Blockchain-Based CPS and IoT in the Automotive Supply Chain

Maha Filali Rotbi, Saad Motahhir, and Abdelaziz El Ghzizal

1 Introduction

The automotive industry is built traditionally as a hierarchical model with a vertical flow of information. This model has proven to be an age-old technique and doesn't comply with the modern-day needs of the consumer. Today's consumer needs customized vehicles, cost-effective models, and more efficient systems. All these lead to complexity in the hierarchical model [1]. Also, small batch sizes and faster manufacturing cycles are not economically viable. The suppliers too are following age-old practices and sometimes fail to deliver as per expectations. The vehicle recall process is of a huge difficulty in a hierarchical model and leads to huge losses and inconvenience to the end consumers. We must keep pivoting and add technological advancements to ensure that the automotive sector is well defined and highly efficient.

The automotive supply chain is one of the most complex manufacturing processes in the world [2]. Nowadays, it is oriented more toward customized products than massive production [1].

Technological development has been happening with the Internet of things (IoT), and it has led to a specialized system for industries called the industrial Internet of things (IIoT) [3]. All efforts have led to the design and develop a revolution in the sector calling it industry 4.0 [3]. With such efforts, all the objects are getting connected and sharing data which makes the system smarter and keeps the record of all the events.

M. Filali Rotbi (✉) · A. El Ghzizal
Innovative Technologies, EST, SMBA University, Fez, Morocco
e-mail: maha.filalirotbi@usmba.ac.ma; abdelaziz.elghzizal@usmba.ac.ma

S. Motahhir
ENSA, Sidi Mohamed Ben Abdellah University, Fez, Morocco
e-mail: saad.motahhir@usmba.ac.ma

Y. Maleh et al. (eds.), *Advances in Blockchain Technology for Cyber Physical Systems*, Internet of Things, https://doi.org/10.1007/978-3-030-93646-4_7

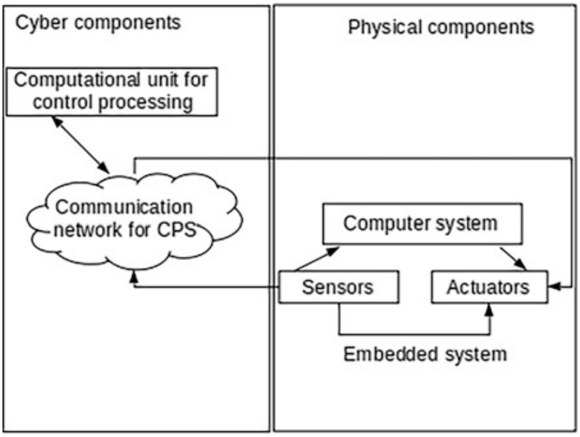

Fig. 1 Basic understanding of CPS

The connectivity is a part of a thought process called cyber-physical system (CPS), and when applied to production systems, it is termed as cyber-physical production systems (CPPS) [4]. Figure 1 showcases how physical components such as actuators and sensors can be connected through communication networks, thereby making it available for cyber-components to churn the data and take effective actions [5]. CPPSs are a core element of industry 4.0 that bring huge advantages and grass root-level changes in the day-to-day operations of the whole supply chain [6]. All the departments, including the supplier factories, need to undergo digitization to be effective for the CPPS. This leads to a new model where the hierarchical-vertical model is broken down to a decentralized-horizontal model [5]. Every single supplier becomes an implementation of CPS and shares data with the principal manufacturer. There are huge advantages of such implementation of IIoT and CPPS.

In the automotive manufacturing process, different puzzle pieces need to operate together efficiently and consistently. Connectedness, smart machines, decentralization, big data, and cybersecurity are core prerequisites for an automated and digitized SC [6].

The traditional automotive SC model is unable to meet the modern automotive manufacturing demands such as decentralization, systems connectedness, data analytics, and data traceability.

The use of CPPS and IIoT provides intelligent connectivity of the production system, high precision manufacturing, efficiency, and productivity gains [7]. However, with the increased connectivity, the large amount of data, and their sensitiveness, several challenges arise such as data integrity, immutability, and security.

In this paper, we discuss how blockchain technology, CPPS, and IIoT can be implemented together to simplify the information flow for the efficient automotive supply-chain management.

The decentralized systems in the supply chain become effective when we can make them aligned with blockchain. Blockchain is a peer-to-peer distributed network. It brings all the supply chain agents on the same platform and makes it a highly efficient decentralized-horizontal system. Modern-day demands of customization and small batch sizes can be implemented easily with no losses. With blockchain-based CPPS in the automotive sector, tracing and tracking become highly efficient, and issues can be solved well before handing out to the consumer, thereby no need for recalls. Even if needed, every part and supplier can be traced back to give faster service.

In [8], the authors present a trust model of healthcare-based Internet of things using blockchain technology, the paper presents a decentralized, interoperable trust architecture for healthcare IoHT that incorporates Blockchains. The implementation of blockchain in the IoHT (Healthcare-based Internet of Things) framework provides privacy, scalability, interoperability, availability, mutual authentication, trustworthy, and data integrity. In the context of healthcare, a study in [9] the authors propose a secure intrusion detection system for CPS in the healthcare sector using blockchain-based data transmission. The presented approach uses sensor devices to collect data and employs a deep belief network (DBN) model to detect intrusions.

An architecture design framework and a suitability application analysis flowchart for blockchain-based food traceability systems are proposed in [10], where the authors identify blockchain-based solutions for food traceability concerns and highlight the benefits and challenges of implementing blockchain-based traceability systems.

In [11], the authors propose a decentralized data management solution for secure transportation systems in smart cities using a private blockchain with Hyperledger fabric which outlines a new method for developing and deploying a decentralized platform that integrates IoT and blockchain technology for a safe, transparent, and reliable transportation system. In the context of quantum computing [12], the authors present a protocol of a blockchain framework for secure data exchanging between IoT nodes. This protocol is based on quantum-inspired quantum walks and is executable on digital computers. This paper proposes implementing quantum hash instead of regular cryptographic hashes to ensure confidentiality and integrity for IoT devices.

Blockchain technology could transform supply-chain management in many ways such as increasing product security, limiting parts counterfeiting, improving quality management, reducing the need for middlemen, and lowering the cost of supply chain transactions [13].

Blockchain turns out to be the best viable option for industry 4.0, which has CPPS as its core production technique. All these efforts make the industry smart by taking care of everything, including ways to control waste, and have the least impact on nature. Blockchain eliminates the need for intermediaries and third parties, which is a key feature of this architecture. It allows customers to track information about their products directly through the network in confidential and secured ways using cryptographic signatures.

In this work, we explored the existing literature. We analyzed the application of blockchain technology in different sectors and then discussed its implementation in the automotive supply chain. This work aims to highlight the opportunities cyber-physical production systems and industrial IoT brings to automotive supply-chain management. A blockchain-based CPPS and IIoT model is suggested to enhance the SCM efficiency. An implementation of this model in a car manufacturing factory is presented with a focus on its advantages and limitations.

Throughout the chapter, we will unravel the blockchain system, understand the CPS and CPPS with industry 4.0, discuss CPPS in automotive supply chain and its challenges, and also present how blockchain makes the whole automotive industry smarter and more efficient.

2 Revisiting the Background of Blockchain

Peer-to-Peer Distributed Networks

A system's architecture determines how the system's components are related to one another. The three main types of software systems' architectures are centralized, distributed, and decentralized. In this subsection, we will explain the difference between the architectures mentioned above and highlight the relationship between blockchain and decentralized systems. As represented in [14], Fig. 2 shows three different types of networks: Centralized, Decentralized, and Distributed.

Centralized systems are conventional systems where nodes are connected to a single central component that stores data and controls all the operations on the system. In this type of system, the failure of the authority unit causes the deficiency of the whole system.

Decentralized systems are systems where there is no central owner but instead there are several central components. Each of them has a copy of the resources that other nodes can access. In a decentralized system, the failure of one or more central nodes doesn't crash the whole system as long as at least one central owner is still running.

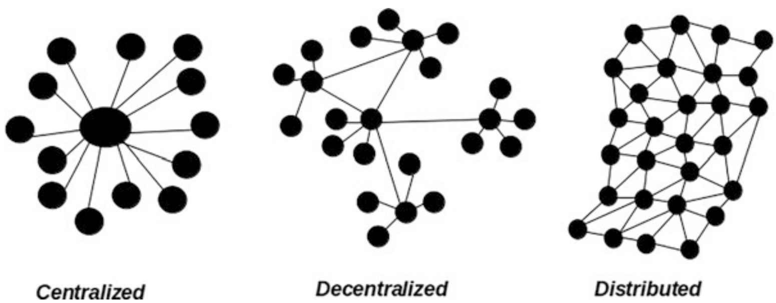

Fig. 2 Centralized, decentralized, and distributed systems

Distributed systems are systems with no central authority, and nodes are interconnected without any central control. Distributed networks eliminate centralization in a way that all nodes have equal access to resources.

Peer-to-peer distributed systems are systems where nodes make their computational resources such as processing power and storage capacity available to one another. Blockchain is a part of the implementation layer of a distributed software system that offers and maintains integrity.

Blockchain Technology

What's Blockchain?

Blockchain technology was first introduced in the context of cryptocurrency. A blockchain can be viewed as a chain of data blocks, and each block contains a number of information related to what we call transactions. Every block is linked to the previous one by means of a pointer, which makes it difficult to alter the data saved into the blocks. Blockchain is a peer-to-peer distributed ledger, and each node of the distributed network holds the final version of the ledger. The ledger is append-only, cryptographically secure and updated only after reaching a consensus among nodes.

Figure 3 represents how blockchain blocks are linked and the information stored in each block.

Generations of Blockchain

In this subsection, we will go over the main tiers of blockchain that were detailed in [15]: Blockchain 1.0, Blockchain 2.0, and Blockchain 3.0:

- Stage 1/Blockchain 1.0: this is exclusively about digital currencies (i.e., bitcoin, Litecoin, Dogecoin, etc.).

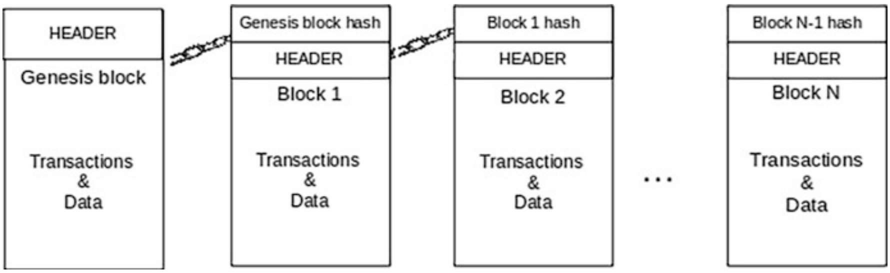

Fig. 3 Blockchain structure

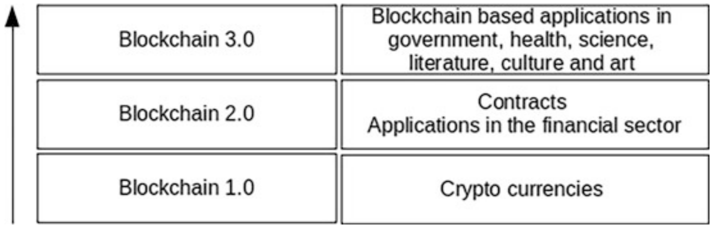

Fig. 4 Generations of blockchain

The purpose of the creation of blockchain was to manage monetary transactions between participants without requiring a third party and using cryptography to make the operation both secure and transparent.

- Stage 2/Blockchain 2.0: in this stage, the technology of blockchain took a further step, and the concepts of contracts and smart contracts were introduced. Financial services go beyond cash transactions such as derivatives, bonds, loans, etc.
- Stage 3/Blockchain 3.0: this refers to blockchain-based applications that goes beyond the financial services industry such as government services, health applications, culture, and art.

Figure 4 shows the different tiers of blockchain.

3 Model Advances in the Automotive Supply Chain

Industry 4.0

Industry 4.0 can be defined as the fourth industrial revolution. It changed the entire value chain of the life cycle of products.

Industry 4.0 is oriented toward the digitization of the manufacturing process. Its concept includes Internet of things (IoT), industrial Internet, cloud-based manufacturing, and smart manufacturing [16].

The industry 4.0 model supports the interconnection of physical components such as sensors and enterprise resources, along with the Internet [17].

The use of IoT applications has been shown to increase manufacturing productivity by 10 to 25%.

Figure 5 illustrates the technologies that revolutionized the industrial sector.

The fourth industrial revolution is considered to be a digital revolution of manufacturing industries. The purpose of industry 4.0 is to create an open, transparent, and smart manufacturing process by improving machines' performance and optimizing their maintenance. It aims to fulfill individual customer needs.

Figure 6 shows the global industry 4.0 market share.

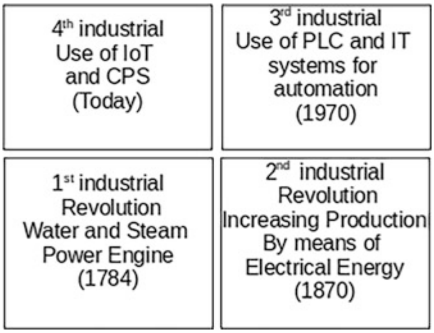

Fig. 5 Industrial revolutions [16]

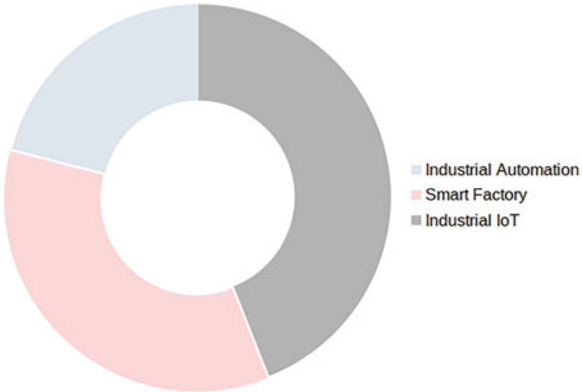

Fig. 6 Global industry 4.0 market share. (Source: Fortune Business Insights, Research report on "Global Industry 4.0 Market")

Industry 4.0 promotes the use of available information and communication networks by CPPS to automate information exchange.

It benefits from technological advances in IoT and industrial IoT to optimize production flow and automate the manufacturing process.

As shown in Fig. 7, a study expects the global industry 4.0 market to exhibit a significant growth of 16.4% in the 2021–2028 period [18].

Industry 4.0 is considered a digital revolution of the industry sector that resulted in many benefits (Fig. 8):

- Increased productivity and resources efficiency
- Real-time data for supply chains and real-time monitoring enabled by the IoT
- Advanced maintenance
- Fully automated and optimized processes
- Customized products and customer integration
- Better working conditions

The industrial Internet does not only digitize horizontal and vertical value chains but also revolutionizes a company's product and service portfolio, with the ultimate goal of better meeting customer needs.

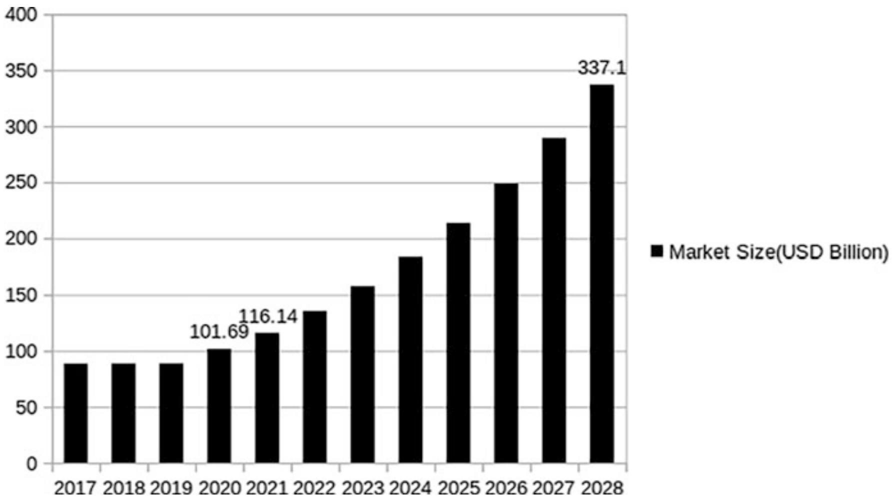

Fig. 7 Global industry 4.0 market size, 2017–2028. (Source: Fortune Business Insights, Research report on "Global Industry 4.0 Market")

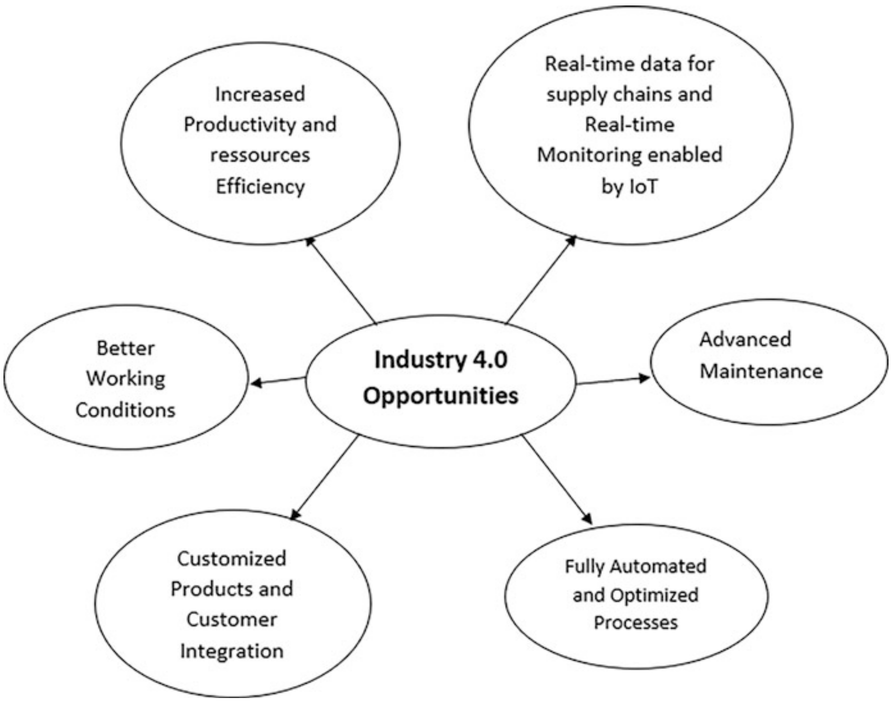

Fig. 8 Industry 4.0 opportunities

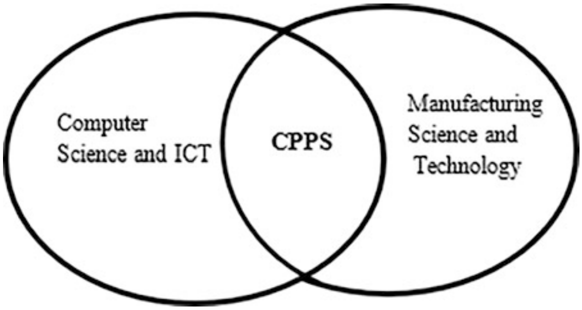

Fig. 9 Cyber-physical production systems

The industrial Internet's potential applications extend far beyond the optimization of manufacturing technology.

In the following subsection, we will focus on CPPS and IIoT and their impact on the automotive supply chain.

Cyber-physical Production Systems and Industrial IoT

Cyber-physical production systems depict the use of cyber-physical systems in a manufacturing environment. CPPSs are autonomous components and sub-systems that work in coordinated and situation-dependent ways in different phases of the production process.

As illustrated in Fig. 9, CPPS combines the technological advances in CS and ICT to provide smart systems and smart production that responds to industry 4.0 challenges.

CPPSs are interconnected and connected to the manufacturing environment. The main key elements of a CPPS are as follows:

- Self-aware: using the connected devices and sensors, CPPS measures and senses the environment where they operate.
- Self-predict: CPPS uses self-aware information to predict their issues.
- Self-evaluate: CPPS offers a synthesis of their performance to users and presents the context and background of the potential issues for diagnostics.

In the production automation domain, CPPS is used in different scenarios such as production networks, maintenance, and diagnosis.

Industrial IoT refers to a network of connected devices and objects that communicate through standard protocols in an industrial environment.

The main feature of IIoT is connectivity, and connected objects are considered smart objects that provide data related to the production process with a high precision that is a great advantage of this technology.

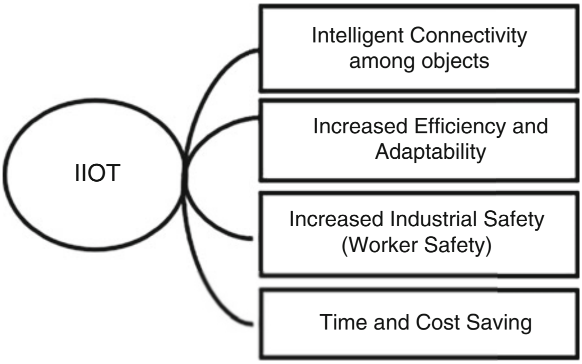

Fig. 10 Industrial Internet of things

The industrial IoT enables intelligent and automated industrial processes by facilitating machine-to-machine communication. It reduces the human interventions that lead to reducing human errors and increasing efficiency.

IIoT provides interaction with the manufacturing environment, real-time communication, and immediate response to changes which make the value chain intelligent and networked.

Research institutions and companies shifted their focus on IoT and CPS because of the flexibility and adaptability capabilities provided to the production system.

In Fig. 10, we resume the core benefits of IIoT.

Cyber-physical Production Systems in the Automotive Supply Chain

The automotive supply chain begins from basic products and components' manufacturing and is far before the automotive assembly line.

Different suppliers of various products play a crucial role in the automotive industry. For example, a small induction sensor used in the assembly line for the production of vehicles is supplied by another company and is a crucial part of the supply chain of that automotive industry [19].

CPPS gives a significant impetus to the automotive supply chain but needs operational advancements from all the participants of the supply chain (including the suppliers and their processes).

The traditional supply chain is a hierarchical vertical model and gives the least control over suppliers' products and transparency to their commitments. That leads to various issues in supply management and hampers production. With CPPS, we can overcome all these issues and provide a seamless experience for users' customization. CPPS gives customers an understanding of the real-time processes of their vehicle under production.

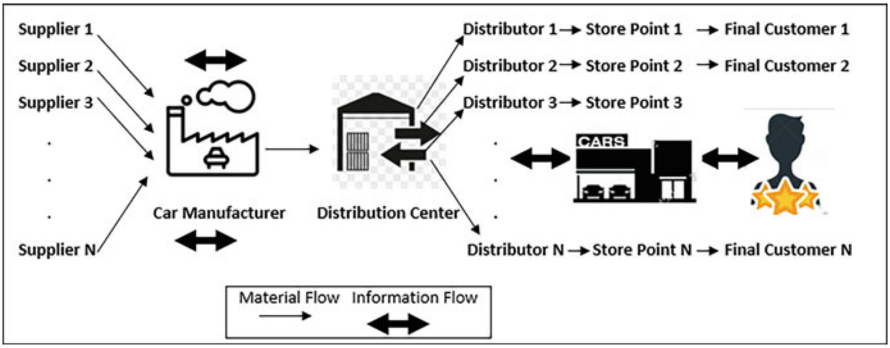

Fig. 11 Generic supply chain

As shown in Fig. 11, the generic supply chain has a simple material flow and information flow with a centralized controller and hierarchical system.

For a seamless CPPS in the automotive supply chain, there must be individual and independent CPS partnered together to fulfill the supply demands. They must create a dynamic, comprehensive, and changeable production system with a high degree of cross-linking [20].

Since it is a culmination of individual CPSs, the hierarchical-vertical supply chain model now becomes interlinked-horizontal decentralized supply chain. Such efforts lead to real-time data access at each stage making the whole automotive system intelligent and efficient. With real-time data in hand, the production hub can determine the workflow and easily monitor-predict the process outcomes and share with end users the status of the production of their vehicles. In situations of high demands, the CPS-based supplier can faster and easily share the data on the ways to fulfill the plans and make practical approaches guided by predictive analysis thanks to the CPS and vertical approach instead of a horizontal supply chain arrangement.

Figure 12 describes how IIoT plays a critical role in the implementation of CPS at each level and hence creating a better CPPS-based supply chain.

The above discussion leads to a concept of value chains which is CPPS-based automotive supply chain. The value chain will organize, optimize, and execute themselves ad hoc. The main enablers of this advancement are intelligent products and logistical objects that know and communicate their current status and location, know their target destinations within the value chain, and control the required production and logistics processes actively [21]. Thus, the digitized value network must be built at the field level. For example, in an industry 4.0 scenario, the purchasing department will be able to track inventories in the own company, as well as in the supply network in real time to keep production running and allow the customer to keep track of the status and degree of completion of his individualized product. The field of view of companies will change from the boundaries of their factories to the whole value network involving all processes and partners from the engineering, sourcing, and production up to final product delivery. For an efficient

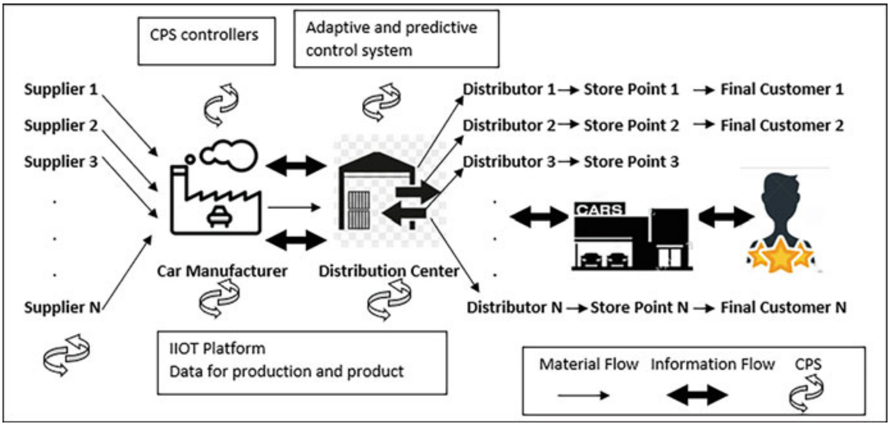

Fig. 12 CPPS-based supply chain

and dynamic exchange of information within an ad-hoc designed value chain, network standards and reference architectures are required [22]. Also, new methods and processes regarding the use of big data to identify customer needs, predictive maintenance for machines, the use of open-innovation principles, and collaborative engineering to produce products that meet the customer needs and new methods of how value chains are decentrally designed, organized, and controlled as well as costs and earnings are allocated within these dynamic value chains have to be developed [23, 24].

The new CPS establishments that will be partners in the CPPS-based value chain will require regulation and reconfiguration of material flow. The current supply chain with the centralized material flow is incapable of future requirement fulfillments of tailor-made products, smaller batch sizes, volatile procurement markets, and sales. This situation is due to centralized architectures that are rigid and unchangeable. The only way out is to have a decentralized control concept and architecture for automated flow systems. For this IIoT offers a great potential to solve weaknesses of centralized systems and create a digitized-decentralized-horizontal flow.

Challenges Facing CPPS and IIoT in the Automotive Supply Chain

Earlier in this chapter, we presented the opportunities brought to the manufacturing industry thanks to the technological advancements arising from industry 4.0.

In this subsection, we will list some challenges that are facing the successful adoption of these technologies (Fig. 13):

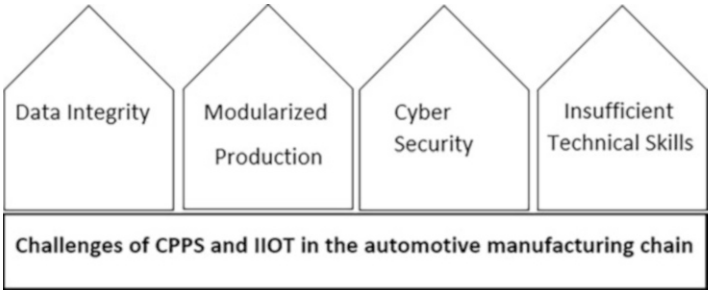

Fig. 13 Challenges of CPPS and IIoT in the automotive industry

- *Data integrity:* in the automotive supply chain, the number of operations is significant, so is the amount of data to be treated. Large amounts of data are collected, accumulated, and shared among different parts of the car manufacturing system.
  The sensitivity of the managed data makes its integrity a big challenge. It is important to ensure that the data recorded by car production systems are of high quality and integrity.
- *Modularized production:* car manufacturing is a complex process where different systems are used at different levels of the process. Equipment and sub-systems should work together and in a modularized and synchronized way to guarantee a distributed decision-making through all manufacturing phases.
- *Cybersecurity:* with the increased connectivity that the industrial Internet provides and the use of standard communications protocols that come with it, a potential need to protect systems and manufacturing data from cyberthreats has arisen. In the context of the automotive supply chain, present and emerging vulnerabilities related to the production systems are of major concern, and interoperability between digital systems expands the attack surface.
- *Insufficient technical qualification:* full automation of the automotive processes leads to a decrease in specific types of work but requires new skill sets. The understanding of the manufacturing processes and required digital tools is of high importance to the successful implementation of these new technologies. To keep up with the digital change, employees across all steps of the automotive value chain need to acquire new skills and qualifications.

4 Blockchain-Based CPS and IoT for the Automotive Supply Chain

As detailed in Sect. 2.2, blockchain is a digital distributed ledger that keeps record of financial transactions in the context of economy. With the third revolution of blockchain, its application is not limited to the financial sector anymore. Blockchain technology can be used in various domains and sectors such as government, health, art, and others.

Blockchain allows data to be shared among all nodes of the network. In this section, we will focus on the implementation of blockchain in industry 4.0 and mainly the automotive industry.

Blockchain-Based Automotive Supply Chain

Automotive manufacturing is one of the most complex sectors. Supply-chain management is critical to the success of the automotive industry. Thousands of parts from around the globe are used in this industry to deliver a high-quality final product. Globalization, changes in manufacturing processes, and customer demands are all factors that impact SCM [25].

The industrial Internet allows satisfying customers' requirements in terms of traceability of material, product, and operations data. Car manufacturers require information from their suppliers to monitor the complete life cycle of a product. With the automation level of CPPS, connectivity, and traceability offered by IIoT and transparency and security guaranteed by blockchain, we can achieve smart automotive factories.

The distributed architecture of blockchain solves the issue of a single point of failure. Participants or nodes are connected to the distributed network and have the same updated version of the ledger. With that being said, it is difficult to alter the data recorded in the blockchain.

Blockchain eliminates the need for intermediaries and third parties, which is a key feature of this architecture. It allows customers to track information about their products directly through the network in confidential and secured ways using cryptographic signatures.

In the following subsection, we present the difference between a traditional automotive supply chain and a blockchain-based supply chain.

Blockchain-Based Automotive Supply Chain

The traditional automotive supply chain model presents several gaps in terms of the relationship among intermediaries, traceability and transparency of operations, and customer ignorance of information about components and products [26].

A traditional automotive supply chain architecture comprises different actors. The main ones are suppliers, car manufacturers, distribution center, distributors, sell points, and final customers.

In a traditional automotive supply chain, information is centralized in each phase of the chain. Users cannot access information about products in different stages,

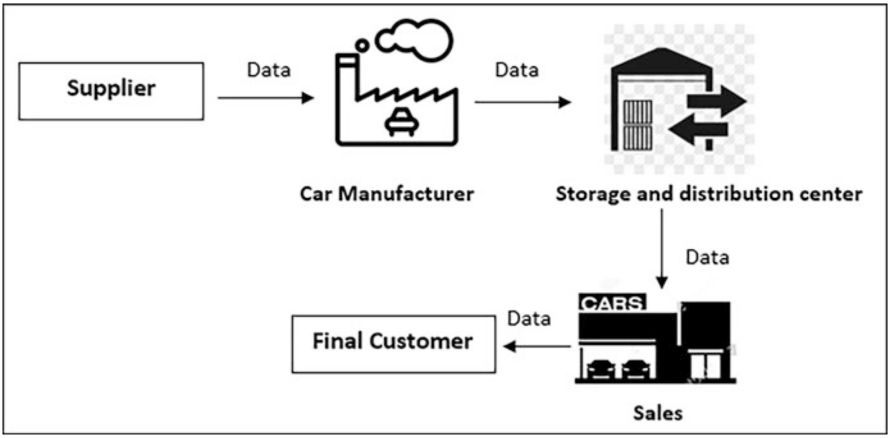

Fig. 14 Traditional supply chain

which makes it difficult to track the quality of the final product throughout the whole process.

Figure 14 presents a traditional supply chain model.

Blockchain technology reinforces supply chain reliability. It provides security, integrity of information, transparency, and traceability of operations results and data.

A blockchain-based system for SC (Fig. 15) has the following characteristics:

- *Consistency:* this ensures that all participants of the network have the same final version of data.
- *System availability:* this means that the system is functioning correctly and treating incoming requests properly at the right time.
- *Partition tolerance:* this guarantees that if a group of nodes is down due to a cyberattack or anything else, the system will still operate correctly.

Along with CPPS and IIoT, BCK (Blockchain)-based SC provides a high level of intelligence, security, transparency, and autonomy to the manufacturing process.

Blockchain Inside a Car Manufacturing Factory

The car manufacturing process is a complex process that requires hundreds of parts and a significant number of operations.

Car production is a sequence of operations and processes until the final product. Each operation comes with an impact on the car's quality. Some operations are more critical than others and require more precision.

Car manufacturing phases are (Fig. 16) as follows:

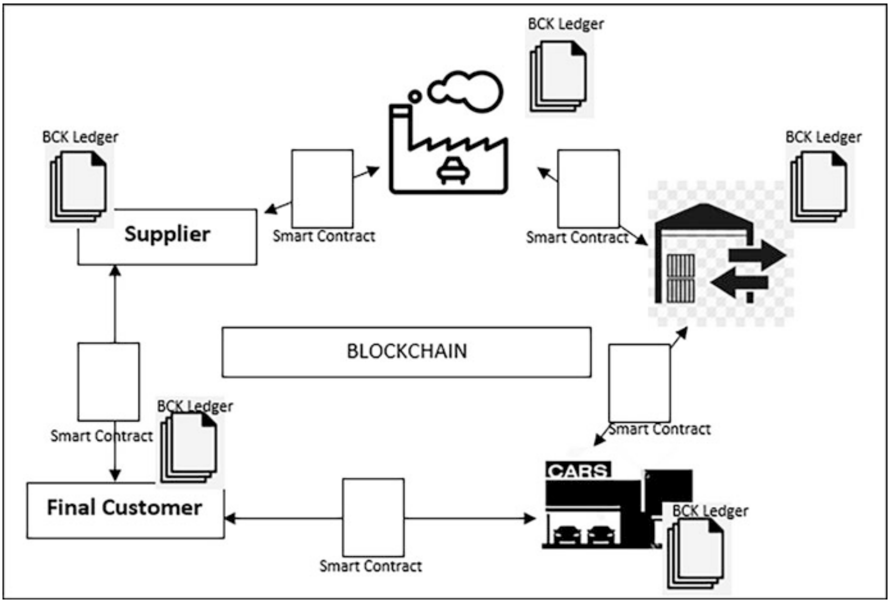

Fig. 15 Blockchain-based supply chain

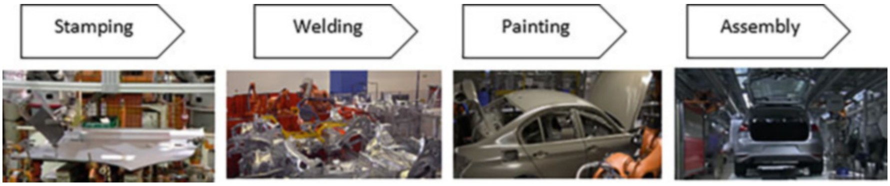

Fig. 16 Car manufacturing phases

1. *Stamping:* hoods, doors, and other body parts are made from sheet metal that has been cut and stamped.
2. *Welding:* robots weld body parts together to form the vehicle's exterior.
3. *Painting:* the welded body is washed and then painted.
4. *Assembly:* the engine, seats, tires, and all interior components of the car are attached to the painted body. Then comes the final inspection process. The output is a finished automobile.

Throughout the whole process, traceability of operation-related data is required, some operations more than others, but still, traceability of this information is essential.

Here comes the role of CPPS and IIoT that offer digitization of information. With intelligent tools and systems, we can get many data related to a given operation in the manufacturing process.

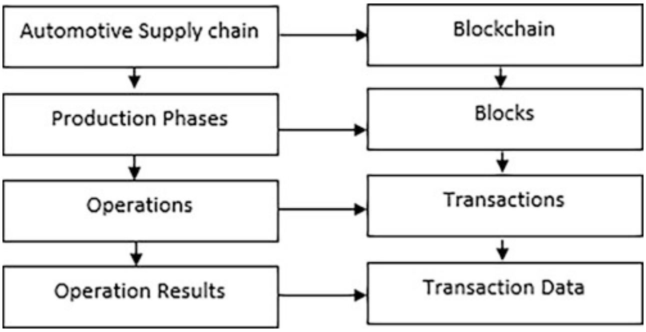

Fig. 17 Correspondence between the automotive supply chain and the blockchain

The recorded data give a history of operations results and operation status. In this way, we get to trace the final product throughout the whole manufacturing process.

The digitization of information and increased connectivity come with several challenges and threats, such as data integrity and security.

In the current supply chain model, not all data are recorded. Available data are only accessible inside the factory network to the authorized parties. To answer the above needs and make the data exchange and traceability transparent, we suggest blockchain technology.

Blockchain allows the record of data in a secure, confidential, and transparent way. Recorded data cannot be tampered or deleted.

From an architectural point of view, blockchain should be seen as a new layer in the data communication architecture as represented in Fig. 17.

Blockchain can be implemented to record operations data and allow customers to follow the production process of their products. It provides confidentiality and integrity of data.

In the context of the automotive supply chain, a private blockchain-oriented enterprise is needed to share data among participants securely, privately, and directly without the need for intermediaries.

In Fig. 18, we present an implementation for blockchain in the automotive manufacturing factory.

Blockchain Inside a Car Manufacturing Factory

- *Limiting part counterfeiting:* a vehicle has a significant number of individual parts that are either manufactured in-house or provided by a supplier. Part counterfeit is a critical problem in the automotive industry. Counterfeited components can find their way to the manufacturing line directly or indirectly. Counterfeit spare parts are untrustworthy because they frequently have degraded quality levels and often fail, causing dissatisfaction among end users and ultimately making customers lose their trust in the brand.

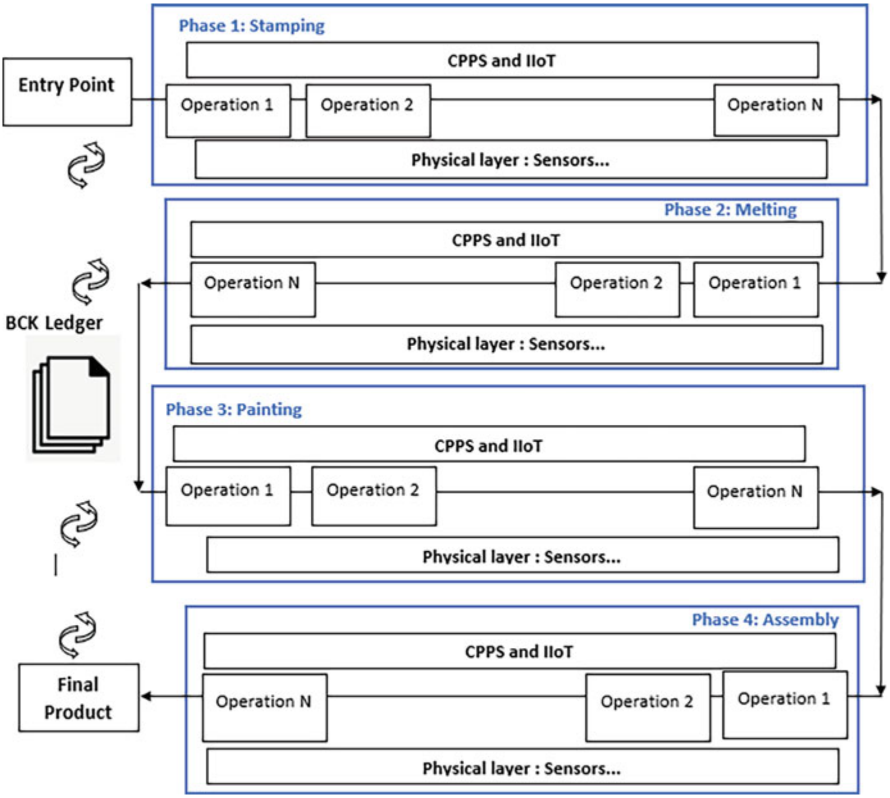

Fig. 18 Blockchain implementation in car manufacturing plant

In this context, blockchain allows to identify and represent parts digitally in a unique way, which makes the process more transparent.

- *Component tracking:* coordination among suppliers providing a significant number of components is not an easy task. Tracking components and parts is complex and prone to errors. In the traditional automotive supply chain model, participants like suppliers, distributors, and dealers do not have a common data-sharing model, which makes it difficult to exchange data related to products such as their location. Blockchain and IoT allow car manufacturers to track components everywhere, in real time and confidentially and securely.
- *Time saving and cost reduction:* in all manufacturing processes, time is money. Part tracking using blockchain prevents production disrupts.
- *Trust establishment:* as explained earlier in this chapter, blockchain offers a high level of transparency, data integrity, and consistency, which enables trust in the whole manufacturing process. The decentralized architecture eliminates the single point of failure issue and makes it complicated to alter data recorded in the blockchain.

Challenges and Limitations of Implementing Blockchain in the Automotive Supply Chain

Despite all the benefits discussed above, blockchain technology has a set of limitations that need to be taken into consideration before thinking about implementing it in the automotive supply chain, and these challenges are detailed in Table 1 as follows:

Table 1 Blockchain-based automotive supply chain challenges

Challenges of blockchain-based automotive supply chain	Explanation and examples
Transactional throughput	As the automotive supply chain is complex, the number of operations and data flow is significant. In the blockchain-based model, the number of operations represents the number of transactions to be done. Blockchain can process limited transactions per second which doesn't comply with real-life scenarios [27] For Ethereum blockchain the number of transactions 20 per second [28]
Latency	The transaction verification and approval process challenge the implementation of blockchain in many sectors [29] The average confirmation time of Ethereum transactions is 5 min [28]
Immutability	One of the core characteristics of blockchain is immutability; once an information is recorded to the blockchain, it is almost impossible to modify it or delete it
Physical limitations of the supply chain systems	The implementation of a blockchain-based model requires several changes in the existing supply chain architecture [30]
High cost of Blockchain implementation	Blockchain implementation requires a significant financial investment [13] The high cost is also due to the energy consumption. As the digital ledger needs to be updated in real time, substantial amounts of computing power are consumed [27, 29]
The gap of technical skills	The implementation and the use of blockchain technology which require a set of technical skills and also the lack of studies evaluating the application of blockchain in the supply-chain management [24] The lack of understanding of blockchain among corporate leaders, the belief that it is a fad, and the desire to wait for wider adoption before committing are all factors working against the technology's adoption [30]

- Transactional throughput: number of transactions
- Latency: time required to record data into the blockchain
- Immutability: data added to the blockchain are not erasable, which means that if any error occurs and somehow wrong information was recorded, it is very complicated to delete it from the blockchain.
- Physical limitations of the supply chain systems: blockchain operates with the IoT, IIoT, and connected systems.
- High cost of blockchain implementation
- The gap of technical skills

5 Conclusions

The process of car manufacturing is one of the most complicated production processes. Many participants such as suppliers, distributors, and dealers contribute to the automotive supply chain. With the increased need for customized products and process adaptability, the need for digitization is of crucial importance.

CPPS and IIoT are technologies that provide digitization of processes-related data and offer connectivity, efficiency, adaptability, and industrial safety. Nonetheless, the increased connectivity of objects and systems in the automotive supply chain expanded the attack surface for cyberattacks. Product tracking throughout the complete manufacturing process is a growing customer demand. Blockchain technology reinforces supply chain reliability. It provides security, integrity of information, transparency, and traceability of operations results and data.

Supply-chain management could be transformed by blockchain technology in a variety of ways, including boosting product security, minimizing counterfeit parts, improving quality management, decreasing the need for middlemen, and cutting the cost of supply chain transactions.

With the automation level of CPPS, connectivity, and traceability offered by IIoT and transparency and security guaranteed by blockchain, the manufacturing process can be intelligent, fully automated, and transparent.

In this chapter, we presented the benefits of industry 4.0 and also the benefits of implementing blockchain technology along with CPPS and IIoT in the automotive supply chain.

Blockchain's huge potential is reshaping the Internet and the entire planet.

The difficulty of blockchain's scalability, on the other hand, is the fundamental reason why this technology hasn't become mainstream yet.

References

1. E. Mavridou, D. Tzovaras, E. Beakiaris, G. Hassapis, M. Gemou, P. Spanidis, *Data Mining and Intelligent Agents for Supporting Mass Customization in the Automotive Industry* (InTech Europe Croatia and InTech, Shangai, 2011)
2. Top 4 Automotive Supply Chain Challenges and Solutions. Blume Global. [Online]. Available: https://www.blumeglobal.com/learning/automotive-supply-chain/. Accessed 04 July 2021
3. D. Serpanos, M. Wolf, Industrial Internet of Things, in *Internet-of-Things (IoT) Systems*, (Springer, Cham, 2017), pp. 37–54
4. H. Kagermann, J. Helbig, A. Hellinger, W. Wahlster, *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry ; Final Report of the Industrie 4.0 Working Group* (Forschungsunion, Berlin, 2013)
5. M. Broy, M.V. Cengarle, E. Geisberger, Cyber-physical systems: imminent challenges, in *Large-Scale Complex IT Systems. Development, Operation and Management Lecture Notes in Computer Science*, (2012), pp. 1–28
6. H. Meissner, J.C. Aurich, Implications of cyber-physical production systems on integrated process planning and scheduling. Proc. Manuf **28**, 167–173 (2019)
7. S. Wiesner, K.-D. Thoben, Cyber-physical product-service systems, in *Multi-Disciplinary Engineering for Cyber-Physical Production Systems*, (2017), pp. 63–88
8. E.M. Abou-Nassar, A.M. Iliyasu, P.M. El-Kafrawy, O.-Y. Song, A.K. Bashir, A.A.A. El-Latif, DITrust chain: Towards Blockchain-based trust models for sustainable healthcare IoT systems. IEEE Access **8**, 111223–111238 (2020)
9. G.N. Nguyen, N.H.L. Viet, M. Elhoseny, K. Shankar, B. Gupta, A.A.A. El-Latif, Secure blockchain enabled Cyber–physical systems in healthcare using deep belief network with ResNet model. J. Parallel Distrib. Comput **153**, 150–160 (2021)
10. H. Feng, X. Wang, Y. Duan, J. Zhang, X. Zhang, Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. J. Clean. Prod. **260**, 121031 (2020)
11. K. Abbas, L.A.A. Tawalbeh, A. Rafiq, A. Muthanna, I.A. Elgendy, A.A.A. El-Latif, Convergence of Blockchain and IoT for secure transportation systems in smart cities. Secur. Commun. Netw **2021**, 1–13 (2021)
12. A.A.A. El-Latif, B. Abd-El-Atty, I. Mehmood, K. Muhammad, S.E. Venegas-Andraca, J. Peng, Quantum-inspired blockchain-based cybersecurity: Securing smart edge utilities in IoT-based smart cities. Inf. Process. Manag. **58**(4), 102549 (2021)
13. R. Cole, M. Stevenson, J. Aitken, Blockchain technology: Implications for operations and supply chain management. Supply Chain Manag. Int. J **24**(4), 469–483 (2019)
14. P. Baran, *On Distributed Communications: I. Introduction to Distributed Communications Networks* (Ft. Belvoir Defense Technical Information Center AUG, Fort Belvoir, 1964)
15. M. Swan, *Blockchain: Blueprint for a New Economy* (OO'Reilly Media, Inc., Sebastopol, 2015)
16. S. Vaidya, P. Ambad, S. Bhosle, Industry 4.0 – A Glimpse. Proc. Manuf **20**, 233–238 (2018)
17. K. Sipsas, K. Alexopoulos, V. Xanthakis, G. Chryssolouris, Collaborative maintenance in flow-line manufacturing environments: An industry 4.0 approach. Proc. CIRP **55**, 236–241 (2016)
18. Industry 4.0 market size, share & COVID-19 impact analysis, by application (Industrial automation, smart factory, and industrial IoT), by vertical (manufacturing, energy & utilities, automotive, oil and gas, aerospace and defense, electronics and consumer goods, and others), and regional forecast, 2021–2028. Industry 4.0 market size, growth and analysis [2021–2028]. [Online]. Available: https://www.fortunebusinessinsights.com/industry-4-0-market-102375. Accessed: 22 June 2021
19. F. Almada-Lobo, The industry 4.0 revolution and the future of Manufacturing Execution Systems (MES). J. Innov. Manag **3**(4), 16–21 (2016)

20. D. Pantförder, F. Mayer, C. Diedrich, P. Göhner, M. Weyrich, B. Vogel-Heuser, Agentenbasierte dynamische Rekonfiguration von vernetzten intelligenten Produktionsanlagen – Evolution statt Revolution, in *Industrie 4.0 in Produktion, Automatisierung und Logistik*, (2014), pp. 145–158
21. S. Dais, Industrie 4.0 – Anstoß, Vision, Vorgehen, in *Industrie 4.0 in Produktion, Automatisierung und Logistik*, (2014), pp. 625–634
22. Referenzarchitekturmodell Industrie 4.0 (RAMI4.0). VDI, 01-Apr-2015. [Online]. Available: https://www.vdi.de/ueber-uns/presse/publikationen/details/referenzarchitekturmodell-industrie-40-rami40. Accessed 25 Jun 2021
23. M. Meyer, Management control in Unternehmenskooperationen. Control. Manag **52**(5), 333–335 (2008)
24. M. Schroeck, R. Shockley, J. Smart , D. Romero Morales, P. Tufano, Analytics: the real-world use of big data: How innovative ..., Jan-2012. [Online]. Available: https://www.researchgate.net/publication/315786855_Analytics_the_real-world_use_of_big_data_How_innovative_enterprises_extract_value_from_uncertain_data_Executive_Report. Accessed 25 June 2021
25. What Are the Main Supply Chain Challenges?. Blume Global. [Online]. Available: https://www.blumeglobal.com/learning/supply-chain-challenges/. Accessed 12 July 2021
26. I.M. Ambe, J.A. Badenhorst-Weiss, An automotive supply chain model for a demand-driven environment. J. Transp. Suppl. Chain Manag **5**(1) (2011)
27. Blockchain for Industry 4.0: A comprehensive review | IEEE ... [Online]. Available: https://ieeexplore.ieee.org/document/9069885. Accessed 5 Sept 2021
28. A. Bhalla, Top cryptocurrencies with their high transaction speeds. Blockchain Certifications, 16-Apr-2021. [Online]. Available: https://www.blockchain-council.org/cryptocurrency/top-cryptocurrencies-with-their-high-transaction-speeds/. Accessed 5 Sept 2021
29. Blockchaintechnologycom, "Advantages & Disadvantages of Blockchain Technology," Blockchain Technology, 23-Nov-2016. [Online]. Available: https://blockchaintechnologycom.wordpress.com/2016/11/21/advantages-disadvantages/. Accessed 01 Sep 2021
30. S. Jabbar, H. Lloyd, M. Hammoudeh, B. Adebisi, U. Raza, Blockchain-enabled supply chain: Analysis, challenges, and future directions. Multimedia Syst **27**(4), 787–806 (2020)