CA-IEM-801-B Blockchain Applications in Industrial Engineering (Intersession)

Professor Rainer Müller

Final assignment:

Automotive Supply Chain Traceability using Blockchains (AutoChain)

Group 9

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Word Count: 4107 (without appendix)

Date: 08/02/2025

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AutoChain: Blockchain-Based Automotive Parts Traceability

1. Introduction

a. Short description of the Blockchain application

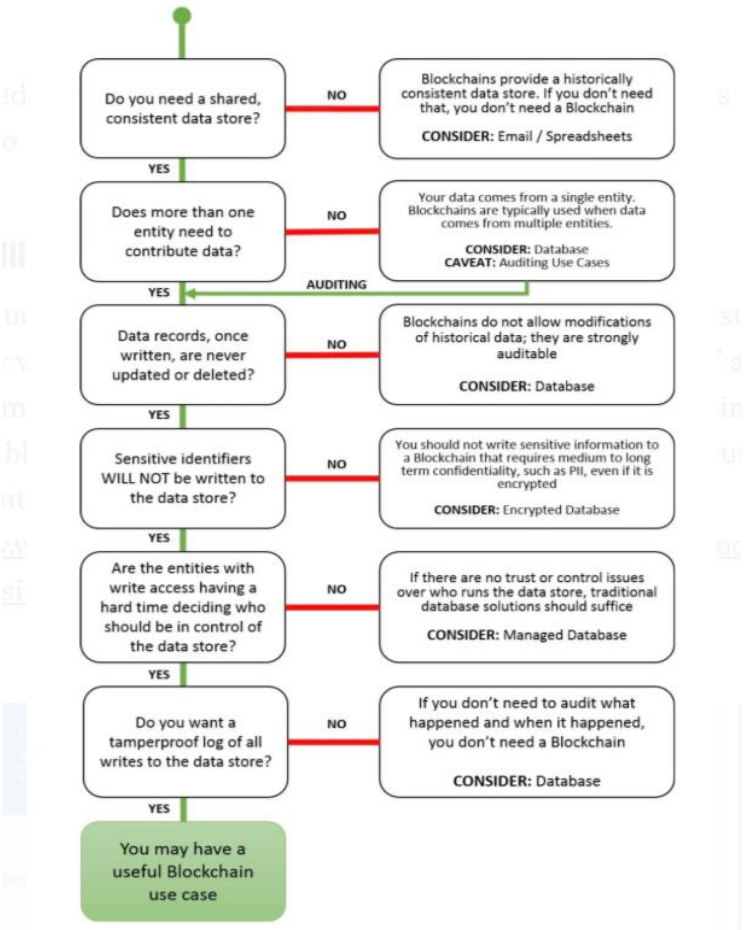
Our group collectively chose a blockchain topic that we named AutoChain. It is designed to provide end-to-end transparency and security in the automotive supply chain. AutoChain enables real-time tracking and verification of automotive parts being delivered from suppliers to manufacturers.

Each component would essentially have a unique digital identity using RFID and stored on the blockchain. This would ensure the transparency and legitimacy of the parts, eventually improving supply chain efficiency.

2. Use Case

Use diagram "Make Blockchain sense and type of blockchain"

As illustrated in Meunier's Blockchain Decision Model (2017), the following diagram (DHS Model) was used to affirm the use of the blockchain.



(Meunier, 2017)

a. Which Pain Points Are Addressed?

One of the most complex supply chain ecosystems is in the automotive industry, it involves many suppliers, production lines, dealerships and customers. As much as it is organized and planned well, there are some significant challenges that are being faced.

The lack of real-time tracking and communication can result in production delays, inefficient inventory planning and monetary losses. This can not only directly impact the Just-in-Time manufacturing models, but also ruin many supplier customer relationships (Hyperledger Fabric, 2023).

This industry also loses billions per year because of counterfeit parts being delivered to chains (Casino, Dasaklis and Patsakis, 2019). These components cause damaged products, ruined reputations and serious hazards. To add, there are compliances with ISO 26262 (functional safety), GDPR (data privacy), EPR (sustainability regulations) requires extensive record-keeping and many organisations rely on paper-based records that can be easily manipulated causing fraud, delays and high administrative costs (Treiblmaier, 2018). Having AutoChain not only provides OEMs (Original Equipment Manufacturers) with tamper-proof data but also improves efficiency and cost-effectiveness in the automotive industry.

b. What is the use case for AutoChain

Manufacturers and suppliers are the most important roles in making sure all of the automotive parts are authentic and present, that is why registering them on the blockchain is very crucial. AutoChain's Main Use Case is to ensure the traceability and authenticity of Automotive components.

1. Tracking parts from suppliers to manufacturers: Manufacturers can now guarantee their parts with this blockchain technology. AutoChain provides real-time tracking of the components being shipped, giving manufacturers a better inventory plan, and reducing any supply chain bottlenecks. As explained above; each part would receive a unique identity that includes information such as unique identification number, production origin and date as well as quality control records. As the parts move throughout the supply chain there are records kept for each transaction, shipment, inspection and most importantly transfer of ownership. AutoChain also improves collaboration between all parties ensuring the parts arrive just in time. Using the blockchain's record keeping history, manufacturers can also pinpoint where delays happen and therefore optimise supplier performance. OEM's (Original Equipment Manufacturers), access to real time analytics allows for better decision making and cost reductions in logistical operations.

2. Counterfeit Prevention and Authentication: AutoChain battles counterfeit components by ensuring that each part has a single blockchain identity that is completely tamper-proof. Every part can be scanned to verify its authenticity, if a faulty or fake component is detected, recalls are executed immediately. This prevents fake components from being used in the production line. AutoChain can protect OEMs (Original Equipment Manufacturers), from any reputational damage, and strengthen the trust between suppliers by avoiding all counterfeit risks.

3. Automated Sustainability reporting: There is no need for manual input when enforcing ISO safety standards, emissions regulations and any other environmental requirements. AutoChain also can record carbon footprint data ensuring parts are being sourced from sustainable suppliers making it easier to choose the perfect company to work with. (Deloitte, 2023).

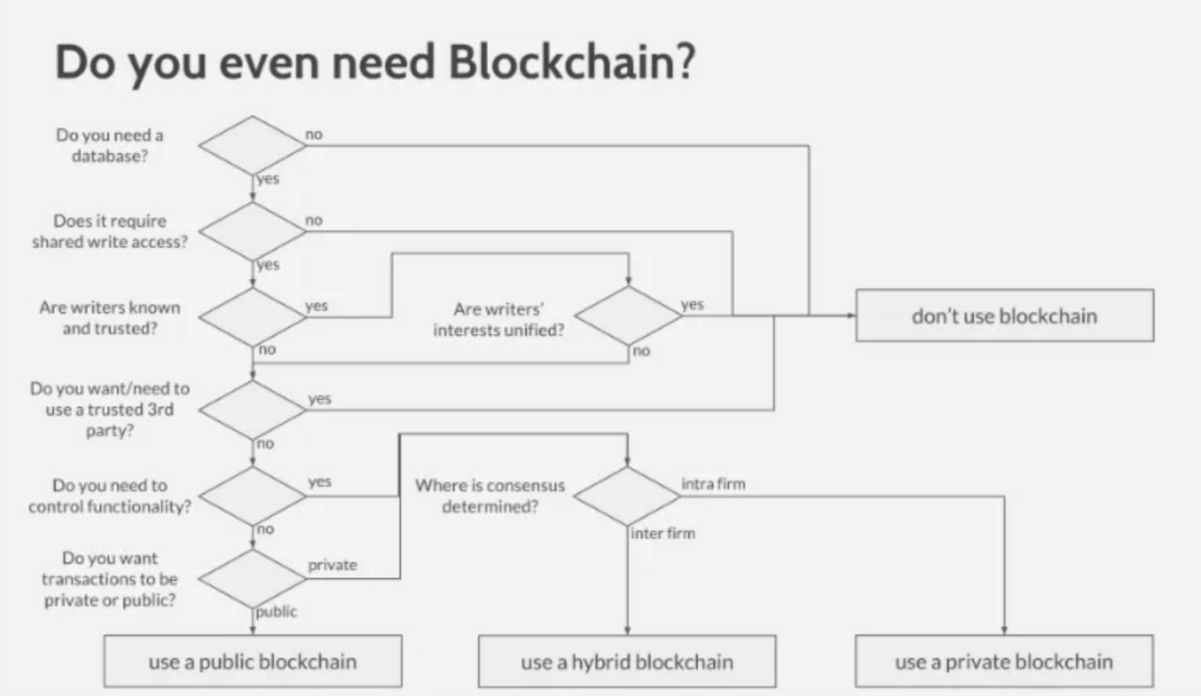
4. Digital Passport for components in vehicles: AutoChain forms a digital product passport that contains the components entire lifecycle history, from its start of manufacturing, repairs, and part replacements. This will create a solid transparent flow of exchange unlike traditional databases that can be easily tampered with. This system also prevents fraud, and provides dealerships with verifiable records making the sale of the vehicle more reliable.

c. Which functions does Blockchain offer?

- Real time tracking for the parts movements across multiple locations.
- Compliance tracking, meeting safety and environmental audits would be automated.
- Providing a permanent ledger making any data tampering or fraud nearly impossible and ensuring complete authenticity.
- Eliminates the reliance on centralized data sharing, reducing errors and many inefficiencies or corruption.
- Optimization of production and logistics is easier with its global visibility.
-

d. Do you really need a blockchain (Diagram: “Make Blockchain sense and type of blockchain”)?

As shown in Meunier's blockchain decision tree diagram (2017), the Suichies model was used to answer the question “do you really need a blockchain?”



(Meunier, 2017)

By applying the Suichies model, it can be determined whether to use a blockchain for the AutoChain solution.

Do you need a database?

Yes: AutoChain has a decentralized ledger that stores data and this ledger acts as a database to ensure transparency and traceability.

Does it require shared write access?

Yes: The involved entities (OEMs, and suppliers) in AutoChain have the ability to write to the blockchain. This is for the stakeholders to have the most updated information.

Are writers known and trusted?

Yes: The writers for AutoChain are the authorized participants in the automotive supply chain. They are the OEMs and suppliers, and need to be verified through KYC (Know Your Customer) processes, ensuring that they are trusted.

Are writers' interests unified?

No: The specific interests of the writers may differ depending on their sector. For example, while manufacturers prioritize quality control, suppliers may prioritize logistics.

Do you want/need to use a trusted 3rd party?

No: AutoChain does not need a trusted third party as the system used is built on permissioned blockchain meaning that authorized participants can trust the network and transactions are validated while there is transparency throughout the supply chain.

Do you need to control functionality?

Yes: To ensure that the blockchain system follows industry regulations and standards, control over functionality is necessary.

Where is consensus determined?

Intra-firm private blockchain: AutoChain has a private and permissioned blockchain network and this is where consensus is determined.

Do you want transactions private or public?

Private: Transactions in AutoChain should remain private, as they involve sensitive data such as production details, quality control records, and compliance information.

3. Actors

a) Type of Blockchain (matrix of public/private & permissioned/permissionless BC)?

The blockchain type would be a permissioned and private blockchain, as only authorized automotive industry participants such as OEMs (Original Equipment Manufacturers), suppliers and regulatory bodies are able to access transactions. AutoChain ensures unauthorised access is prevented and protects any sensitive data regarding the supply chain. The reason why a private blockchain is important is because the automotive industry usually requires trust between stakeholders, very tight data control, adherence to safety and quality standards, and a public blockchain can not provide that effectively.

b) Which Actors Are Involved?

1. Validators, they would be the OEMs (Original Equipment Manufacturers), Suppliers, and other stakeholders responsible for verifying, registering and maintaining the transactions of parts.
2. Nodes, which would be, logistics providers, and the authorized dealership of AutoChain that operates the blockchain nodes providing security.

3. Administrators, a governance group that ensures compliance with AutoChain's rules and updates. Note: This would not be considered a third party since the governance group are AutoChain owners.

AutoChain only would allow verified industry participants to access the transactions to ensure high security and efficiency, unlike public blockchains which rely on miners. (Hyperledger Fabric, 2023).

c) Who May Read Data in the Blockchain?

1. Manufacturers & Suppliers would have complete access to track parts, production details and any other statuses.
2. Logistics Providers can not modify the blockchain data but can only track shipments.
3. Administrators (AutoChain owners) can access compliance reports to ensure all the industry standards are adhered but do not have access to blockchain data.

Accessing data in AutoChain is not lenient and is based on permission levels. This prevents any data leaks, and privacy concerns which are often issues in public blockchains. (Casino, Dasaklis, & Patsakis, 2019).

d) Who May Validate Data in the Blockchain?

1. Manufacturers and OEMs (Original Equipment Manufacturers), validate the production details, quality control records and integrity of the parts.
2. Suppliers validate integrity of the parts, material sourcing and any handovers.
3. Administrators verify if there is compliance with the ISO and other standards for the automotive industry.

AutoChain uses Proof-of-Authority (PoA), not everyone can validate the data. The PoA model can ensure more secure and faster transactions than Proof-of-Work (PoW) or Proof-of-Stake (PoS) that is used in public blockchains. (Mdpi, 2021).

e) How Are Users/Actors Registered on the Blockchain?

1. Manufacturers and suppliers have to surpass a know your customer (KYC) verifying process and own industry certifications.

2. Regulatory Bodies can be registered through proof of employment.

3. Logistics Providers have to be registered with supply chain partners including specific roles.

AutoChain will ensure strict identity guidelines making fraud close to impossible (BMW Group, 2021).

f) Are There Any Intermediaries Cut Out?

Yes there are some intermediaries cut out including some traditional intermediaries like third party part authentication services, paper based verification processes and any middlemen that would be responsible for tracking or authenticating parts.

The cutting of the traditional intermediaries reduces operational delays and lowers the risk of supply chain fraud as well as any extra costs of labor or losses (Volvo Cars, 2020).

g) Who Is the "Boss" of the Blockchain (Is There Any)?

AutoChain's decentralized governance model, would be managed by the automotive industry association, so there is not one boss to be exact.

The governance would be shared with: OEMs (Original Equipment Manufacturers), (like Porsche, Mercedes etc.), Suppliers (like Forvia, Bosch), Regulatory Agencies and Logistics partners (DHL or others).

Decision-making would also be decentralized as no single entity can control the blockchain and changes have to be approved by every member of the blockchain.

This collaborative governance model makes sure that not one stakeholder can manipulate the system to their advantage, making AutoChain a trustworthy and transparent solution (Mdpi, 2021).

3. Technical

a) Type of Blockchain (matrix of public/private, permissioned/permissionless BC)?

In the case of AutoChain, the most fitting type of blockchain is a Permissioned Private Blockchain. In private blockchains nodes share the same ledger and the permissions have to be granted (Polge et al., 2020). Additionally, they are immutable, which brings a level of transparency which is crucial for all stakeholders in the supply chain. The importance of the blockchain being permissioned lies in the fact that the privacy needs to be assured. As the blockchain concept needs to ensure the highest level of data protection for all above-mentioned parties, only those parties which are directly involved in the supply chain process will have access to the system. This is especially important from the industrial and technical perspective, as the engineering design of the parts and quality control records need to be protected from the public.

b) What will be agreed in the consensus?

AutoChain consensus will focus on ensuring that each individual part is registered on the blockchain, as well as on the transfer of ownership, updates of the supply chain and the timestamps (parts transfer and time of shipment and receiving of parts). As the consensus is used to keep the blockchain concept independent of a central authority and preserve agreement among the nodes in the network (Lashkari & Musilek, 2021), it will require for the stakeholders such as manufacturers and logistic providers to achieve the mutual agreement. This will increase the level of security in the following ways:

1. The transfer of ownership will be clearly defined. All of the parties involved will have to define and agree on the exact moment when each of the parts changes the owner (for example, from the supplier to the logistics operator, etc.)
2. Each automotive part will be authentically registered on the blockchain and each party will be able to check the correspondence to the other party's claims (technical specifications).
3. The supply chain quality control and inspection data will be stored in a central system accessible to all relevant stakeholders, and only to them. This means that for any updates on the supply chain (for example, changes in the quality control protocols), there will need to be an achieved consensus first.
4. All of the timestamps will be defined and checked by all parties involved.

c) How is immutability achieved?

A block in the blockchain is considered to be immutable when it is not possible to change it or erase it (Landerreche et al., 2018). This allows for nodes to reach consensus on the complete state by only agreeing on the most recent changes of the state (Landerreche et al., 2018). In the case of AutoChain, the immutability is achieved through cryptographic hashing and permissioned access control. Cryptographic hashing in each of the blocks that store the data of a particular automotive part (technical specifications, shipping date, transfer of ownership etc.) is contained in the following block, which makes any unauthorized alterations evident. As it has already been discussed, Permissioned Access Control prevents unauthorized changes from happening.

d) Is there a Token/Cryptocurrency? Why is it Needed?

There is no need to have a cryptocurrency, as monetary transactions are not controlled by the blockchain. Rather, the data concerning the movement of the parts through the supply chain is stored in the blocks, where all other financial aspects take place outside of the blockchain system. The smart contract solution can be implemented, but it is just an addition to the system and it will be discussed further in another section. However, digital tokens which represent part ownership (during the process of changing hands from one stakeholder to another) will ease up the tracking process. Each part will have a digital certificate verifying its authenticity and the history of quality control checks.

e) How is Consensus Achieved? (Consensus Algorithm)

The main purpose of the consensus algorithm is to enable the system to ensure the consistency, security and the stability of the blockchain while enabling the system to achieve the consensus (Zhong et al., 2023). If there are malfunctioning nodes in the system, they can be split into Byzantine fault nodes (nodes that publish error messages to other nodes or do not let the consensus be achieved) and non-Byzantine fault nodes (the nodes which crash and become unusable) (Zhong et al., 2023). Therefore, the most fitting consensus algorithm for AutoChain would be the practical Byzantine fault tolerance (PBFT). This algorithm would prevent the malicious tampering with the confidential technical data connected to the automotive parts and it would require less processing power compared to PoW (Proof of Work), as there would be no mining involved. The algorithm is designed to work even if there are some Byzantine fault nodes present in the overall well functioning chain (Zhong et al., 2023). In the case of AutoChain this means that there are multiple rounds for each node before the consensus is reached. The only downside to the PBFT is that there is a high level of communication needed to reach the consensus, which makes it less scalable. However, in the case of AutoChain, the increased level of communication is necessary to ensure the security and data protection and, therefore, the high-level scalability is traded for higher level of security.

f) Which Data is Stored in a Block?

In AutoChain, each block contains the following information:

1. Nonce - The unique, proof-of-validation number.
2. Block number - The number of the block in the sequence
3. Previous Block Hash - As it has already been mentioned, the hash of the previous block will ensure immutability and the integrity of the chain. This means that even the actors with the access to the chain

don’t have the right to change the chain without the consensus, keeping the integrity of the chain intact.

4. Current block hash - The unique cryptographic hash of the block
5. Automotive part details - Part ID, manufacturing and engineering details (technical drawings, quality control records, production date)
6. Supply chain events (inspections, dates of movement along the supply chain, transfer of ownership)
7. Compliance with regulations

g) Discussion of the Blockchain Trilemma (Security, Decentralization, Scalability)

Security - As it has been already discussed, security is a definite priority for AutoChain. All of the involved parties, including the manufacturing, suppliers, logistics providers, and other supply chain participants handle sensitive data that needs to be secured in the blockchain. This pillar of the Blockchain Trilemma is prioritized over the other two.

Decentralization - Decentralization is not fully achieved, since AutoChain has controlled participation. The upper management and key stakeholders make the decisions on accepting new participants, which limits the fully decentralized system. However, after being added to the blockchain, all of the decisions need to reach a consensus, which still makes AutoChain a decentralized system.

Scalability - The choice of the Consensus Algorithm makes the scalability medium priority for AutoChain. As it has been discussed under point e), there is communication overhead which limits scalability. However, since AutoChain does not need to scale to a large number of users like the public blockchain would, this limited scalability is an acceptable trade-off for the increased security level.

h) How can we Update the blockchain software? (Forks)

A blockchain fork is created when two miners independently discover and broadcast a new block with the same reference to a previous block (Yiu, 2021). There are two types of forks: hard forks and soft forks. When a big change occurs and is no longer compatible with the old runes, a hard fork is introduced, and this requires everyone using the blockchain to adapt to the new version (Yiu, 2021). A soft fork, unlike a hard fork, allows for the usage of the old and the new versions. (Yiu, 2021) For example, Bitcoin introduced an update called Segregated Witness (SegWit) to improve transactions, but did not invalidate the blocks that were mined from the earlier runes. This is the case for AutoChain. Whenever there is a way to improve a certain feature, such as part-tracking features, not every stakeholder and miner would need to

upgrade to the new rules immediately. However, all nodes will transition to the new version over time. Collaboration and strategic planning are needed in AutoChain to ensure a smooth process in regards to how to utilize forks.

i) Could - depending on the concept (extra points possible):

i. Smart Contracts

Smart contracts are used in a blockchain based system as they help in executing transactions with specific agreements more easily. (Al-Saif et al., 2021) By using smart contracts, AutoChain automates supply chain agreements, which has an effect in reducing manual paperwork and disputes. For example, a car's part goes through the supply chain and reaches its destination, and its authenticity is confirmed, payment is automatically made to the supplier by the system or contract. There are predefined conditions that must be met for smart contracts to execute payments automatically. For instance, when an electronic vehicle confirms receiving the energy it requests, the energy provider instantly gets money by the use of smart contracts (Al-Saif et al., 2021). For AutoChain, if a car manufacturing company requested a specific part that has its own quality standard and the part that arrives meets these requirements, the blockchain system instantly releases payment to the supplier.

5. Discussion

a. Do you really need a Blockchain?

The automotive sector is one of the most advanced and highly complex industries and it integrates numerous Industry 4.0 technologies such as IoT-connected vehicles, robotics, and cyber-physical systems (Fraga-Lamas and Fernández-Caramés, 2019). Having this complexity creates the need for reliable and transparent data management among various stakeholders (Fraga-Lamas and Fernández-Caramés, 2019). Blockchain is needed in the automotive industry as it plays a crucial role in solving major challenges such as counterfeit parts, lack of transparency and insufficiency in traditional record-keeping.

AutoChains JIT tracking feature ensures the punctual delivery of each component. In this industry even a one-minute delay in the supply chain can result in huge losses financially. This feature makes sure that each shipment arrives exactly when needed. Real-time, immutable tracking is used by AutoChain and this gives the participants of the supply chain full transparency regarding the movement of inventories. Manufacturers and suppliers can rely on this feature to get up-to-date shipment information and they can align their

operations dynamically to have the materials readily available and reduce excess storage costs.

Counterfeit parts are one of the biggest issues in the industry as they pose financial risks for manufacturers and severe safety risks for consumers. From research, it can be inferred that traditional supply chain management systems face difficulty when it comes to effectively detecting and preventing the circulation of fake components. That is why a reliable tracking system is needed to ensure that the parts used are authentic. AutoChain's technology uses a system that helps record each component's journey securely and this reduces the risks that are associated with counterfeit products (Surjandy & Rahmanda, 2019).

Eliminating manual record-keeping, blockchain benefits the industry in cost minimization. By using real-time tracking of parts and smart contracts companies benefit from reduction of costs, faster operations, and a more streamlined supply chain. (Fraga-Lamas & Fernández-Caramés, 2019).

The centralization of different traditional databases gives a chance to manipulate or delete data and this creates difficulties to establish trust among the different entities. The immutability of blockchain fixes this issue, as a record that is once added cannot be altered or erased, and all the entities in AutoChain are able to establish the trust needed to foster a secure and reliable environment.

b. Is there a unique selling point?

When comparing AutoChain to generic blockchain solutions, it can be seen that it is tailored for the automotive industry by addressing the specific challenges faced on a day to day basis. Having a multi-tier supply chain, JIT manufacturing, and by meeting strict regulatory standards, AutoChain improves transparency, eliminates counterfeiting, decreases financial loss, and streamlines the entire supply chain, making it an essential tool for manufacturers, suppliers and stakeholders.

When compared to traditional supply chain solutions which depend on centralized databases, AutoChain reduces the vulnerability to fraud and inefficiencies.

The end-to-end transparency of AutoChain sets it apart from other supply chain solutions. While many other supply chain solutions lack visibility for all stakeholders, AutoChain uses RFID technology and this allows the automotive parts to be tracked in real-time from production to final delivery. Making sure that only verified and authentic components reach the market is the aim of this method. This in turn will decrease the risk of counterfeit parts

that could potentially cause safety concerns and have negative effects on the finances of manufacturers and consumers. Thus, this will enhance the trust consumers have while also helping manufacturers comply with regulatory standards.

The other factor is the use of smart contracts. When AutoChain is using smart contracts, it is removing manual paperwork and third-party intermediaries and this will help in cutting down costs and improve efficiency. One example given above explains that once a part has been delivered to a customer where it is verified as authentic, a payment is automatically triggered by a smart contract. This process will reduce delays and disputes in payment and compliance with industry standards proving that AutoChain is a transformative solution for the automotive supply chain.

Limitations

Scalability is a limitation for Autochain. Since AutoChain favors security over scalability, as the number of actors and transactions grow, the consensus process may slow down. A lot of suppliers and manufacturers being located in different places could make this problem worse.

Additional Insights - Attack Scenarios

Since security attacks are a challenge faced by blockchain systems, AutoChain has been designed to address these problems. The primary attack scenarios are sybil attacks, 51% attacks and double-spending. To mitigate sybil attacks, AutoChain uses a permissioned blockchain that consists only of verified participants. In addition, each participant goes through a Know Your Customer process to make sure they are legitimate. This significantly reduces the risk of sybil attacks. Using the Proof of Authority consensus mechanism makes it difficult for a single party to control more than 50% of the network, making it nearly impossible to launch a 51% attack, especially when compared to public blockchains. By using a secure and immutable ledger, AutoChain eliminates double-spending.

Conclusion

AutoChain is an innovative solution for transparent tracking of automotive parts across the supply chain. It is a private and permissioned type of a blockchain which has security as a main priority. It increases the operational efficiency, saves time and eases up the process of pinpointing problematic supply chain areas, which makes it easier to mitigate risks and improve the trust between suppliers, manufacturers, and logistics providers.

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