertise in BT (Upadhyay et al., 2020), information security based on BT (Al-Saif et. al., 2017), data accumulation (Kumar et al., 2021), high costs of implementation and cyber security (Markov & Vitliemov, 2020), etc.

In this way, it is possible to conclude that despite certain shortcomings, practice and conducted research in real environment show that the implementation of BT in SCM in the automotive industry provides a comprehensive process of managing all products and services in ASC in a decentralized, safe, reliable and transparent way.

This paper was written as a systematic literature review of the application of BT in SCM in the automotive industry. Its results, which indicate the areas of application of this technology, advantages and disadvantages, represent an excellent starting point for future research. Our next research would be empirical and aimed at identifying a specific problem in the domain of SCM in an automotive company and finding a possible optimal solution that BT could offer.

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✉ **Correspondence**

Radenko Marić

University of Novi Sad, Faculty of Economics in Subotica, Subotica, Serbia
Segedinski put 9-11, 24000 Subotica, Serbia

E-mail: radenko.maric@ef.uns.ac.rs