Frankfurt School Blockchain Center

APRIL 2018

FSBC Working Paper

Analysis of Blockchain Technology in the Mobility Sector

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Since the creation of the first automobile by Carl Benz in the year 1886, various emerging technologies and trends, that disrupted and completely changed other industries, have passed the automotive sector unmolested. With focus on the prolonging value chain of connected cars, a radical change is to be expected due to new emerging information technologies such as blockchain. This paper provides a proposal for the evaluation and categorization of blockchain use cases, as well as a brief overview over promising use cases in the mobility sector and their challenges.

Being seen as the digital universal weapon, blockchain technology might be the answer to security and privacy concerns in the area of payments and smart contracts. Blockchain technology had its first appearance in the financial sector as a crypto currency. Now, various companies and start-ups from different industries are engaging in the realization of projects, whose functionalities extend cryptocurrencies by far. Blockchain technology can simplify, optimize and automatize many different processes. But which implications does it have on the mobility sector?

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„It is a real challenge to find a use case which is suitable for the implementation of blockchain technology and where blockchain provides a surplus in value."

Blockchain analysis. There are many use cases, that can be realized using blockchain technology. But from the economic and technical perspective, the realization doesn't make sense every time. Therefore, you will find a proposal for the analysis of potential blockchain use cases on suitability in the following. This analysis aims less on technical specifications and the blockchain protocol which is to be used. Rather the parameters and circumstances of the use cases which determine the realization are to be examined. Therefore, four criteria were identified and presented in Table 1. The higher the criteria are developed in the use case, the higher is the added value when implementing blockchain technology.

Table 1

Criteria for the evaluation of blockchain suitability

Criteria	low	medium	high
Multi-party process	– 1 to 3 stakeholders	– 4-10 stakeholders	– More than 10 stakeholders
Single-source of truth	– No matching of data between parties necessary	– Matching of data with blockchain, but no central function	– Added value is based on matched data from the blockchain
Missing trust	– Existing trust between stakeholders	– Stakeholders know each other, but don't trust each other	– No existing trust
Open ecosystem	– No open ecosystem, closed process	– Mostly closed process with connections to other areas	– Open ecosystem, unlimited access

Blockchain technology has a lot of different characteristics, that are suitable for many different purposes. With the following categorization, a clear assignment of the use cases according to their characteristics is supposed to be enabled. This might help to develop a general understanding of blockchain technology in the mobility sector. The identified characteristics are shown in Table 2.

Table 2

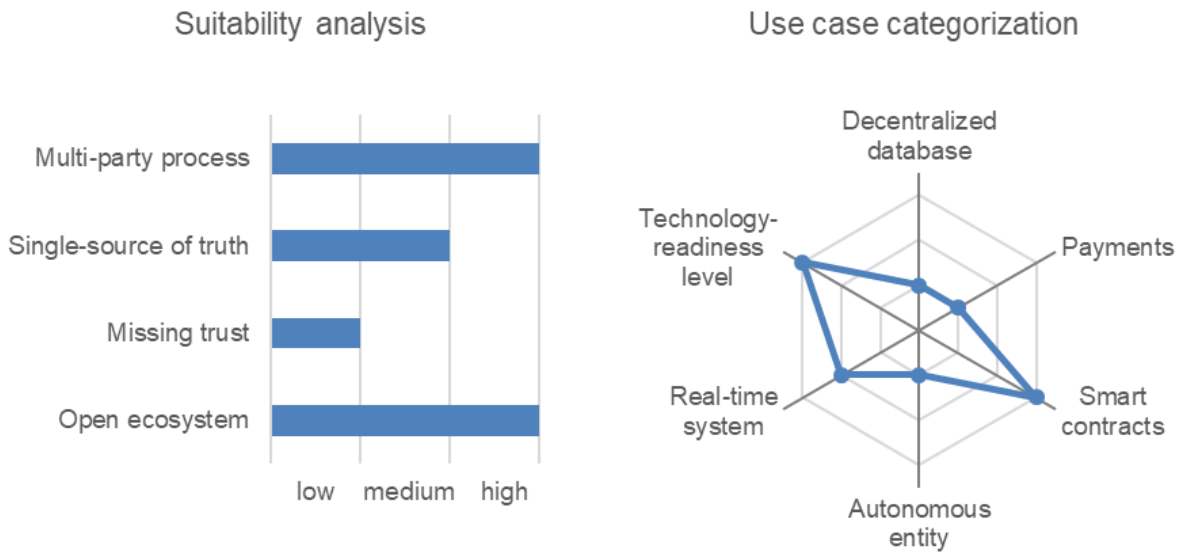
Characteristics for the categorization of the use cases

Characteristic	low	medium	high
Decentralized database	– Pure database functionalities not in focus	– Database functionalities required	– Database functionalities are essential feature
Payments	– No payments	– Payments included but no central task	– Payments are central functionality
Smart contracts	– No automated processes	– Partly automatized processes with smart contracts	– Completely automated processes
Autonomous entity	– No autonomous decision-making	– Low degree of freedom in decision-making	– High degree of freedom in decision-making
Real-time system	– Time to validation neglectable	– Time to validation max. 10 minutes (Bitcoin)	– Time to validation max. 20 seconds (real-time)
Technology-readiness level	– Technology available in more than 5 years	– Technology available in the next 2-5 years	– Technology available in less than 2 years

To simplify the display of this analysis, the evaluation of blockchain suitability is illustrated in a bar chart. The categorization of the use cases is illustrated in a spider chart. Examples of both illustrations are shown in the following Figure 1.

Figure 1

Example use case analysis



Blockchain use case: car-wallet and payments

With an integrated Wallet-App, cars are enabled to make payments on their own. With blockchain, payments concerning every aspect of the car's mobility can be executed fast, secure and automatically. Especially regarding coming car generations with advanced autonomous functions, the automation of payments and their integration into the vehicle gains more and more importance.

EV charging-payments. One of the most mentioned payment scenarios is EV charging. During short term charging at traffic lights, very small amounts of power are being charged through inductive loops in the ground. The charging process itself would have a volume of a few cents. But with blockchain technology even those small transactions can be realized profitably.

Platooning. The digitalization and networking of automated vehicles is a key element in the increase of efficiency. Cars need to communicate with each other to, for example, buy data for the optimization of their operational

strategy. At the so-called *Platooning*, several vehicles drive behind each other in very close distance. Safety is ensured by the communication of the involved vehicles and the real-time exchange of sensor data. The reduction of the distance between the vehicles leads to significant savings in terms of consumptions due to reduced wind resistance of the following vehicles. In general, these savings need to be passed on to the leading vehicles as well. Without having any savings itself, this vehicle leads the platoon, detects and bypasses potential dangers and shares its sensor data with the other vehicles. With a smart contract on blockchain technology, the payment process could be securely automated with real-time data. In addition to this, transportation infrastructure could negotiate with the vehicles on the streets in order to optimize the traffic situation. Thus, it would be possible, that such a platoon buys a green wave as a premium product to further increase energy savings and reducing traffic volume. Besides the payment function, blockchain technology could help validating the sensor data communication.

Temporary vehicle functions. In the automotive industry it is common that extra equipment in cars needs to be bought with the initial order. A later upgrade is mostly unavailable or involves a great deal of expenses. Blockchain technology could enable the temporary activation of extra equipment. Therefore, the vehicles need to be fully equipped ex-factory. Users then can unlock various extra features for a limited period of time via a smart contract, directly when they need it. For example, if the user is on a long highway trip, he could unlock cruise control for the length of his journey, which he wouldn't need in his daily routine. Besides additional income through the unlocking of the extra equipment, automakers too can achieve economies of scale through the plus built in components. In this scenario, blockchain technology enables secure payments and the safe and unmanipulable unlocking of extra equipment via a smart contract.

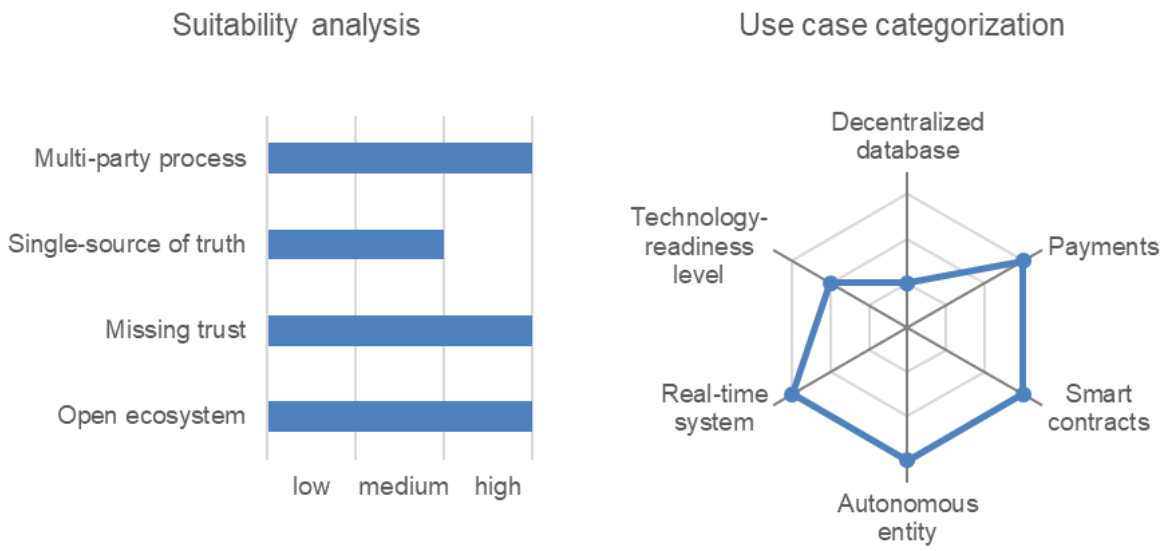
The presented use cases and scenarios for the car-wallet and payments are multi-party processes with many possible participants. Blockchain technology provides the single source of truth, because validation of payments can only be done this way. Trust between the stakeholders is non-existing due to the fact that either the parties don't know each other or one of the participants is a machine. Yet you will find an open ecosystem with low entry barriers.

The data base functionality is not essential in this use case. Instead the execution and validation of payments and smart contracts is the central

element of this use case. Together with artificial intelligence, the vehicle can be developed to an autonomous entity. The necessity of a real-time system has been shown before. The technology readiness level is estimated as medium, due to the fact that some firms already started working on the realization of these features, but the entire mobility sector needs to be involved[1] (see Figure 2).

Figure 2

Use case analysis car-wallet and payments



Blockchain use case: smart insurance

A vehicle black box enables the exact documentation of the vehicle status. Blockchain technology enables the unmanipulable and transparent logging of the vehicles' sensor data in a decentralized network. With regard to coming autonomous vehicles, this unimpeachable documentation of a blockchain black box could help to resolve the circumstances of an accident. In theory, blockchain technology could enable insurances to be unbound to the vehicle due to the logging of sensor data. The insurance could be taken along into other vehicles like a user profile, for example in carsharing.

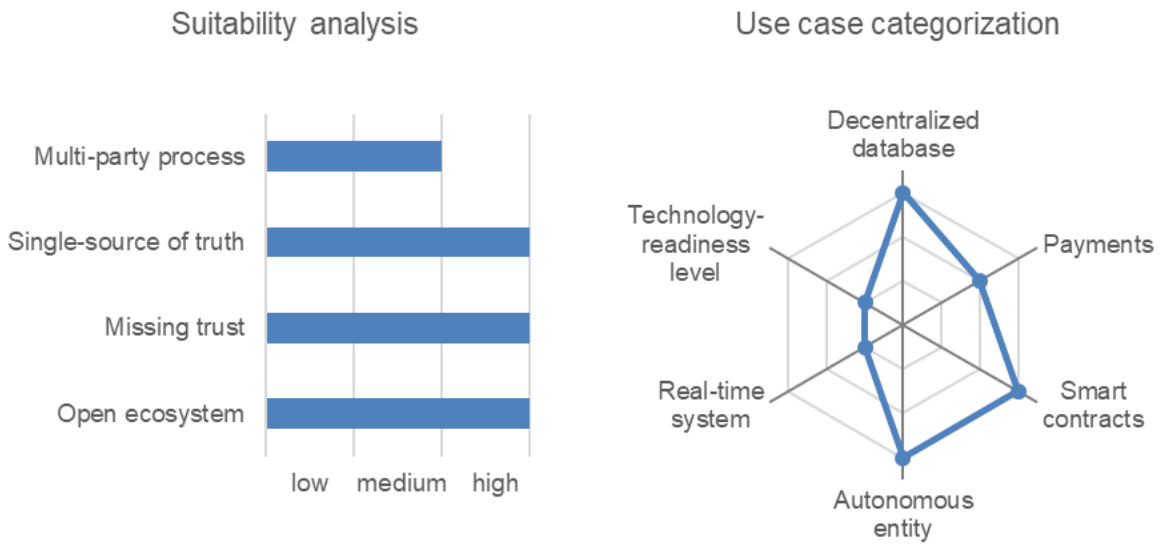
Insurances consider in their rates neither driving style, travel time, route nor frequency, although this data is available real-time in most cases due to connected cars. In a smart contract, this data could be processed inside the car and implemented into the insurance plan. In such a smart insurance, various clauses relying on data from the car can be implemented and are activated by certain triggers. Thus, PAYD or usage-based tariffs can be realized on a secure data basis from the car or respectively the blockchain black box. Another promising scenario is located in freight traffic. Depending on location and route, there are various risks, like robbery or vehicle or freight damage due to bad roads. With a smart contract, the insurance plan could be adjusted according to the real-time risks.

A smart insurance is usually a multi-party process with few participants. The circle of participants is limited to insurance company and reinsurer, owner and driver. All parties trust on the data from the blockchain black box, which represents the single source of truth. Furthermore, there is no trust between the parties. In this open ecosystem, every vehicle can start collecting data in a blockchain black box, which the insurance company can access to provide the smart contract.

In the presented use case Smart Insurance, the focus lies on the decentral database functionality. Payments and smart contracts are implemented as well. Vehicles are becoming autonomous entities with a limited degree of freedom. Real-time functionalities are not in the focus. Technology readiness level is to be evaluated as low (see Figure 3).

Figure 3

Use case analysis smart insurance



Blockchain use case: self-owning car

The concept of the self-owning car was introduced by Mike Hearn, a Google employee, in 2013. As a self-owning car, the vehicle represents an own financial entity. Besides natural persons, only corporate entities are able to close a deal. One reason for this circumstance is the missing trust between the parties. Natural persons, as well as corporate entities, are liable and tangible, which machines are not. This missing trust can be replaced with blockchain technology. The vehicle has due to blockchain technology its own accounting identity and with enough artificial intelligence, it becomes an autonomous entity. Under certain circumstances, the vehicle is able to earn and spend money. A human decision maker is becoming redundant due to the implementation of artificial intelligence. Revenues can be achieved with carsharing, expenses emerge by repairs or charging. The advantage for the customer is the omission of the payment and accounting process, especially in corporate fleets. The vehicle itself can publish a detailed record of all transactions at the end of the month, bills are being paid instantly.

With blockchain technology and artificial intelligence, vehicles can maintain themselves for the first time in history. This opens completely new possibilities of vehicle ownership. Incentives to buy a car could vanish, because of the high availability of P2P-Carsharing via blockchain and the decrease of individual costs for mobility. As soon as the incentives decrease, the number of cars on the street would also decrease. This is the point where blockchain once again gets into the game. Theoretically, vehicles can be kept as independent firms.

Therefore, two scenarios are created. On the one hand side it would enable suppliers, OEMs and workers to charge their performance and output directly to the vehicle's account. Instead of receiving a compensation, they turn into shareholders and receive a constant revenue share of the car, which is offering P2P-carsharing to the public. Effects on the financial situation and tax regulations need to be examined individually. Instead of buying a car, customers or companies could become investors into such self-owning cars by acquiring shares via a Decentralized Autonomous Organization (DAO)[2].

At both scenarios, it is possible to implement temporal limitations. The self-owning car tries to pay back the investments including an appropriate yield in the time permitted. After X years and the successfully paid off investment the car doesn't need to make profit anymore due to missing stake- and shareholders. Therefore, it could offer individual mobility at net cost price.

The advantages of blockchain technology in this scenario can be summed up as the following: the vehicle becomes a financial entity; missing trust is replaced by blockchain technology. The self-owning car is able to make transactions and maintain itself. Thus, the effort for accounting and payment processes decrease and new possibilities of vehicle ownership arise.

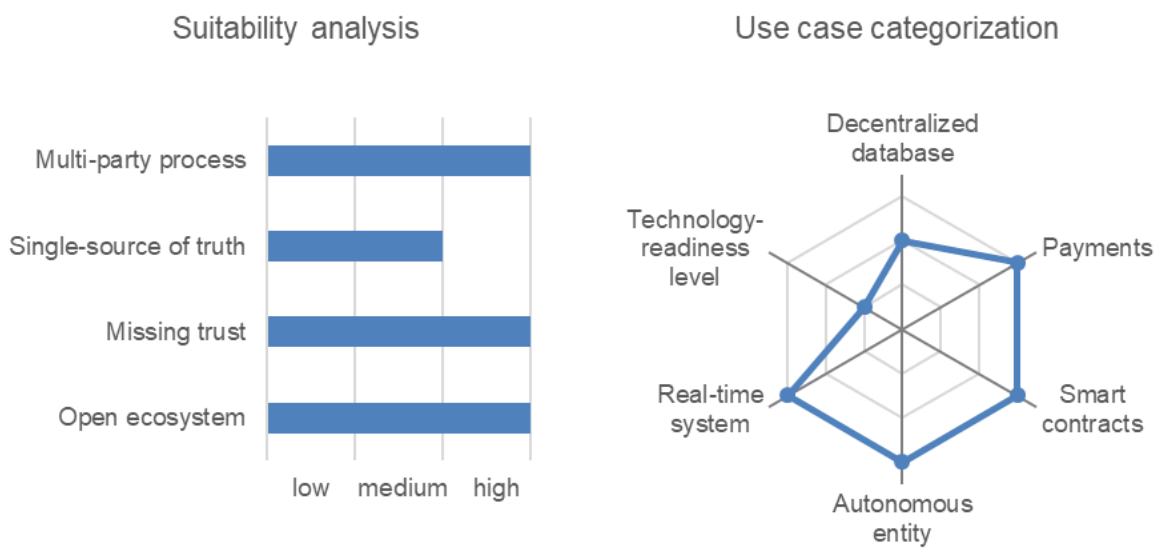
Is there enough artificial intelligence in the self-owning car, it can participate in carsharing, negotiate fares and create revenue. The blockchain technology enables the car to act as an autonomous and financial entity. Corporates or private persons can become investors and shareholders via a smart contract or a DAO.

The self-owning car can start transactions with many different parties. Blockchain as a single source of truth matters less in this scenario. As at least one party is a machine, trust can't be existing in the process. The self-owning car is an open ecosystem, which everybody can participate in.

With the implementation of different accounting features, the self-owning car is a decentralized database, which functionalities are not in the focus. Different payment scenarios and smart contracts as well as a huge degree of freedom in the decision-making process mark this use case. A real-time system is essential to the self-owning car. The technology readiness level is to be estimated as very low (see Figure 4).

Figure 4

Use case analysis: self-owning car



More promising blockchain use cases in the mobility sector

Digital twin. The recording of data of components in a decentralized database offers the possibility to ensure congruence between data of assets in the real world and those in the database and therefore creating a digital twin. Recorded data could include manufacturer, seller but also the mechanic's name or real-time data about the components status. This way a

transparent and secure proof of origin could be created on this open blockchain ecosystem.

Leasing and vehicle financing. Smart contracts could optimize and automate various processes in the vehicle leasing and financing section. For instance, it is possible to prevent that cars, whose leasing rates haven't been paid yet, are being used by deactivating the unlocking system.

Carsharing. Blockchain technology could enable a secure digital identity at carsharing. A single registration in the blockchain ecosystem carsharing is good to be used for all carsharing offers from different service providers in the ecosystem. While using carsharing, the user generates a lot of personal data. In the blockchain ecosystem, data sovereignty would go back to the user since encryption ensures that there is no linkage between the real-world identity and the one in the blockchain ecosystem. This way, user profile roaming would be possible, too. Personal settings and preferences could be saved in the car without any concerns of becoming a transparent customer. Both features could also be very exciting in P2P carsharing.

Keyless authentication. Via a smart contract, vehicles' access rights and rights of use could be easily managed. More functions like local and temporal limitations enabling P2P carsharing can be implemented. The rights then can be assigned to anyone participating in this open blockchain ecosystem. This function might lay the foundation for a lot of new services.

Infrastructure sharing. Sharing Economy won't spare mobility infrastructure. By establishing a new blockchain ecosystem charging, problems in the transaction settlement between the parties could be dissolved. Charging providers connect their stations to the open blockchain ecosystem[3]. As a result, entry barriers for customers, mostly in the form of several RFID cards and different accounts, are omitted by participating in only one ecosystem. In this ecosystem, private charging spots could be easily integrated as well. This way, network coverage could be improved by far.

Mileage database. By continuously uploading data into the blockchain, a transparent, anonymous and manipulation proof database for mileage can be established. The upload of data can be done either in the repair shop or

autonomously by the vehicle itself. As a result, odometer fraud can be prevented. With the aid of a blockchain certificate, it can be proofed that the mileage shown in the odometer in the car equals the real driving data.

Digital service record. An extension to the mileage database could be the digital service record. In the same way as the mileage data, workshop visits and repairs can as well be recorded in the blockchain. The traceability of the data could improve resale value. Blockchain technology offers a completely open ecosystem, where free and authorized repairer as well as the manufacturer use one open ecosystem.

Challenges of blockchain technology

On its way to mature products and services, blockchain technology is facing a lot of challenges. In the following tables 3, 4 and 5 some of those challenges are presented from the technical, economic and regulatory point of view.

On the technical side, scalability is the most frequent named challenge. Common blockchain systems don't have the capacities, which are required for a mature product or service up to this date.

Not only technical but also economic challenges have to be overcome. To realize a service, a profit needs to be expected.

Table 3

Technical challenges of blockchain technology

Criteria	Description		
Scalability	– Enormous data quantities in every node → Blockchain-Bloat[4]	– Vehicle as a node doubtful, CPU-resources used for other purposes (assistance systems, autonomous driving)	– Amount of transactions per second not on the level of central systems (VISA/MasterCard)
Stability of the systems	– Ethereum-Client often crashes	– Documentation and debugging are expandable	– Missing functionalities in the programming languages
Security management for private keys and passwords	– Security Management in Prototype status easy, the bigger the project, the harder it gets	– Who owns the rights to reset a password?	– What happens to the assets, if passwords can't be reset?
Standards and standardization	– Different Car-IT-Systems of OEMs	– No standard for Car2X-communication	– Consistent data communication in open systems necessary
Integration in existing systems	– Limited capacities in the vehicle, high energy consumption due to network synchronization	– CPU-resources in the vehicle are being used for other purposes	– Creeping migration into existing IT-systems necessary
Real-time systems	– Transaction time for some use cases very low	– Offline-transactions need to be possible (parking garage/tunnel)	– Public blockchains unsuitable due to high background activity

Table 4

Economic challenges of blockchain technology

Criteria	Description		
Profitability	– Transaction costs are central profitability criteria at payments	– Proof-of-Work-mechanism is enormous waste of resources	– Alternative consensus mechanisms like Proof-of-Stake or Sidechains could be considered as possible solutions
Dependency on cryptocurrencies	– Criteria for the calculation of transaction costs on Public Blockchains	– Extreme fluctuation in price, cf. XBT[5] or ETH[6]	– Introduction of fiat-backed[7] crypto currencies desirable
Skilled worker shortage and professional exchange	– Few specialists in blockchain technology on the market (programmer, architects, managers)	– Professional exchange aggravated due to lack of platforms	– Shortage in advanced training offers of universities and colleges
Competition	– Difficult shift of mind: collaboration instead of competition	– Asia and North America are a lot more likely to invest and to innovate	– Lethargy and everlasting decision-making process in big industry firms slows down development
Development horizon and life span	– Development horizon totally unclear, life span not assessable	– Vehicle as ever-lasting product: 4 years of development, 6 years of production and 10 years in the market	– Services based on blockchain need to last for 16-20 years versus young technology

In order to establish products and services based on blockchain technology, it is inevitable to set the right boundary conditions., which don't exist yet. Therefore, it is necessary that universities and colleges, as well as the politics, start participating in the discussion and development of blockchain technology and take the initiative in setting the right conditions.

Table 5

Societal and regulatory challenges of blockchain technology

Criteria	Description		
Privacy and digital identity	– High degree of privacy and anonymity due to encryption in blockchain technology	– EU-Directive: all personal data must be able to be deleted	– Deletion of personal and encrypted data nearly impossible
Understanding, awareness and hype	– Technical comprehension of blockchain technology essential for profound decision making	– Lack of competence in blockchain technology in top management and politics	– Negative reputation of Bitcoin influences decision making process
Consumer trust	– Consumer trust is another key criterion for the success of blockchain technology	– First prototypes should extend and not limit consumers' possibilities[8]	– Customers need no technical understanding, but should rather trust in security and anonymity of blockchain

Conclusion

With blockchain technology, even the smallest transactions can be executed at minimum costs. As a result, business models with a strong dependence on transaction costs, like the inductive charging at traffic lights, are becoming feasible. Blockchain technology encourages the building of ecosystems with many participants, who share similar interests but don't trust each other because of the competition in the market. The shared blockchain ecosystem enables the cooperation of all parties and therefore leads to increasing efficiencies. Such an ecosystem might be used as a platform form charging stations, making entry barriers such as customer cards and accounts redundant[9].

The high amount of identified blockchain use cases shows the many intersections of the technology in the mobility sector as well as the high interest of the industry. However, firms are slowly increasing their research and development activities. On its way to mature products and services,

various challenges concerning technical, economical or regulatory issues are to be overcome.

This paper can serve interested readers as a basis for discussion about approaches and ideas of blockchain technology in the mobility sector. The findings of the paper can be used for identifying intersections of blockchain technology with the own environment, processes and business models. The proposed use cases are supposed to serve as motivation and inspiration.

The results shown in this paper are based upon the evaluation of 20 interviews with blockchain experts and decision makers from the mobility sector. At this point we want to thank all experts, who took their time to share their knowledge and experience with us.

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1 See https://car-ewallet.zf.com.
2 See Schlatt, V., Schweizer, A., Urbach, N. & Fridgen, G. (2016). Blockchain: Grundlagen, Anwendungen und Potenziale. Projektgruppe Wirtschaftsinformatik des Fraunhofer-Instituts für Angewandte Informationstechnik FIT.
3 See https://shareandcharge.com.
4 Elimination of nodes in the system due to lack of capacity, increasing centralization.
5 See https://coinmarketcap.com/currencies/bitcoin.
6 See https://coinmarketcap.com/currencies/ethereum.
7 Backed by escrow deposit, stable exchange rate.
8 Limitation of functionalities are unsuitable for a positive user experience. See use case leasing and vehicle financing.
9 See www.share&charge.io.