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Blockchain-based supply chain system in automotive industry for small and medium sized manufacturing

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Abstract. Blockchain technology enables a single database source to maintain permanent information about products and manufacturers and share transparent data in the supply chain from suppliers, factories, and distributors. In the automotive industry, blockchain technology has improved the transparency of the value chain and improved the operational efficiency of the supply chain. This research designed a blockchain-based supply chain system framework to meet the business needs of the automotive industry and improve operational performance. This research is based on the ongoing European Union Horizon 2020 project AVANGARD. The features of blockchain are investigated and aligned concerning SCM in the automotive industry.

Keywords: Blockchain, Supply chain management, automotive industry, small and medium sized enterprise.

1 Introduction

With the rapid development of various technologies, the automotive market will be completely different from today. We expect more integrated, personalised, shared, and connected cars in the automotive industry (Lawson, 2018). It is believed that the impact of blockchain in the automotive industry is so significant. Therefore, it is vital to be aware of the potential for this disruptive technology and understand how it changes the complex automotive industry.

Blockchain is known as a technology that supports bitcoin and other similar currencies but is also much more than that. In the automotive industry, using blockchain technology can transform products, services and processes. Heutger & Kuckelhaus (2018) illustrate several interesting industrial examples of using blockchain technology to managing physical assets in the automotive and its manufacturing industry, for instance, Groupe Renault storing the digital assets of its vehicles on the blockchain; Microsoft and VISEO connecting maintenance events by blockchain; Bosch and local certification authority using blockchain to prevent illegal odometer manipulation (Heutger & Kuckelhaus, 2018). Various cases demonstrate how automotive companies have moved fast to seize the potential of using. There is a lot of research addressing the

usage and implementation of blockchain in the automotive industry (Rabah, 2018). From previous research and practical cases, three different use case categories of blockchain application in the automotive industry are summarised, namely 1) verification and authentication for process improvements, 2) vehicle (assets) management in transfer and distribution, 3) transparent finance, payments and insurance to increase the security (Rabah, 2018; Lawson, 2018; Sharma et al., 2019; Fraga-Lamas & Fernández-Caramés, 2019).

Although blockchain has many advantages and brings many benefits to the automotive industry, different stakeholders in the industry confront other challenges (Fraga-Lamas & Fernández-Caramés, 2019). It always lacks a clear roadmap when it comes to adopting blockchain. To the best of our knowledge, most researchers focused on the particular phase of the life cycle in the automotive industry. There is a need to design a complete framework to provide on-demand, customised blockchain-based services meeting all critical requirements for the automotive industry. Besides, more and more SMEs join the automotive industry to improve efficiency, optimise investments and processes, and increase flexibility (Calabrese, 2001). The automotive industry is not only for big players.

Small and medium enterprises (SMEs) have low product volumes and relatively a large number of partners. As a result, these limitations constitute bottleneck problems and restrict SMEs' access to different advanced technologies and business models (Vatankhah Barenji et al., 2020), which, in turn, prevents them from quickly penetrating new markets. Based on Vatankhah Barenji et al. (2020), it's crucial to provide a solution for SMEs to solve 1) centralisation management problem; 2) security & trust issues; 3) heterogeneous data challenges. Therefore, using emergent blockchain technology can solve the above barriers and provide a distributed solution for SMEs (Wu et al., 2017).

This study aims to study blockchain technology and its impact on the automotive industry and SMEs. Subsequently, we will examine the case for a blockchain-based supply chain and elaborate on implementing it in the automotive industry. This paper is based on an ongoing EU Horizon 2020 project AVANGARD (Advanced manufacturing solutions tightly aligned with business needs), started in 2019. The project's goal is to design a concept of Microfactory for the production of urban electric vehicles and addresses its associated challenges. This project aims to apply Industry 4.0 solutions and minimise the footprint of both the production and use phases of the vehicles. The whole manufacturing and supply chain process are digitalised. From an electronic device, the client will be able to configure the vehicle, make the purchase order, and follow the vehicle manufacturing, assembly, and delivery evolution. At the same time, the manufacturing system can receive the order and decide the most suitable microfactory of the system to manufacture this vehicle attending to location, workload, availability of goods and environmental impact.

To address our goal of this research, the rest of this paper is organised as follows: an overview of blockchain technology and analyses of blockchain technology's implications for the supply chain are provided in Section 2. Section 3 will present an in-depth analysis of using blockchain in a cloud-based automotive supply chain system. In section 4, we will discuss blockchain's growth opportunities and challenges in the

automotive industry and how companies can act to the changes. We will also conclude this research in this section.

2 Literature Review

In this section, literature related to the blockchain is discussed. The collected literature is analysed from four levels. The first level is about blockchain technology and its main characteristics. The second level is about its impact on supply chain management. The third level is its impact on the automotive industry, and the progressive level is its impact on SMEs. This will serve as a ground for designing a blockchain-based supply chain system for automotive industry.

2.1 Blockchain technology and its impact on supply chain management

Bitcoin is a hot topic nowadays in this digital currency era. However, the blockchain technology behind it could prove much more significant (Swan, 2015). Blockchain is a digital, decentralised, distributed ledger technology that provides a way for information to be recorded, shared and maintained by a community. Here are three critical characteristics of blockchain:

- **Transparent:** The transactions are recorded near real-time to the blockchain and also synchronized on multiple computer systems. At the same time, it is visible to all participants with identical copies maintained. This principle can remove disputes, reduce uncertainty and, at the same time, increase trustworthiness (Lawson, 2018; Chen et al., 2018; Ko et al., 2018; Sundarakani et al., 2021).
- **Decentralised:** From the business point of view, it is a peer-2-peer network that is entirely organized and managed by its associated members, without relying on a single middle authority or unified infrastructure that built trust (Hackius & Petersen, 2017). From the technical point of view, decentralisation indicates a design of distributed system structure to deal with the data processing from verification, storage, maintenance, and transmission. In this structure, the trust between distributing nodes is built through mathematical methods rather than centralised organizations (Chen et al., 2018).
- **Immutable:** One or more transactions are grouped to form a new block. All members of the network can verify the transactions in the block. If no consensus on the validity of the new block is reached, the block is rejected. Likewise, if consensus exists that the transactions in the block are valid, the block is added to the chain (Hackius & Petersen, 2017). It is nearly impossible to tamper information to a blockchain without been detected. Blockchain can increase the trustworthiness of data and decrease the chances of fraud (Lawson, 2018).

From the time it was developed, blockchain has been described as an efficient and permanent ledger to record events, transactions, and information. The various unique features of blockchain technology have seen it considered for applications in many areas to improve the scope of the business areas and operational performance, including

commerce, judiciary, finance, banking, healthcare, military and defence, equity crowdfunding, securities issuance, trading and settlement, insurance, notary public, music industry, Internet of Things, and other non-financial applications (Aslam et al., 2021).

Today blockchain is being deployed in many forms. Still, blockchain technology has the potential to open new business models. This is mainly related to the complete public trust that is a unique characteristic of this technology. According to Piscini et al. (2017), blockchain technology is a gatekeeper in the emerging trust economy of different parties on the supply chain.

The blockchain can create value for the industry through three main points: (a) unlocking business efficiencies, (b) disintermediating suppliers, and (c) enabling new business and customer offerings (Sánchez Pérez et al., 2020). In logistics, Blockchain technology introduced the digital distributed ledger for shipment management. Similarly, blockchain can be implemented in the supply chain with practical benefits, such as efficient, timely, and transparent transactions (Aslam et al., 2021).

According to the Council of Supply Chain Management Professionals (CSCMP), SCM is based on two fundamental approaches; (i) planning, implementing, and controlling the primary activities and delivering value for the ultimate customers; (ii) the centralised management and coordination of corresponding business processes within as well as across the companies. Pain points of the supply chain:

- Weak control by the core enterprise.
- Lack of supervision, hard to trace and match.
- Information isolation.
- Lack of trust.

The integration of the supply chain can be considered a force that is trying to uplift the relationships between all the segments in the supply chain to enable better decision-making by providing visibility and highlighting the bottlenecks. Blockchain for supply chain management is a digital innovation and emergent allowing technology. It offers distinctive features such as real-time information sharing, improved security, transparency, reliability, traceability, and visibility which improve the efficiency of the supply chain.

2.2 Challenges and Opportunities of Blockchain in Automotive Industry

The industrial sector (including the automotive ones) is considered a primary target of blockchain technology. The first application of blockchain in the automotive industry is digital currency bitcoin and digital payments. However, same as in other industries, the main features of blockchain could be beneficial for applications more than digital currency and digital payment in the automotive industry. Since 2017, at the Frankfurt auto show, auto supplier ZF and IBM announced they were jointly developing a blockchain-based vehicle services payment platform. Another example is a blockchain-based platform called "Dubbed Car eWallet". It provides different services to change the vehicle business model more simply and securely, from the car-sharing pool, shopping in the car, dealership maintenance, and payments processing. Furthermore, French carmaker Renault also are researching applications for blockchain technology.

Blockchain is used to certify information about repair and maintenance when it is resold (Boucher, 2020).

The automotive industry has its unique importance, considering its ranges from government regulatory parties, manufacturers, suppliers, and vendors to spare parts suppliers (Sharma et al., 2019) and cover many sectors across the entire supply chain from upstream to downstream. The automotive industry becomes a complex and wide-ranging ecosystem (Sharma et al., 2019).

Some of the most typical applications of blockchain technologies are their use in the transfer of assets and digital applications and distributed information records created using smart contracts, considered an ideal way to program logical business and operations. It impacts all industry sectors, and it is not surprising that the automotive industry has also been influenced by this revolution (Sharma et al., 2019).

The integration of the automotive industry and blockchain technology offers exciting solutions to some of the most pressing automotive problems, especially those related to the connected automotive industry. The power of this technology can drive innovation and solutions across the entire automotive ecosystem. To this day, there have been made several efforts to use blockchain for improving the automotive industry. This study identifies various automotive critical functional areas that can be leveraged using blockchain technology and their growth potential.

It is well noticed that blockchain technology becoming more vital and crucial in the automotive industry. It influences the industry in the same way as other prominent technologies such as artificial intelligence, machine learning, 3D printing, and IoT. (Zoria, 2019)

It has been widely realized that primary automotive industries have started to use blockchain technology in various scenarios over the last two years, such as vehicle supply chain, security, car service, autonomous vehicles, manufacturing process, insurance, etc. Like General Motors (GM), Porsche, BMW have partnered with blockchain start-ups like XAIN, Spring Labs, and VeChain Thor to address complex issues.

Table 1. Examples of blockchain applications in automotive industry

Key Functional Areas	Example	References
Smart Manufacturing	<ul style="list-style-type: none"> • Identification <p>Blockchain can be used with digital twins, and can monitor and track digital asset information more effectively than traditional manufacturing. Through RFID tags, the authenticity of each material and asset can be verified. In addition, the blockchain can also protect data sharing between machines and prevent counterfeiting problems. This also helps to issue a safe and direct recall and improve quality control.</p>	Fraga-Lamas, P., & Fernández-Caramés, 2019; Li et al., 2018;
Supply Chain & Logistics Monitoring	<ul style="list-style-type: none"> • Visibility and traceability of supply chain & logistics 	Kshetri, 2018; Saberi et al., 2018; Sharma

	<p>The automotive supply chain is considered to be very complex because it contains many types of assets, stakeholders and parties. A complete supply chain needs to manage the transfer of products and related transactions and the exchange of knowledge between organizations. Blockchain provides visibility, transparency and optimization of logistics, while providing seamless integration of transaction, payment and logistics information. For supply chain stakeholders, it is always clear to exchange knowledge and obtain constant details about who performs what, when and where.</p>	<p>et al., 2019; Stenholm et al., 2017; Supranee & Rotchanakitu mnuai, 2017</p>
Autonomous vehicles	<ul style="list-style-type: none"> • Car-as-a-Service <p>Blockchain technology contributes to the development of autonomous vehicles. Blockchain solutions can interconnect autonomous vehicles and realize car sharing services. Data about autonomous vehicles will be exchanged in a safe, reliable and seamless manner. Blockchain can protect user privacy while protecting data security. In addition, the platform can process all payments after the trip, and update user records with the history of the trips performed.</p>	<p>Sharma et al., 2019; Fraga-Lamas, P., & Fernández-Caramés, 2019; Singh & Kim (2019); Pedrosa & Pau, 2018</p>
Aftersales services	<ul style="list-style-type: none"> • Ownership transfer <p>Blockchain technology increases the transparency of transactions and simplifies the process of car ownership changes. Buyers and sellers can execute goods transactions by using smart contracts without the need for an intermediary.</p> <ul style="list-style-type: none"> • Automated Services <p>Most cars have error records. Once this information is shared on the blockchain, service professionals can easily access this information, diagnose problems quickly, and repair the car in a shorter time. When the car needs maintenance, the service request can be triggered automatically. This will enable condition-based maintenance services. In addition, maintenance status can be easily tracked without visiting the mechanical station.</p>	<p>Sund et al., 2020; Sharma et al., 2019;</p>
Insurance& Security	<ul style="list-style-type: none"> • Insurance <p>Most insurance claims are fraudulent, and covert methods are used when issuing insurance policies and managing stocks, leading to increased operating costs and inefficiency. Blockchain solves this problem by implementing transparent recording of vehicle sensor data in a decentralised network. Blockchain provides new additional services for remote communication, providing insurance companies with driver location, driving</p>	<p>Sharma et al., 2019; Fraga-Lamas & Fernández-Caramés, 2019;</p>

duration, acceleration and braking behaviour, vehicle speed, and other information. Blockchain can also incorporate insurance into other carriers, such as user files; this process can be called car sharing.

- Security

Vehicles are becoming more and more autonomous, which makes them more closely connected and more vulnerable to deadly cyber-attacks. This is why the blockchain uses a robust encryption root that cannot be reverse engineered. The distributed ledger feature of the blockchain facilitates data storage and provides immutability.

Moreover, SMEs companies are considered the backbone of most of the economies (Eurostat, 2011), and their survival is vital for a healthy economy. In Europe alone, there are approximately 21 million companies belonging to the SME sector. These 21 million companies provide a source of income for approximately 90 million people on the African continent. SMEs have to be strengthened to overcome the economic challenges surrounding them. (Ilbiz & Durst, 2019). Despite their status as the essential part of any economy, SMEs find it difficult to:

- find investors/finance;
- scale their operations;
- process payments;
- hire additional services.

With all the emerging technologies, SMEs must find ways to collaborate and share competency in a trustable manner to seize more business opportunities in a turbulent market environment. The new digitalisation trends and automation can form a significant challenge for SMEs (Paardenkooper, 2019). In many current solutions and research, SMEs have encountered some bottleneck problems. To address these challenges, blockchain technology has been introduced recently for the manufacturing industry as peer to peer network, which can be omitted third part and improve the system's security (Vatankhah Barenji et al., 2020).

3 Design of Blockchain-based supply chain system for automotive industry

The automotive industry is one of the most promising applications of blockchain. In the previous section, we have evaluated the opportunities of using blockchain across the automotive industry to improve the supply chain. We also analysed the characteristics of blockchain in resolving business issues for SMEs. In this section, we will discuss the scenario in the electric vehicles sector.

Particularly in the electric vehicles (EVs) sector, the reality is that more and more SMEs are capable of developing EVs and this will re-shaping the automotive value chain (Özel et al., 2014). In most of the automotive industry, a centralised manufacturing model is a primary choice. Many giga-factories operating in Europe,

China, and the USA. The current status of automotive factories consists of the production plant in which the final products are stored in the inventory (stock). Afterwards, the distributor collects a specific high volume for its region and each of the retailers' request from the distributor for the needs of the user/market. However, manufacturing plants across Europe seeking into reduced wasted materials, energy consumptions and carbon footprint. Therefore, more and more SMEs are involved in manufacturer EVs locally based on local/regional needs. This manufacturing model only consists of modular production and the retailers in the broader region. Therefore, the supply chain is simplified, only consists of suppliers, regional factories, dealers, and customers. Here in this demand-driven electric vehicles manufacturing, there are many use cases that need to be improved and verified through blockchain technology.

3.1 Functional requirement

This paper is based on the ongoing EU Horizon 2020 project AVANGARD (Advanced manufacturing solutions tightly aligned with business needs) started in 2019. The goal of the project is to design a concept of Microfactory for the production of urban electric vehicles and addresses its associated challenges. This project aims to apply Industry 4.0 solutions and minimize the footprint of both the production and use phase of the vehicles. The whole manufacturing and supply chain process is digitalised. From an electronic device, the client will be able to configure the vehicle, make the purchase order and follow the evolution of the vehicle manufacturing, assembly and delivery. At the same time, the manufacturing system is able to receive the order and decide the most suitable microfactory of the system to manufacture this vehicle attending to location, work load, availability of goods and environmental impact.

Within this project, the blockchain technology is used to secure the whole process, and also to fulfil the track and trace functionalities of the supply chain and recording transactions among stakeholders and machines/software under its immutable and verifiable framework. The proposed blockchain component needs to be able to satisfy the following parameters:

- F1: Support the required decentralisation, which will ensure trust and immutability, whilst unconstructive facilitation of business level processes is guaranteed
- F2: Record key transactional activities either organically recorded by value chain actors, or programmatically sourced by key IoT devices and software components
- F3: Facilitate granular access to key data points by participating actors based on defined stratification, supported by smart contract functionality

According to the market demands, following information needs to be secured by blockchain:

- I1: Certification of origin: Customers who order the car will receive a certification of origin of all the materials which will be stored on a blockchain network. From suppliers to end consumer, the certifications are accessible and

placed on a blockchain to be shared in a secure environment, i.e. Made in Italy, Poland, Greece, Portugal.

- I2: Certification of critical process: Besides verifying virtual information of the product, it is also essential to warrant the physical movements of products in the supply chain.
- I3: Cost control: from extraction to end-of-life management and governing supply chain activities and its financial flow with smart contracts. For instance, in areas of financial transitions between participants in the entire ecosystem. For example, EV may use a windshield wiper which comes from a supplier, and to calculate the carbon footprint of whole car the amount of carbon emission during the production should be shared by the supplier.
- I4: IPR management: Blockchain enabled IPR management system is secure, immutable, and traceable. The provided IPR is easily checked by customers and any other participates in the supply chain. The IPR saved in blockchain also be used when customers want to sell the electric car in future.

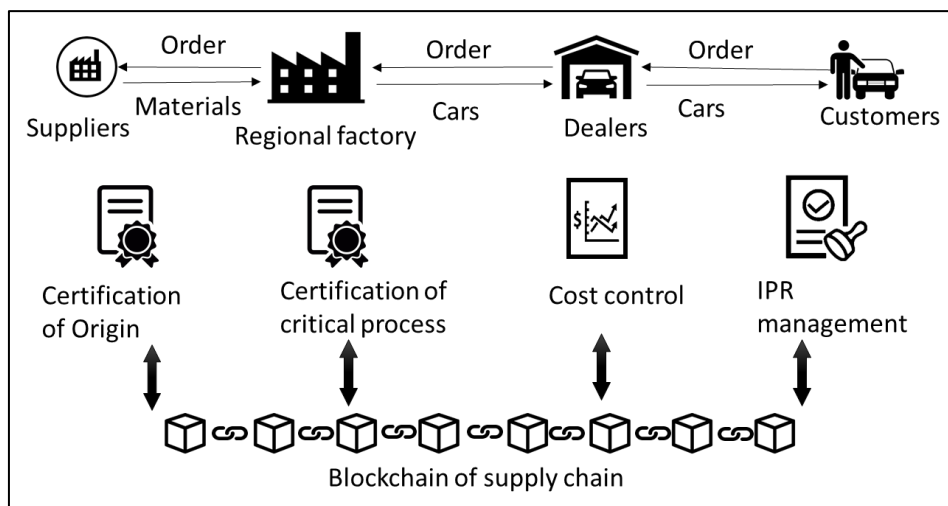


Fig. 1. A scenario of how blockchain technology can support certification and verification in regional demand-driven factory

Based on the business requirements and information requirements, the basic functional requirements of designing a blockchain-based supply chain system in demand-driven electric vehicles factory are as follows:

Table 2. Functional Requirements

Requirement	Req ID	Functional Requirements
driven from		

F1,I1	REQ1	Track and trace: materials and products provided by all the suppliers.
F2,I2	REQ2	Activity record: manufacturing process, such as processing craft, time, operators and other information.
F2,I2	REQ3	Quality control: connect all the key information through IoT technologies, and trace the process and quality in the entire life cycle.
F2,I3	REQ4	Sale-service: track the order and supply process, and provide flexible price plan to customers. Customer can reduce waiting time by increase the price..
F3,I4	REQ5	Aftersales-service: failing product tracing, to recall and maintain the products with quality problems, and record service information

- Customer/User registration. Customers or other users from the participating stakeholders will have to be able to register to the system, whilst creating their unique identity in the process. This will allow for logging activities under a unique identification schema.

- Stakeholder managed Software/Hardware registration. Manufacturing value chain stakeholders are expected to register their software (e.g., ERP, MES) or hardware (e.g., 3D printer etc.) to the Blockchain network. This will allow to attest ownership to participating actors, create a unique ID for the software/hardware components and facilitate logging of manufacturing processes. For example, information about production start and end time resulting from MES planning and execution, energy consumed resulting from IoT monitoring, material consumed, logging CO2 production data, etc.

- Customer order requests. The necessary rules and REST APIs will be coded to support the implementation of front-end elements in the web applications that allow the logging of a customer's order including metadata, hashing of design files etc. This transaction and textual metadata will be logged, files will be hashed and all state changes along with the actual files will also be forwarded to the relevant external databases via the ledger-sync subscriber. In the case of a design, file upload the hash will be compared against prior uploads. If a match is found under a different ID, and not under a suitable creative commons license, then the customers will be warned of infringing IP rights. If there is no match, then they will be asked to indicate if they produced the design or not and choose a creative commons license. This can be further extrapolated in future iterations to support an open marketplace of designs.

- Quotation, Acceptance, Payment. The system and/or system users will propose a quote for the order, which will either be rejected, accepted, lead to an order adaptation, and proceed with payment. All these transactions will be foreseen, coded in the Transaction Processors for handling and logging, supported by the required Rest APIs and logged accordingly. The metadata will similarly be forwarded to the external database via the ledger-sync subscriber.

- With the various software and hardware components registered, the smart contract functionality of the Transaction Processors' code, can log agreed upon activities during the production process, from order finalisation to asset dispatched to the customer. This will be facilitated per case, logged in the Blockchain as well as forwarded to the external databases. Furthermore, logged transactions could be accessed granularly by the participating stakeholders, creating a vehicle passport that holds the overall history of the produced vehicle, yet with subsets of metadata and

transactional logs accessible depending on defined access rights. As such the blockchain component will facilitate admin roles that can manage access rights for registered users, and potentially system components. Thus, a vehicle passport is envisioned as a complete historical record, yet fostering restricted access based on user roles, thus not exposing sensitive manufacturing information but facilitating the expected transparency to customers and stakeholders alike.

3.2 Technical architecture

To facilitate the functional requirement described in section 3.1, a Block-based Supply chain System, namely BSS, is proposed as an integrated solution to organize and manage all related activities and operations. This subsection will discuss the technical architecture of BSS.

In this BSS platform, it is possible that the system/user can audit and certify some processes and data across the entire supply chain of EV, from suppliers, manufacturer, and dealers to customers. As blockchain is a vertical enabler, several functionalities can be facilitated and audited accordingly by employing blockchain-based user identities, transactional activity logging at various levels of abstractions depending on the business modelling of the final solution or the various components to be employed. Subsequently, blockchain logging and transactional activity can be deployed as either privately accessible by some or all of the manufacturing partners and/or publicly accessible by other stakeholders participating in the manufacturing value chains from collaborators to consumers.

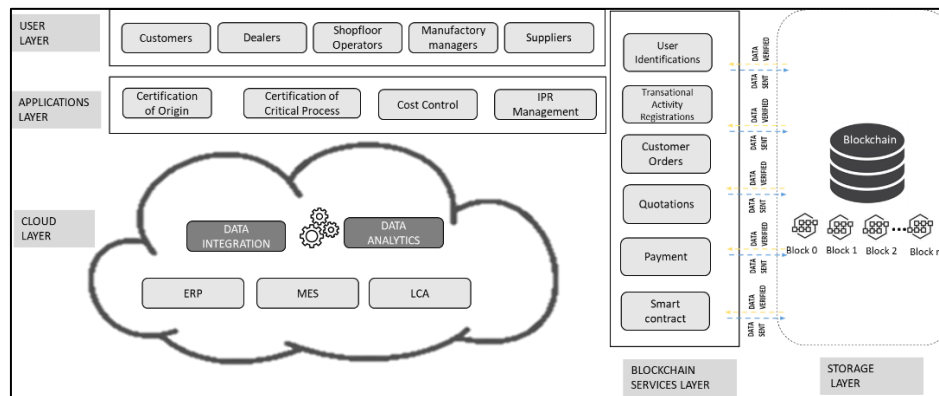


Figure 2 Blockchain-based Supply chain System (BSS) implementation framework

The technical implementation framework of this proposed BSS depicted with a cross-layered structure in Figure 2. The supply chain consists of suppliers, regional factories, dealers, and customers. Therefore, the track record for all the generated data while EV transfer between each party are store in the form of a distributed ledger. In this framework, it consists of five main layers, from top to bottom, namely user layer, application layer, blockchain services layer, and storage layer:

- **User layer:** Different stakeholders in the manufacturing value chains, such as customers, dealers, shop floor operators, manufacturing managers, and suppliers have different access to the cloud and blockchain services. The manager is the head of the supply chain system, initiates system changes based on conditions set in the smart contract.
- **Application layer:** this layer defines various typical application scenarios and instances of blockchain-based supply chain. As described in section 3.1, the blockchain can be applied to secure information: certification of origin, certification of critical process, cost control, and IPR management.
- **Cloud layer:** The cloud layer is providing a cloud-based infrastructure to connect different tools, such as ERP, MES, and LCA, and also integrate different data sets.
- **Blockchain services layer:** The blockchain services layer is responsible for synthesizing all related information from three other layers in vertical position. It consists of six components: user identifications, transactional activity registrations, customer orders, quotations, payment, and smart contract.
- **Storage layer:** All the data blocks are generated in this layer. It is not only acting as a data storage, but also operating encryption method, managing chain structure, and adding timestamp to data block. The chain structure defines block header, block body and address.

3.3 Implementation

In this project, a hybrid blockchain is implemented in order to facilitate value chains of disparate partners, allow access to transactional data under a stratified model from completely private up to and including public access, support ease of integration with various setups such as software tools, IoT devices and stakeholders themselves. All the above without sacrificing decentralisation, immutability and eventually trust among participating actors.

By considering the overall technical architecture of BSS and comparing different blockchain framework, Hyperledger Sawtooth was chosen to support BSS. The reasons are:

- Sawtooth can be configured to support both private permission and public permissionless network configurations out of the box
- Sawtooth's architecture is based on pluggable components that allow for flexibility and scalability.
- Sawtooth requires no transaction costs

The Sawtooth blockchain node will be set up as per Figure 3, with the Validator Nodes constructed as a multi-container Docker environment. A Docker within the frame of Sawtooth supports encapsulation, isolation, portability, and control over the external communication of each docker image, supporting scalability, efficient use of system resources, faster software delivery cycles, and instant rollout. This approach is considered ideal for supporting the upcoming cloud services integration activities.

Each Validator Node will include the Validator, the Transaction Processors, the Consensus Engine, and the required Rest APIs and Clients. The **Clients** could interface

with any system, software, device, or any stakeholder interacting with BSS interfaces. The **BSS RestAPI** receives requests from the frontend implantation and facilitates communication with the Validator. The **BSS Transaction Processor** holds application-specific code equivalent to smart contract functionality. Implementation will be undertaken in the Python programming language.

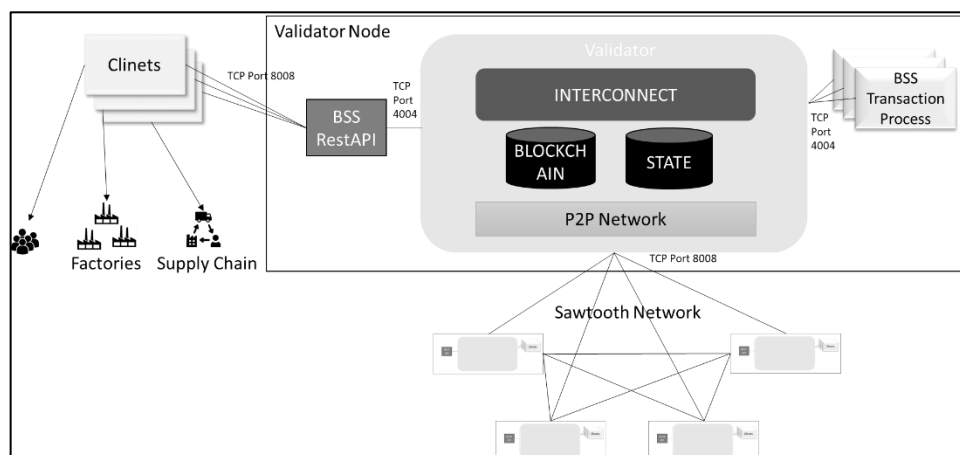


Figure 3: Sawtooth Validator Node

The multi-container Docker environment will clone the pilot implementation setup, based on the following configuration (Table 3):

Table 3. Blockchain component configuration

AWS Cloud Server - Sawtooth Blockchain Component	
Instance Type	1 x EC2
Server Type	Large
Storage	64 GB SSD
Processor	2 x vCPUs (Intel Xeon Processor, up to 3.0 GHz Intel Scalable Processor, each vCPU thread of an Intel Xeon core)
Memory	8 GB
Operating System	Ubuntu 18.04.5 LTS

3.4 Blockchain demonstrator

This sub section presents a blockchain based demonstrator for the proposed Blockchain based Supply Chain System (BSS). In the demonstration, we described a use case of certificates exchange and data sharing with other partners by members of a manufacturing supply chain in the EV market. The implementation has to fulfil the following requirements:

- Allow members to create their own network of partners
- Allow members to create, upload and manage a certificate with fixed and variable properties
- Allow members to share the certificate with other members either a certificate or its metadata.
- All members can verify the authenticity of a certificate if it has been uploaded by a member of the supply chain
- Allow members to handle custodianship and ownership separately taking under consideration one of the main complexities of any value chain
- Support policies to facilitate transfer of custodianship and/or ownership to members of a partner network
- Visualize at least one set of variable parameters and allow for manual update of their values.

Figure 4-7 present the screen shot of the dashboard of proposed BSS.

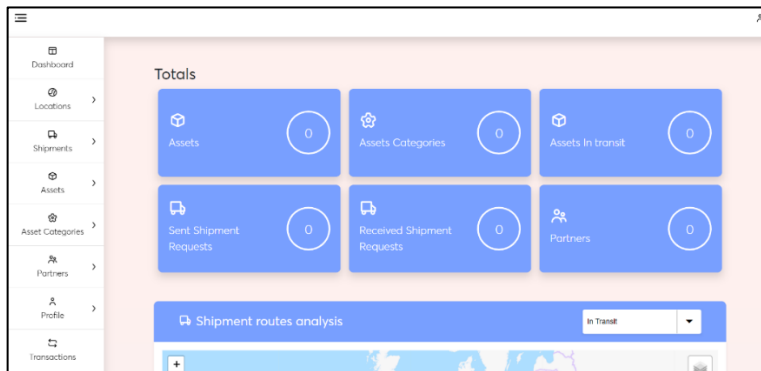


Figure 4. The main Page of BSS-

Figure 4 demonstrates the dashboard which holds an overview of Number of assets users' own across facilities and those that users don't own but are currently in users facilities. Users can create asset categories, and check assets in transit, Sent/Received shipment requests, and also check number of partners in users' network. Other data are also included, along with a map for visualising the shipments in transit or already delivered.

Add partner
Partner network

Partner key

Add

Sent Requests List

Filter by status

▼
Apply filter
Add partner

Name	Public key	Status	Actions
Konstantinos Kallipolitis	02ec742588437d07f2f3d154d794d9...	Open	👁 🗑

← Back

Sent partner request

To partner

Name	Mobile	Email
Konstantinos Kallipolitis	-	owner_b@company.com
Company	Role	
Ideas Forward - Athens	Owner	

Partner Key

Copy

Request status: Open

Figure 5. Add new partner information pages

Figure 5 demonstrates how to add a new partner. A partner can be either a colleague from user's company, or a driver from a logistics company in the case of this demo. Colleagues can be co-owners of any assets that the user has, just by adding them to assets. To add a partner user needs to know their Blockchain or Partner Key which acts as a unique identifier. By pressing Add a request is sent to partners which they can accept or decline. Conversely user can delete it if it was sent by mistake. By pressing the eye icon, user can see more details about this partner.

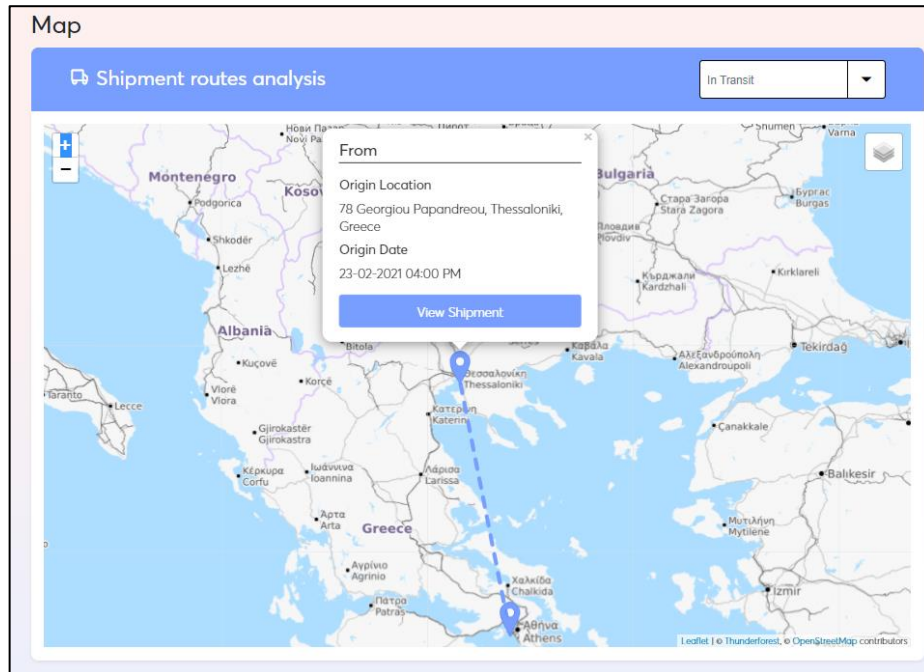


Figure 6. The shipment routes analysis shown on map

Figure 6 shows three shipment routes. Once the shipment requests have been sent, user can go to Locations > Map and see shipments in Transit or Delivered. Upcoming features will include a filter to customise the time span user wants to check out. In Transit shipments are depicted in a dashed line. Delivered shipments are depicted with a solid line. Now that shipments are sent and delivered, user can go to Locations > Assets by location and monitor how many of user's assets are where. In this list user can see: How many of the common assets amongst user and partners are located to which location. How many of the assets users don't own but are currently in user's location.

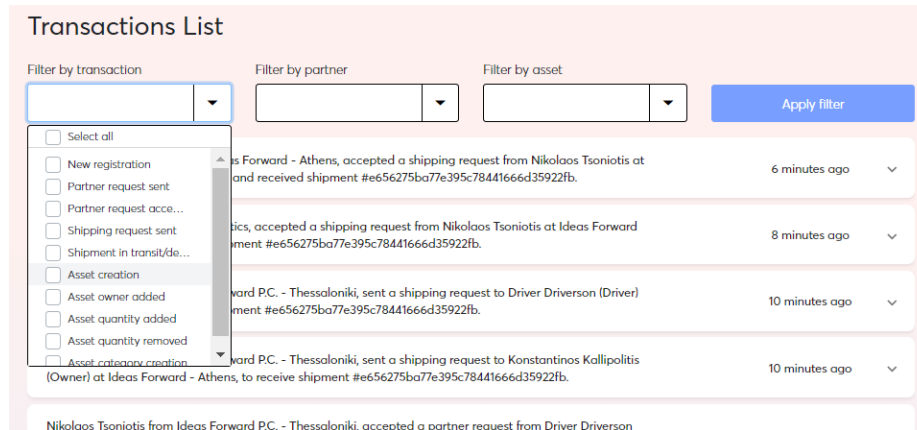


Figure 7. The transaction is listed in the blockchain.

Figure 7 depicts the transaction records. This is a Blockchain powered Supply Chain pilot system. All relevant transactions are logged in the blockchain and can be accessed by participants, as depicted in Figure 7. Participants are restricted to access only those transactions that derive from their own network of partners. Measures are in place to avoid data spill overs between networks. Finally as transactions increase in numbers, the user is facilitated to filter them for quick identification per:

- Transaction Type
- Partner transactions
- Asset oriented transactions

4 Discussions and Conclusions

Blockchain technology is a revolutionary innovation that can transform lots of existing traditional systems into more secure, distributed, transparent, collaborative systems while empowering its users. Blockchain-driven solutions can seamlessly aggregate all information, provide important services and add value to industrial companies. The most important capability of blockchain is that it helps to unlock the full potential of other advent technologies, such as cloud, augmented reality, IoT and 3D printing. With the development and growth of maturity, blockchain technology will allow manufacturers to fully deploy other advanced technologies and innovative business models. Therefore, more efficient factory operations that require data sharing and collaboration between complex companies and machine networks will be created and become the new norm for the entire industry (Galea-Pace, 2020)

This research demonstrate integration of blockchain and supply chain in automotive industry. In future, the entire automotive industry could collaborate on a single trustable blockchain-based platform to store the information of every vehicle and related assets, including important events, transactions and status updates. This would allow, for example, certification of origin, IPR management, and maintenance data to be stored together as a comprehensive record. However, the primary requirement to make the

blockchain-enabled functionalities become a reality is the industry-wide collaboration (Heutger & Kuckelhaus, 2018).

In many previous research papers or practical cases, the examples of blockchain being implemented in global international giants. However, when it comes to SMEs, they often tend to suffer from resource constraints in technology adoption (Gupta, 2019). Therefore, we proposed a blockchain-based architecture to support SMEs in the automotive industry, namely Blockchain-based Supply chain System (BSS).

Firstly, this research paper demonstrates using blockchain to register transactional activities in the supply chain system. This data is fully traceable and visible to authorised parties such as the customers, dealers, shop floor operators, manufactory managers, and suppliers. Manufacturing companies can provide a very useful and practical data management service to their customers. Secondly, this BSS aims to support the certification exchange among partners. Blockchain is used as an enabling technology to secure access and interactions and also to provide an immutable audit trail. Thirdly, For SMEs, there's a necessity to be effective. Blockchain can ensure trust between different parties to share and update data in an effective manner. According to our pilot implementation and demonstration, it is proved that blockchain technologies will build a trustful ecosystem for the automotive market.

Hereby, we summarise three main benefits of using blockchain in the automotive industry to manage the supply chain:

1. Improvement of business efficiencies: The record on blockchain will become a reference for future supplies and a source of learning and continuous improvement. This will improve the quality control and help in possible recall and maintenance.
2. Supporting business transparency: The end-users and every participant who interest in early-stage materials can know the process. Registering materials information and share the information with customers can increase customer satisfaction.
3. Enhancing business offerings: Blockchain-based solutions can create additional value-added services. The manufacturer can not only ensure that the correct version of the part is provided to the customer but also ensure that the number of authorised copies is provided, thereby eliminating the risk of version control errors.

Nevertheless, it is very challenging to implement blockchain to support supply chain system, especially in SMEs. It is challenging to collect data from machines and processes employed in production activities whilst ensuring data immutability and ownership is respected throughout. It is even more challenging to gather data from stakeholders' activities and interactions within a value chain. Although blockchain solutions can create value for industrial organisations in several different ways, this does not mean that it is an equally viable solution for all companies or industrial manufacturing. Furthermore, regulators worldwide are still examining the potential responses to the ever-increasing influence of blockchain-led solutions. Based on many previous cases, regulatory concerns are the number one barrier to blockchain adoption (Galea-Pace, 2020).

Most companies have seen the benefits of Blockchain. However, since Blockchain is a foundational technology that is adopted gradually instead of sudden, it might take years until it profoundly changes the supply chain management landscape.

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