POLITECNICO DI TORINO

Department of Management and Production Engineering

Master's in Engineering and Management

Master's Degree Thesis

"Application of the Blockchain technology in the automotive industry"

Candidate:

GOLEMI Florian

Student s233401

Supervisors:

Prof. PERBOLI Guido

Dr. ROSANO Mariangela

Contents

List of figures

List of tables

Acknowledgments

First of all, I would like to thank the Polytechnic University of Turin for giving me the opportunity to be part of this great institution of knowledge. It has been an amazing journey.

I want also to dedicate a special thanks to all my professors who have taught me a lot. I still have goosebumps when I think of the moments you all inspired me, and most importantly, taught me to be humble. It has been a great pleasure sharing the classrooms and hallways with you.

I have met amazing people during this journey, you have all shaped who I am today, thank you.

Special thanks goes to Antonella Monni. Thank you for all the love, the advices, the critiques, the smiles, the food, and the support that you have given to me. I am honored and eternally grateful for having you by my side.

Last, but not the least, I would like to thank my family, for believing in me and supporting me all the way. I have learned a lot from you as well. From all your sacrifices. I love you.

Abstract

In the last couple of decades, the automotive industry has come a long way; it is now one of the most sophisticated, complex, and technologically advanced industries. It consists of innovations like electric, hybrid, and self-driving smart cars. In the age of IoT (Internet of things) connected vehicles, the industry has seen an increasing involvement of many Industry 4.0 technologies, such as manufacturing systems, robotics, advanced cyber-physical systems, or augmented reality. One such technology that can benefit the automotive industry is blockchain, which can enhance its data security, privacy, traceability, anonymity, robustness, accountability, integrity, transparency, trustworthiness, and authentication, as well as provide higher operational efficiency and long-term sustainability to the whole industry. This thesis focuses on applying blockchain technologies to the automotive industry in various areas and provides a case study of one such application. First the technology is introduced, its features and challenges are evaluated, then a literature review is done to compare how blockchain can impact the automotive industry. Finally, a use case is evaluated with various frameworks. Thus, the feasibility of blockchain is evaluated after examining the state-of-the-art in the automotive sector and devising the primary challenges stakeholders are facing. Furthermore, the thesis illustrates the most applicable use cases because the broad adoption of blockchain opens a wide area of short-term and medium-term automotive applications that are promising and can force the companies to have another look at their business models.

Chapter 1 Introduction

The automotive industry is one of the most technologically advanced industries with innovations ranging from hybrid, electric and self-driving smart cars to the Industrial Internet of Things (IIoT) integration in the form of IoT-connected cars. Under the Industry 4.0. paradigm, which represents the next stage in the digitalization of the sector, the automotive industry is facing operational inefficiencies and security issues that lead to cyber-attacks, unnecessary casualties, incidents, losses, costs and inflated prices for parts and services. Such issues are currently passed on to the different and heterogeneous stakeholders (i.e., individual and corporate car owners, service users, logistic businesses' clients or end customers) involved in the vehicle lifecycle. Industry 4.0 harnesses the advances from multiple fields, which allow for the massive deployment of sensors, the application of big data techniques, the improvements in connectivity and computational power, the emergence of new machine learning approaches, the development of new computing paradigms (e.g., cloud, fog, mist and edge computing), novel human-machine interfaces, IIoT enhancements or the use of robotics and 3-D/4-D printing. The increasing capabilities offered by complex heterogeneous connected and autonomous networked systems enable a wide range of features and services, but they come with the threat of malicious attacks or additional risks that make cybersecurity even more challenging. In scenarios where the controlled systems are vehicles or vehicle-related systems, public safety is at stake, therefore strong cybersecurity becomes an essential requirement.

OEMs digital transformation strategy roadmap is to currently develop digital services and move to a Car as a Service (CaaS) business model in the 2020s to then develop a Mobility as a Service (MaaS) model to eventually position the vehicle as an element of the future connected living solutions by 2030s. In this context, blockchain technologies represent nowadays a move in the evolution of the Internet, enabling the migration from the 'Internet of Information' to the 'Internet of Value' and the creation of a true peer-to-peer sharing economy. According to a survey report from World Economic Forum, 10% of the worldwide Gross Domestic Product (GDP) will be stored on a blockchain based system by 2027. Considering also the prospects of the automotive ecosystem, blockchain technology can offer a seamless decentralized platform where information about insurance, proof of ownership, patents, repairs, maintenance and tangible/intangible assets can be securely recorded, tracked and managed. The ensured integrity of ledgers is one of the main aspects when dealing with transactions between the participants of the automotive industry. Their accuracy and immutability are essential for enforcing real-life contractual relations, avoiding poor practices and efficiently managing the supply chain. Furthermore, the ability to access verified data in real-time opens up a realm of opportunities and business models such as the automation of processes through the Internet of Things (IoT) and smart contracts, advances in predictive maintenance and forensics, smart charging services for electric vehicles, peer-to-peer lending, leasing and financing, or the introduction of novel models of collaborative mobility or MaaS.

Although a detailed description of the inner workings of blockchain technology is out of the scope of this paper, the basic theories and concepts are provided to help the reader get an understanding of the technology. Specifically, a comprehensive overview of blockchain that emphasizes its application to IoT is provided. There is not much research work which is focused on the use of blockchain to enable cybersecurity. For instance, Dai et al. reviewed the main security issues that blockchain can tackle. Other works focused on specific security aspects. An example is presented where a cloud-based access control model is proposed. Other authors focused on user identity management for cloud-based blockchain applications. Regarding the utilization of blockchain for specific applications, in it is used to guarantee security and scalability in smart grid communications. Similarly, a Cyber-Physical System (CPS) that makes use of a payment system based on reputation is presented in. Interesting work is presented in, where a framework for fighting cyber-attacks when multiple organizations participate in information sharing is proposed. In the article, some game-based cyber-attacks are formally analyzed and validated through simulations. Finally, Ortega et al., authors review the use of blockchain and Content-Centric Networking (CCN) to ensure the security requirements for trusted 5G vehicular networks.

This work presents a holistic approach to blockchain for the automotive industry that includes a literature review on existing research. The current state of the art and how the blockchain can be applied to the automotive industry. A use case if provided and evaluated using various frameworks. The specifics of the blockchain implementation and other technical details of each use case are out of the scope of this research.

The rest of this paper is organized as follows. Section 2 discusses the concepts and jargon which will be used throughout the paper. An additional glossary is provided in the appendix. Section 3 overviews the literature and research already done by various researchers to get a grasp on state of the art. Section 4 identifies scenarios where the automotive industry could leverage blockchain capabilities to enhance security, to reduce costs and to increase operation efficiency. Section 5 discusses the various frameworks which will be used to evaluate the use case. Section 6 analyzes optimization strategies for designing blockchain-based automotive applications and studies their main challenges. Technical framework however out of the scope of this thesis is briefly discussed in Section 7 Finally, Section 8 is devoted to results and section 9 is conclusions.

Chapter 2 Concepts

This thesis is based on a new technology called Blockchain. It is really important to understand the concept behind this technology as well as related topics. There are many topics such as the Internet of Things (IOT), Artificial Intelligence (AI), etc. and jargons which are referred to extensively throughout this research. In this section some of the main concepts are explained and a useful glossary of terms is provided in the appendix. They can be consulted as a reference in the future.

2.1 Blockchain

Blockchain was initially just a term in computer science about how data can be structured and exchanged. Blockchains are known as the "fifth evolution" of computing nowadays. The distributed database is a novel technique. Innovation comes from new ways of incorporating old technologies. You can think of blockchains as distributed databases that are managed by a group of people and that store and exchange data.

Blockchains and blockchain implementations are of many different kinds. Blockchain is an all-encompassing system that is being integrated across the world across networks and hardware. The Blockchain is a ledger which helps to keep track of all transactions involved that have been confirmed. This is not, however a personal ledger that will monitor your transactions, but a shared public ledger that automatically contains all the transactions that have taken place across the entire network. This means that anybody who wishes to will have a view of all transactions around the network that have occurred.

You cannot erase your own transaction information from Blockchain, neither anyone else's. You can only write in this ever-growing network of data records that has a record of every transaction ever made. All the data records are concrete and cannot be tampered with. For example, no one can edit or delete any transaction from their Bitcoin wallet or from anyone else's; once included, that information is forever there to stay.

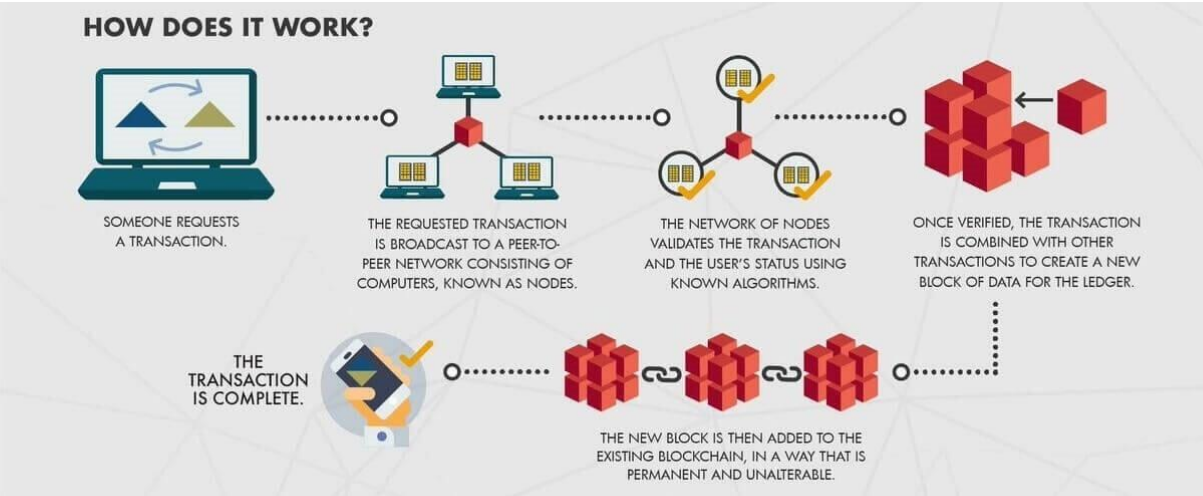

Figure 1: The process of Blockchain

In the absence of an intermediary that you can trust, i.e. a reputed bank or any other financial institution that plays a role in our transactions - it is the concept of Blockchain that can put the security back into this process. One can also flip this around and also consider the many instances in financial history where the third party themselves were attempting to carry out fraud in transactions, and so Blockchain eliminates this risk.

Also, without this intermediary, transactions can be almost instant. Frequently, there is a significant waiting time for an intermediary to process the transaction. Blockchain transactions can be processed almost instantaneously.

2.1.1 Types of Blockchain

Public blockchains: Public blockchains, such as Bitcoins and ethereums, are large, distributed networks that are run via a native token. They're open for anyone to partake at any level and have open-source code that their community maintains.

Permissioned blockchains: Permissioned blockchains, such as Ripple, etc. control roles that entities can play within the network. They're still huge and distributed systems that use a native token. Their source code might or might not be open-source.

Private blockchains: Private blockchains are usually smaller and do not employ a token. Their membership is closely controlled. These types of blockchains are preferred by consortiums that have trusted members and trade confidential information.

Although the concept of Blockchain was introduced to implement total transparency into Bitcoin transactions, sometimes the need to limit access - especially in the case of writing and creating Blockchain entries - arises. This is why the two other types of Blockchain apart from public Blockchain were introduced - to allow individuals and institutions to limit their transactions to themselves and not let outsiders edit or compromise their internal Blockchain.

Apart from the context of visibility and ability to edit, there are two other classifications of Blockchain that you need to understand to grasp the concept.

Blockchain 1.0 is referred to when Blockchain was used mainly for financial transactions. With this, users were able to instantly send and receive cash from one another instead waiting for days for each transaction to complete. With this, the transaction fee worldwide became as low as below 1% whereas banks and financial institutions charge from 7 to 30%.

Blockchain 2.0 was expanded from the previous version to make it simpler and more transparent to the public. Blockchain 2.0 is mostly related to the contracts. It runs on a totally new protocol, appropriately known as the Blockchain 2.0 protocol. It differentiates between the asset and the programmable infrastructure. Blockchain 2.0 also grows the technology to decentralize the market to include even more kinds of assets, namely: real estate, automobiles, art, etc.

The concept of Blockchain is ever-shifting; every time a new requirement arises, Blockchain is modified to fit the requirements of the users. The evolution from Blockchain 1.0 to 2.0, newer ideas are constantly emerging, whenever needed.

2.1.2 Core of Blockchain

The blockchain sees this as a triad of combustion of the known fields of 1) game theory, 2) cryptography, and 3) software engineering. Both fields have existed independently for a long time, but for the first time, they have intersected harmoniously together and morphed within blockchain technology.

Game theory is the analysis of the conflict and cooperation mathematical models among intelligent rational decision-makers.' And this is connected to the blockchain because a known game theory dilemma called the Byzantine Generals problem had to be solved by the Bitcoin blockchain, originally created by Satoshi Nakamoto. Solving the issue means mitigating any attempts by a small group of dishonest generals who might otherwise turn traitors and lying about organizing their assault to ensure victory. This is done by incorporating a mechanism to validate the effort that has been put into the production of these messages, to ensure their authenticity, and time-limiting the criteria for seeing untampered messages. It is important to enforce a "Byzantine Fault Tolerance" because it begins with the presumption that you cannot trust anybody, and yet it offers confidence that during its trip, the transaction has traveled and arrived safely based on respecting the network while surviving possible attacks.

This new method of achieving security has fundamental consequences for the function of the transaction, as it calls into question the nature and functions of the trusted intermediaries currently held by the Conventional Transaction Validation Authority. This makes us contemplate the existential question: why do we need a central responsibility to ensure central trust if when the transaction moves from one peer to another, we can achieve the same trustworthiness through a network where trust is inserted in it?

The science of cryptography is used in different ways to provide a blockchain network with encryption, and it is based on three fundamental concepts: hashing, keys, and digital signatures. A "hash" is a specific fingerprint that helps to verify that, without the need to actually see it a certain piece of information has not been changed. Keys are used in at least two combinations: a private one and a public one. Picture a door that needs two keys to open it for an example. In this scenario, the sender uses the public key to encrypt information that can only be deciphered by the private key owner. Your secret key, you never show it. A mathematical computation that is applied to prove the validity of a (digital message or document is a digital signature.

Public/private domination, which is the yin-yang of the blockchain, is focused on cryptography: public exposure, yet private inspection. It's a bit like an address at home. You can publicly publish your home address, but that does not provide any detail about what the inside looks like in your home. In order to access your private home, you'll need your private key, and because you have identified that address as yours, no one else can claim an address identical to theirs.

While for a while the principles of cryptography have been around, software developers are feasting on integrating it with creativity in game theory, on creating the general structures of blockchains, where apparent uncertainty is mitigated with sheer mathematical certainty.

2.1.3 Blockchain proofs

The burden of proving that something happened is a blockchain specialty. The hierarchy of proof methods ranges from being embedded as part of a consensus protocol (such as Proof-of-Work or Proof-of-Stake), to Proof-as-a-Service (such as proving identity or ownership), to a Proof-in-the-Service, where proving something is part of another service (such as a land registry or a wedding registration).

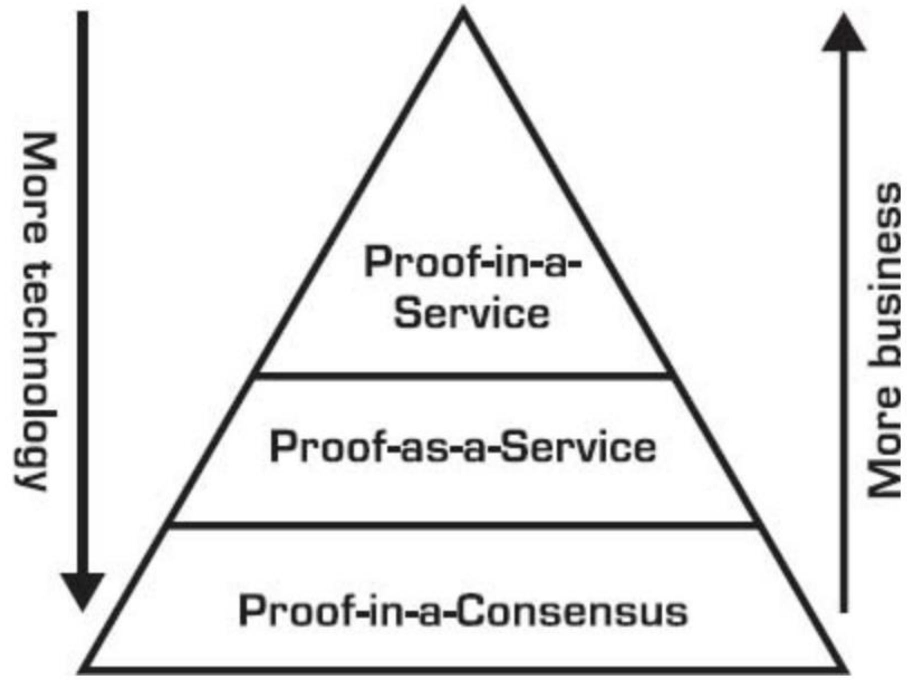

Figure 2: The proofs pyramid

2.1.4 Blockchain properties

Digital Cryptocurrency

The digital currency feature is probably the most "visible element in a blockchain, especially if for example, Bitcoin (BTC) or Ethereum (ETH), the blockchain is a public one. Cryptocurrency is typically an economic proxy of a blockchain's viable operations and protection. Often it is represented by a coin, which is another type of an underlying cryptocurrency's associated representation.

One of the difficult issues with cryptocurrencies is their instability in prices, which is sufficient to hold most customers away. "Robert Sams quoted Nick Szabo in a 2014 document outlining a method for strengthening cryptocurrency: "The key instability in bitcoin is due to variability in speculation, which in turn is due to real uncertainty about its future. If cryptocurrency gains more popularity and understanding, the future would be less unpredictable, resulting in a more secure and incremental adoption curve. More effective liquidity mechanisms may not help minimize genuine uncertainty.

Cryptocurrency is just like any other currency outside of the proper blockchain operations. It can be exchanged on exchanges and can be used to buy products and services or to sell them. In blockchain networks, cryptocurrency is very powerful, but every time it passes into the real world of conventional currency (also referred to as "fiat currency"), there is friction.

Decentralized Computing Infrastructure

The blockchain can also be imagined as a software design method that ties together a number of computers that typically adopt the same "consensus" mechanism for releasing or documenting what data they carry, and where cryptography verifies all relevant interactions.

From a physical viewpoint, what really drives blockchains is networked computer servers. But these servers do not need to be set up by developers, and that is part of a blockchain's magic. The network allows a request to the blockchain, as compared to the web where an HTTP (Hypertext Transfer Protocol) request is submitted to the server, for blockchain applications.

Transaction Platform

A blockchain network can verify a number of digitized value-related transactions relating to digital money or properties. A transaction is documented on a "block" that is storage space any time a consensus is reached. The blockchain keeps track of these deals that can be subsequently checked as having taken place. This giant transaction processing network is therefore the blockchain, capable of managing microtransactions and large-value transactions alike.

Decentralized Database

The blockchain shatters the processing model of database/transaction. A blockchain is like a place where in a linear container space (the block) one can store any data semi-publicly. Since the container has the signature on it, anybody can check that anyone has put that information, but only the person who stored (or a program) can open what's inside the container, because only you securely hold the private keys to that information.

So, except that part of the stored information, its "header," is public, the blockchain behaves just like a database. Blockchains are not really powerful databases, admittedly. Their task is not to replace massive databases, but rather it is the job of software developers to find out how their applications can be re-written to take advantage of the state transfer capabilities of the blockchain.

Shared, Distributed Accounting Ledger

The blockchain is also a distributed, transparent, time-stamped asset ledger that keeps track of any transaction ever processed on its network, enabling the machine of a user to check the validity of each transaction so that no double-counting can ever take place. It is possible to share this ledger with multiple parties, and it can be private, public, or semi-private.

While being a distributed transaction ledger is a common way of defining blockchains, it is just one of its features, and some see it as the killer app.

Software Development Platform

A blockchain is for developers, a series of software technologies first and foremost. Yeah, they have an underlying political and social underpinning (decentralization), but technical novelties are carried with them. For software developers, this new collection of development tools is an exciting occurrence. The blockchain includes technologies that are decentralized and cryptographically safe to create a new breed of applications. Blockchains are thus, a modern way to construct applications. Blockchains may also provide a number of APIs, including a language for transaction scripting, a communication API for P2P nodes, and a client API to verify transactions on the network.

Open-Source Software

Most blockchains are open-source, which not only implies that the platform is public, but it also ensures that on top of the core software, progress will happen in a shared manner.

The main Bitcoin protocol is open source, for instance. It has been maintained by a community of "core developers," who continue to improve it over time, since its original creation by its creator Satoshi Nakamoto. Moreover, hundreds of individual developers are innovating with complementary products, utilities, and software that take full advantage of the soundness of the Bitcoin protocol.

A important aspect is the fact that blockchain software is open source. The more accessible a blockchain's foundation is the better the ecosystem can become around it.

Financial Services Marketplace

Money is the cornerstone of crypto-currency-based blockchains. If the blockchain is managed like another asset, it will become part of a financial instrument, paving way to the development of a variety of new financial products.

For the next generation of financial services, blockchains deliver an incredible innovation climate. These will become popular as crypto-currency volatility subsides. Cryptocurrency variants of futures, options, swaps, synthetic instruments, investments, loans, and several other conventional instruments can create a modern trading marketplace for financial services.

Peer-to-Peer Network

On blockchains, there is nothing "central". Architecturally, the blockchain's base layer is a peer-to-peer network. At its node locations, a blockchain pushes for decentralization via peer processing. Truly, the network is the machine. At the peer-to-peer level, you check any other transaction. A blockchain may in essence, be regarded as a completely decentralized thin computing cloud.

Any user, no matter where they are in the world, and regardless of business hours, can reach and transact with another user instantly. There is no immediate need for an intermediary to filter, block, or pause a transaction between either of the two or more users or nodes consuming a transaction. Any network node is authorized to provide services based on its knowledge of transactions somewhere else within the network.

Blockchains often produce a marketplace of consumers in addition to providing a technical P2P network. Blockchain networks and frameworks on top of them with a number of sizes and vibrancy, build their own (distributed) economies.

Trust Services Layer

As an atomic unit of operation, all blockchains generally hold trust. It is in essence, a function and a service provided. But trust doesn't only extend to purchases. Data, programs, practices, identification, business theory, terms of an agreement, or physical objects are protected. It refers to almost anything with an intrinsic or related value attached to it that can be digitized as a (smart) asset.

Now, consider the potential mix of technologies that will appear on top of these 10 strong characteristics and functions. It's quick to envision the amazing empowering abilities of blockchains by merging them together.

2.1.5 Blockchain advantages

Entrepreneurs and startups do not need to ask. They have taken to this new technology like ducks to water and are busy creating new businesses and solutions that want to replace existing ones, using different rules. Enterprises are the ones asking, because the benefits are not necessarily obvious to them. The blockchain introduced itself as a headache initially for large businesses. This was something that was not anticipated.

The blockchain has significance for artists. They found the story of fortune inside before eating the cookie. But since the cookie is being sold, Bitcoin, blockchains or cryptocurrencies do not have much value (yet for the general population of consumers and several businesses.

Engineers usually want a technical problem to be solved. But if solving the technological problem does not lead to solving an end-user question, users will ask, "Was that a problem-seeking solution... because I don't see this problem."

The end-user mentality only needs to work with a clear solution. The end-user does not care who created a specific technical novelty or who dreamt of it. Company stakeholders are also part of this equation because they recognize that they cost money for problems, and they welcome the solutions that fix these issues.

Generically, the blockchain's benefits can be examined on a long list:

- Cost savings: direct or indirect.
- Speed: removing time delays.
- Transparency: delivering the right information to the right people.
- Better privacy: defending consumers, businesses via more granular controls.
- Lower risk: better visibility, less exposure, less fraud, less tampering.

- Access: more equitable access.
- Productivity: more work output.
- Efficiency: faster processing or reporting.
- Quality: fewer errors or more satisfaction.

2.1.6 Blockchain challenges

There are many challenges facing Blockchain. They can be usually classified into four types as follows:

Table 1: Blockchain Challenges

TECHNICAL	MARKET/BUSINESS
• Underdeveloped ecosystem infrastructure • Lack of mature applications • Scarcity in developers • Immature middleware and tools • Scalability • Legacy systems • Trade-offs with databases • Privacy • Security • Lack of standards	• Moving assets to the blockchain • Quality of project ideas • Critical mass of users • Quality of start-ups • Venture capital • Volatility of cryptocurrency • Onboarding new users • Few poster applications companies • Not enough qualified individuals • Costs issues • Innovators dilemma

BEHAVIORAL/EDUCATIONAL	LEGAL/REGULATORY
• Lack of understanding of the potential value • Limited executive vision • Change management • Trusting a network • Few best practices • Low usability factor	• Unclear regulations • Government interferences • Compliance requirements • Hype • Taxation and reporting

2.1.7 Blockchain & GDPR

Ironically, GDPR states that data should be handled in a centralized manner, whereas blockchain tends to process information in a decentralized way. Also, GDPR provides the right to erasure, the right to rectification, and the principle of data minimization. These rights and principles are, at first sight, not compatible with those of blockchain.

Several European authorities, such as the European Commission, through the creation of the Blockchain Observatory, are currently working on the most suitable designs to bring answers and best practices to the table. Meanwhile, decision makers should remain cautious: the paradox between GDPR and blockchain becomes a challenge if the project is entirely supported by a public blockchain. The more decentralized and transparent your blockchain project is, the more conditions should be respected to comply with GDPR. Because information flows transparently on the ledger within a public infrastructure, no personal data can be exposed.

2.2 Internet of Things (IOT)

The Internet of Things is a system of interconnected computing devices, mechanical and digital, objects, animals or people with unique identifiers (UIDs) and the ability to transmit information over a public without the need for interaction between humans or between humans and computers.

A human with a heart monitor implant, an animal with a biochip transponder, a vehicle that has built-in sensors to warn the driver whenever the tire pressure is low, or some other natural or man-made object that can be given an Internet Protocol (IP) address and can transmit data over a network can be one of the stuff on the internet.

Organizations in a number of industries are increasingly using IoT to work more effectively, better understand clients to provide improved customer experience, enhance decision-making, and increase the company's value.

2.2.1 Core of IOT

An IoT ecosystem is consisting of web-enabled smart devices that capture, transmit and act on data they obtain from their environments using embedded systems, such as processors, sensors and communication hardware. By connecting to an IoT gateway or any other edge node, IoT devices share the sensor data they collect when data is either sent to the cloud for local processing or analysis. These devices often interact with other similar devices and act on the data they get from each other. Without human interaction, the machines do much of the work, although people may communicate with the devices—for example, to set them up, send them instructions or access the data.

The protocols used with these web-enabled devices for connectivity, networking and communication rely largely on the particular IoT applications deployed. To help make data collection processes faster and more complex, IoT can also make use of artificial intelligence (AI) and machine learning.

2.2.2 Applications of IOT

Some of the common applications of IOT are as follows:

- Smart home
- Wearables
- Smart city
- Smart grids
- Industrial internet
- Connected health
- Smart retail
- Smart farming
- Smart supply chain
- Connected car

We'll focus on the last one as they essential elements in implementing Blockchain technology.

2.2.3 Pros & Cons of IOT

- The following are some of the IoT benefits:
- Ability to access data from anywhere on any computer at any time;
- Enhanced communication between electronic devices connected;
- Saving time and money by transmitting data packets over a connected network
- Automation of activities to increase the efficiency of the services of an organization and to reduce the need for human interaction.

Some drawbacks of IoT consist of the following points:

- As the no. of connected devices increases and more data is exchanged between devices, it also increases the ability for a hacker to steal sensitive information.
- Enterprises will ultimately have to deal with large numbers—maybe even millions—of IoT devices, and it will be difficult to collect and handle data from all those devices.
- If there is a system error, any connected computer is likely to become corrupt.
- Since there is no international compatibility standard for IoT, communicating with each other is challenging for devices from different manufacturers.

2.2.4 Blockchain & IOT

Blockchain and IoT are two emerging technologies that actually can come along together. Being implemented as a truly distributed system incorporating cryptographic algorithms, blockchain provides trust and security to the members of the network who cannot update information without the agreement of everyone else. Moreover, chained data makes it nearly impossible to modify the ledger. In this fashion, cybersecurity within IoT finds its interest in blockchain.

Sensors are usually installed in the periphery of the infrastructure and data is stored in its core, the so-called cloud. The challenge is that many enterprises wish to integrate intelligence right into the sensors, which as a result raises security questions. By authenticating sensors and terminals on the blockchain, we can implement the first level of security. Because every movement can be traced on the blockchain, the origin of the data can also be stated, that is, from which sensors it comes.

Silicon Valley's startup, Xage, came up with the idea of securing billions of devices on the blockchain to create a secure environment for them to operate. They provide a trustless mechanism for companies to ensure that their devices cannot be compromised. By connecting reliable devices to the blockchain it becomes easier to protect them from malicious intrusion and an unexpected hack. The objective is to control the information flow between stakeholders, thanks to security timestamps appended on the servers. This kind of utilization of the distributed ledger technology might seem surprising as this is not its main function, but its purposes are wide enough to seek other means to solve business issues such as erasing a single point of failure.

The combination of IoT and blockchain is a truly disruptive approach as it integrates two promising technologies. It is crucial to emphasize that most of the projects launched using sensors and blockchain are not even in the pilot phase. Investments in IoT have exploded in several industries and IDC, a market research firm, forecasted the total amount to reach $1 trillion by 2022. Because data recorded on the blockchain is verified and encrypted using cryptography, it is less prone to being hacked or changed without permission. Blockchain eliminates intermediaries, making it more efficient than many legacy systems and cybersecurity.

Chapter 3 Literature Review

A study of academic sources on a particular subject is a literature review. It offers an overview of existing knowledge, enabling you to recognize hypotheses, approaches, and gaps in current research that are important.

The selection, assessment and study of publications (such as books and journal articles) that contribute to your research question includes performing a literature review. In the course of writing a literature review, there are five primary stages. Not only does a good literature review summarize sources that it analyzes, synthesizes, and analyses to provide a clear understanding of the state of knowledge on the subject.

A literature review is done to show one's familiarity with the topic and scholarly articles. Also, to position oneself relative to other researchers. It can help to show how the research addresses a gap or contributes to a debate.

3.1 Literature Review Process

Though the literature review is different for each case, they follow similar steps. They are:

3.1.1 Search for relevant literature

Using relevant keywords such as **Blockchain, Automotive industry, Internet of things,** etc. A list of scholarly articles can be searched. The databases used are:

- Google Scholar
- ScienceDirect
- ResearchGate
- JSTOR
- EBSCO
- University Library

The relevance of research to this thesis is determined by reading the abstract. The bibliography of those articles was also checked. If the same citation appears in many places, then that article is important and was included in our research.

3.1.2 Evaluate Sources

It is not possible to read everything. For this reason, the sources must be evaluated according to the relevance to the thesis. Initially, there were around 50 articles. After careful elimination, the number was brought down to 15. There is a mix of articles that focus on Blockchain and the Automotive industry or IOT and the automotive industry or IOT and Blockchain in the manufacturing sector. They were selected to grasp the whole argument.

3.1.3 Identify themes and gaps

After reading the literature, there are certain things that were established.

- Trends and trends (in philosophy, methodology or outcomes): are those methods more or less common over time?
- Topics: What are the problems or ideas in literature?
- Debates, disagreements and contradictions: where do sources disagree with each other?
- Pivotal publications: Are there any significant hypotheses or research that have shifted the field's direction?
- Gaps: What in the literature is missing? Are there shortcomings that need to be resolved?

3.1.4 Outline the structure

There are various approaches to organizing the body of a literature review. These can be:

- Chronological
- Thematic
- Methodological
- Theoretical

For this research, a Methodological approach has been chosen which was appropriate. The results were evaluated on the basis of qualitative versus quantitative research.

3.2 Analysis of Blockchain in Automotive industry in Literature

3.2.1 Blockchain Applications for Industry 4.0 and Industrial IoT: A Review

This paper analyses various use cases of Blockchain in industries. Supply chain and manufacturing being the highlight. The taxi industry is also expected to change as highlighted by this paper. As seen in multiple case studies reviewed in this paper, there have been significant investments in blockchain. In spite of scalability issues, the traditional method of centralized data sharing has been considered safer compared to a decentralized approach and has been in practice in the industry for so long now. This is set to change now with blockchain promising solutions for addressing both security and integrity issues. In the paper, they surveyed the latest research work conducted on blockchain applicability in multiple IIoT-specific industries. We also looked into various commercial implementations of blockchain in the Industry 4.0 and IIoT to provide an Abstract measure of adoption in practice. And they further discussed the challenges faced by each of these industries for implementing blockchain. While many blockchain projects have emerged in the last few years, research in the blockchain is in its infancy. For blockchain to be fully utilizable and customizable, industry-oriented research should be further directed to address many of these challenges including personal data protection, scalability of block data, data secrecy and privacy of the participating organization, blockchain integration and adoption cost, and governmental regulations.

3.2.2 Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger

The authors review the current state of this technology and some of its implementations in this paper. In this article, the possible advantage of such technologies in the supply chain of manufacturing is then addressed and a vision for the future supply chain of blockchain ready production is suggested. As an example, the processing of cardboard boxes is used to illustrate how such technology can be utilized in a global supply chain network. Finally, there is a summary of the specifications and difficulties of implementing this technology in future production systems.

The proposed framework allows the collection of a large amount of data on goods and consumers in the manufacturing sector, which can be useful for a number of different individuals, companies, governments and researchers. For example, this enables customers to easily access detailed information relevant to any product that has been manufactured via a supply chain allowed by a blockchain, enabling them to make informed purchase decisions. Development, manufacturing and distribution companies may gain an enhanced understanding of how their goods are used further down the supply chain. To develop their technology and marketing, as well as their production accounting and revenue accounting, this level of input can be used. Integrating smart contracts into this framework will enhance the protection of transactions, as only the buyer who has signed the relevant contract with the seller can receive each item, enabling the system to recognize fraudulent transactions or misplaced items.

3.2.3 Blockchain opportunities in the automotive market - spare parts case study

This research is in line with the current research. The author follows the GUEST methodology and uses various analysis techniques and frameworks to justify the use of Blockchain in the automotive industry. Supply chain and logistics, in particular, are considered as fertile ground due to the several parties involved and the lack of trust that usually characterize the industry. The author developed a business model of a Software service (SaaS) blockchain-based to manage the automotive spare parts. He considered all the main actors involved in the process to offer them a useful tool to solve their business problems with the blockchain.

3.2.4 Blockchain applications in insurance

This paper from Deloitte explains that some customers are known to indulge in a practice called "crash for cash," which deliberately causes an accident to make claims. IoT devices with accurate sensors would prevent such scenarios. Another thing an insurer is protected from is multiple claims fraud. Scammers buy insurance policies from multiple insurers under made-up identities. Through a staged crash, they make multiple claims against the same accident. Such frauds are currently difficult to detect, as data is not shared by different insurers. A Blockchain network where multiple insurers are present and where fraudulent identity management is enforced will make it easy to detect multiple claims fraud.

3.2.5 The automotive industry fueled by Blockchain?

This paper from UINC takes an interesting approach. It divides all the use cases into groups. These are:

- Automotive Iot Interactions
- Automotive title transfer
- Supply chain management
- Smart manufacturing
- Insurance & insurance claim processing
- Loyalty based microtransactions/ infotainment
- Automotive financing process

3.2.6 Blockchain in Automotive Domain

Overall, a dedicated multi-tier interconnected blockchain platform based on the fundamentals of scalability and interoperability can benefit many stakeholders, like - a shared ledger - between automotive manufacturers, automotive dealerships, regulators, auto finance-cum-insurance companies, vehicle leasing companies, buyers, sellers and even garages, providing higher degree transparency and trust in all kind of vehicular transactions, preventing disputes and lowering the overall cost of maintenance and services by tracking ownership, sale, and accident history. And, at the same time, it could significantly streamline processes, especially those that rely on regulatory and compliance approvals. The author reiterates that the blockchain is all about bringing transparency and efficiency into the existing systems which are running the upstream and downstream supply chains and making them more proactive and predictive.

3.2.7 Blockchain in Automotive Supply Chain

A description of information flows and technology is outlined in this document, enabling the supply chain within the automotive industry. The supply base of many car manufacturers is being restructured, with significant repercussions for the way dealers communicate with their automotive partners. Electronic Data Interchange (EDI) is by far the most common technique of communication used in automotive manufacturing, although new techniques are also used.

The author concludes that the critical ingredient for success in managing a supply chain is fast, precise data from a wide range of information including inventory level, sales data and predicting, order status for tracking tracing, production distribution schedule, presentation metrics and purchasing procurement. The addition of all the different information flows in the internal information systems is automating the supply chain and understanding competence benefits. The capability to respond quickly to market changes and to regulate inventory, production, and transportation systems accordingly is necessary for the automotive supply chain to remain profitable. Suppliers are still under pressure to conform to carmaker demands in the field of blockchain to minimize the risk of losing the business. The consolidation into larger first-tier suppliers has been one of the results and one of the initiators of new supply chain partnering.

3.2.8 A Review on Blockchain Technologies for an Advanced and Cyber-Resilient Automotive Industry

This article covered a broad suite of issues that arise from the advent of a disruptive technology like blockchain. In addition, they present a holistic approach to a blockchain-based advanced automotive industry with a review of the main scenarios and the optimization strategies for designing and deploying these applications.

They discuss the lack of a clear regulatory environment (e.g., decentralized ownership, contingencies in smart contracts, international jurisdiction, cross-border trade) and democratic-by-design models of governance are concerns that hinder the potential impact of blockchain. Companies in countries with supportive regulations will have a competitive advantage to develop innovative business models, that they will be willing to exploit legally. Furthermore, blockchain can enable value distribution models interoperable across organizations, improving the economic sustainability of both contributors and organizations.

They emphasize that Automotive companies will have to experiment with different blockchain projects in order to discover where the ROI/value resides or can be created (e.g., whether if there will be additional sources of revenues or profits, disruptive added-value services, cost savings, stronger brand image, cyber resilience, fraud reduction, improvements in customers' user experience). Nevertheless, in some scenarios the payoff may require that companies wait until blockchain solutions are more robust, scalable, interoperable or demand less custom development (i.e., long-term investment).

3.2.9 How Is Blockchain Technology Impacting the Automotive Industry

This article lists the various aspects of the automotive industry where blockchain is making a difference. They are:

- Supply chain
- Manufacturing process
- Autonomous vehicles
- Identification and tracking
- Ownership transfer
- Automated vehicle maintenance
- Insurance
- Security
- Financing
- Infotainment

In addition to the above-mentioned blockchain effects, blockchain includes intelligent contracts that are equipped with Internet of Things (IoT) services to enable authentication and validation processes. With the use of smart contracts, Blockchain often activates machine-to-machine (M2M) transactions.

3.3 Conclusion of Research Review

Many other pieces of literatures were analyzed; not all of them are mentioned in detail. But a summary of them is as follows.

Data from millions of IoT devices was uploaded via the Internet link via the Cloud on the Internet of Cloud (IoC) based on virtualization technology. Blockchain-based intelligent resource management was developed for cloud data centers by Xu et al. The Internet of Vehicles (IoV) has recently become highly creative, and a new trend is emerging for many applications in this field of science. With the goal of developing smart contact between vehicles and different types of networks, such as vehicle-to-sensor, vehicle-to-human, vehicle-to-road and vehicle-to-vehicle, it is focused on integrating vehicles into the IoT. The security paradigm is not centralized in many applications. For that reason, on the basis of Blockchain electric vehicle and charging pile management, Huang et al. developed an ecosystem model. For the calculation of hash functions of charging piles of electric vehicles, this model uses Elliptic Curve Cryptography (ECC).

In addition, PETCON, a P2P electricity trading system, was established by Kang et al. to demonstrate localized and detailed P2P electricity trading activities. The PETCON framework uses a Blockchain consortium method for publicly evaluating, checking, and exchanging transaction records, although a trustworthy authority is not necessary. In addition, Li et al. developed CreditCoin, a privacy-preserving system, to ensure that adequate announcements are forwarded without exposing the identities of users. The Blockchain is used by this device to send anonymous announcements via a protocol of aggregation between vehicles. As a consequence, confidence in the sharing of IoV data is enhanced. Finally, Yang et al. suggested a reputation system based on Blockchain to test data legitimacy in the IoV. Depending on the senders' reputation values, this system judges if the received messages are true or false. Yong, Yuan, et al. developed a Blockchain solution aimed at solving security problems and performance limitations in Intelligent Transportation Systems (ITS). The authors merged mandatory vehicle information (i.e. vehicle insurance and traffic regulations) with other relevant information, such as the provision of alerts and weather forecast information and traffic jams.

After reviewing various articles and thesis, it is concluded there are many potential areas in the automotive industry that can benefit from Blockchain. The most impactful of them were supply chain & manufacturing. There is not much research on other use cases, but they are important, nonetheless. After the literature review, a detailed role of blockchain is presented in the next chapter.

Chapter 4 Blockchain in the Automotive industry

In a market that is just evolving, the enormous excitement around Distributed-Ledger-Technologies (DLT) such as blockchain appears to thinly conceal that they are still young. Most administrators are also searching for simple ideas for success and a comprehensive understanding of the importance and value of applications. Blockchain is bound to affect every vertical and domain of the industry and the digital revolution that is on its way, amid several uncertainties.

Technological advancements have mostly been influenced by the automobile industry and have been influenced by these innovations in return. DLT provides a variety of opportunities and future advantages to vehicle producers, suppliers and associated service providers across the automotive ecosystem. DLT is known to be the enabler for vehicles to autonomously obtain and carry out all sorts of orders and transactions, and through multiple constituencies.

4.1 Applications of Blockchain in the automotive industry

There are several key areas where Blockchain can be utilized or is already being used. Some of them were already discussed briefly in the literature review in 3.2.5.

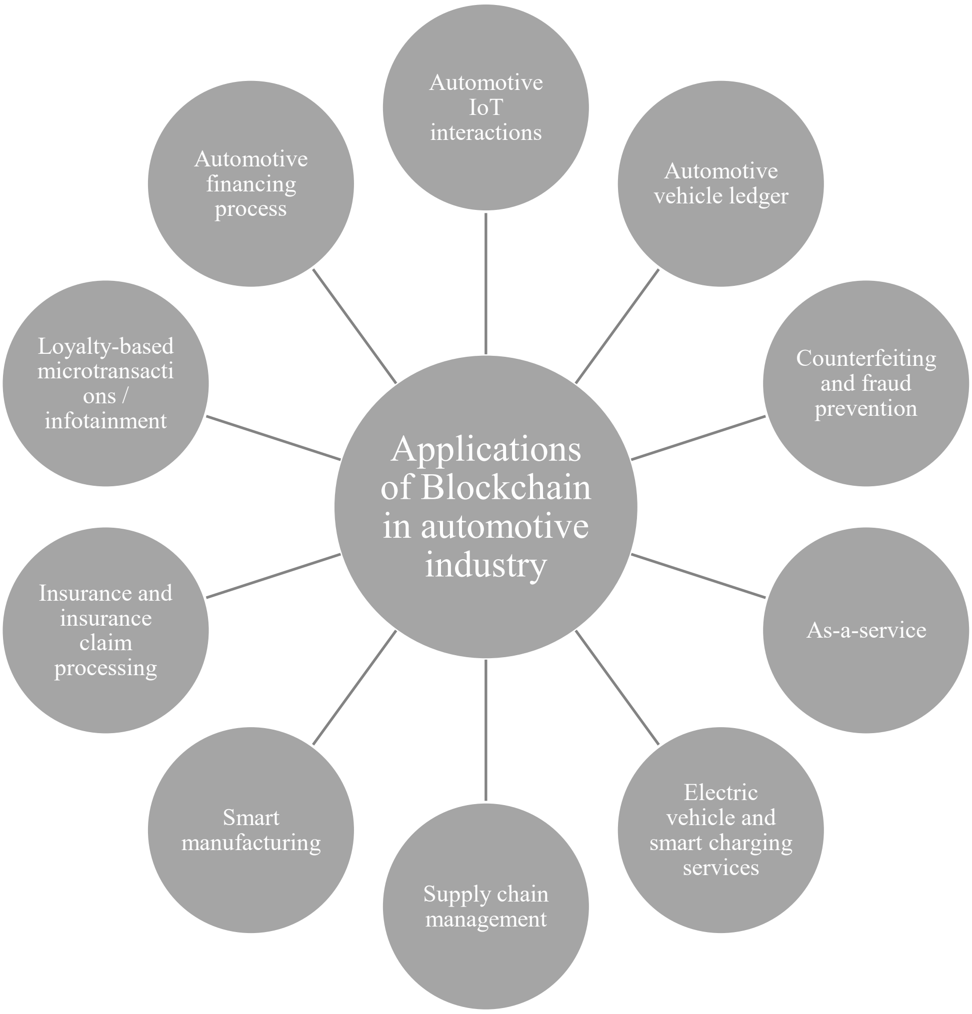

Figure 3: Applications of Blockchain in Automotive industry

The above figure illustrates some of the areas in the automotive industry where blockchain can be implemented.

They will be analyzed in detail as follows.

4.1.1 Automotive Iot Interactions

Vehicles are becoming interconnected Cyber-Physical systems (CPSs). These CPSs have special-purpose sensors, control units. The penetration of the IoT paradigm in vehicles enables the collection of a huge amount of data. For instance, most vehicles manufactured in the last decade have On-Board diagnostics (OBD) ports, which are used for retrieving vehicle diagnostics. Another major development is the deployment of an Event Data Recorder (EDR) to store incident data based on triggering events (e.g., drastic speed reduction). Sensors and devices connected over a defined mobile network will enable the collection of data like driving events (e.g., mileage, speed), safety events (e.g., spare part replacement warning), maintenance events (e.g., annual service) and will be able to send these data to a ledger shared among the stakeholders (including the owner).

IoT applications help to monitor and control devices remotely and create new insights from real-time data. IoT, together with blockchain, can help to track, process and exchange transactions among connected devices. An example of intelligent communication between vehicles is proposed in. Other authors presented a lightweight scalable blockchain solution to face the challenges of traditional security and privacy methods in IoT-connected cars: centralization, lack of privacy or safety threats.

4.1.2 Automotive vehicle ledger

A ledger that securely stores, updates, traces and shares data (e.g., car's maintenance, ownership history) in real time. Manufacturers can partner with a blockchain service provider to create a unique ledger among the network of OEMs to address logistics monitoring and control (e.g., issues related to spare parts quality and authenticity). The ledger can gather information about cars' history from different sources and even charge users to access the data. The platform could be extended to receive payment for the rendered services (e.g., repairing a vehicle, or purchasing/selling vehicle data from/to a third party).

4.1.3 Counterfeiting and fraud prevention

Blockchain and IoT can provide an effective way to avoid fraud. On the one hand, counterparties can update the status of the items from the source to the point of sale, or even in some cases the whole lifecycle. On the other hand, sensors can be added to assets (e.g., to each part pallet shipped from the Original Equipment Supplier (OES)) to track their real-time location and status (e.g., that the shipment complies with the Estimated Time of Arrival (ETA)). It must be noted that this strategy will imply an extensive level of cooperation among automotive stakeholders and software developers.

Regarding odometer fraud, a solution that uses an in-car connector can be proposed to send vehicle mileage data to its digital logbook on a regular basis. If tampering is suspected, the displayed mileage can be compared with the recorded via an app. Furthermore, a car owner can log its mileage on a blockchain and receive a certificate of accuracy that could be used for guaranteeing selling conditions.

4.1.4 As-a-Service

Emerging technologies have created a new 'As-a-Service' business model in which initiatives such as Car Next Door are growing fast. A blockchain-based platform would enable the interconnection of IoT-connected vehicles, autonomous vehicles, car-sharing, ride-sharing or ride-hailing providers and end-users to create a solution that records and executes agreements and monetary transactions to allow vehicle owners to monetize trips. Data (e.g., cost per mile, keys to unlock the car, insurance details, payment/billing details, information about vehicle owners, drivers and passengers) would be exchanged in a secure, reliable and seamless manner. The connections between the involved parties would be secured in order to protect their privacy (e.g., there would be no link between the actual user's identity and his/her route) and any unauthorized accesses to the vehicle (i.e., only authorized users would be able to locate, to unlock and to use a specific car). Furthermore, the platform could process all the payments upon completion of the trip and update the user's record with a history of the trip performed.

4.1.5 Electric Vehicles and smart charging services

The electric vehicle industry is growing in parallel with the demand for charging infrastructure. The connection of electric vehicles to the owner's smart home and/or smart devices could lead to advanced services. For instance, the charging procedure might be customized according to the user's personal habits (e.g., through the personal calendar). Such data could be used to guarantee that the vehicle is fully charged when needed. Furthermore, it also enables us to choose the cheapest or more convenient charging cycle (e.g., avoiding peak load times).

A blockchain-based solution can be proposed for distributed accounting, for managing contracts or for automating billing and payments. Two scenarios could be considered: when the car owner charges the vehicle at a charging station owned by a third party or when the car owner discharges the electricity from the electric vehicle to the grid to support the stabilization of the energy network. The location and behavior of the user (e.g., using a specific charger on a specific day) could be tracked, but such location information can remain private.

In the literature, there are some examples of implementations. For instance, a decentralized security model based on the lightning network and smart contracts are proposed. It involves registration, scheduling, authentication and charging phases. The proposed security model can be easily integrated with current scheduling mechanisms to enhance the security of trading between electric vehicles and charging piles. Another interesting example is described in, where a privacy-preserving selection of charging stations is presented.

4.1.6 Supply chain management

Visibility of the supply chain is a key business problem, with most firms having little to no data on their own second and third tier providers. The openness and visibility of the end-to-end supply chain will help model the movement of products from raw materials to production, testing and finished goods, allowing new forms of operational risk and sustainability analytics.

A variety of system organizations, including persons, physical resources, expertise, procedures, and financial contracts and transactions, form the supply chain in manufacturing systems that enable the transfer of a product from supplier to customer. It is very difficult to provide an overall image of all transactions within the chains in a large supply chain system. Usually, this data is stored in various locations and is open to some device entities. In structures like that. Customers typically have partial access to the total details (being the final customer or the larger business within the chain). In certain instances, for a retailer, part of the knowledge is regarded as a product. Because of the low degree of transparency, the tractability of transactions is therefore dependent on trust between the actors in the system.

A big problem with getting this kind of centralized structure is that it becomes a single failure point that makes the whole system open to failure (e.g. hacking or corruption). In the past decades, numerous accidents have shown that even a tight and expensive security mechanism does not guarantee full data security, leaving organizations at potential risk in a network.

Via the use of permanent data records, distributed storage, and managed user accesses, Blockchain technology will theoretically enhance accountability and traceability problems within the manufacturing supply chain.

This article proposes a decentralized distributed system that uses Blockchain technologies to capture, store and maintain each individual product's key product information throughout its life cycle. Such a distributed block of information potentially creates a secure, shared record of transactions for each individual product along with specific product information.

4.1.7 Smart manufacturing

The inclusion of blockchain in software-based manufacturing can increase productivity and quality control, reducing the costs for tracking in inspections (e.g., it simplifies version management), warranty, inventory management, ownership issues, maintenance, or recycling tasks.

A blockchain can also be used in a digital twin, which represents digitally a physical asset in order to monitor its current state and to recreate its past and future. In the automotive industry, assets (e.g., vehicles, tools, parts) may send data and notify events to its digital twin during their lifecycle. Thus, blockchain can be used to store securely all the mentioned information.

For example, a unique sensor can be added to each and every parts pallet before it is shipped from the original equipment supplier (OES)-end and tracks its real-time status and location, to make sure that the shipment conforms with the expected time of arrival (ETA) at the assembly dock. All of this works in conjunction with the Internet of Things (IoT) to form an effective anti-counterfeit strategy by using countermeasure technologies based on blockchain principles, where each supply chain partner proactively takes part in updating the status (attributes) of the item as it traverses from the point of manufacture to the point of sale. The whole concept demands an extensive and exhaustive level of cooperation among automotive manufacturers, OEMs, software developers and cybersecurity firms at a scale that has never been achieved before.

4.1.8 Insurance & insurance claim processing

A blockchain-based solution that allows insurance providers to create customized car insurance contracts based on real driving activity and to automate insurance payments. and financial settlement following an insurance claim. Driving behaviour events (e.g. speeding, mileage) and safety events (e.g. damaged parts, collisions) of a vehicle's owner could be stored on the blockchain, shared and used to calculate insurance premiums and payments. As the record is linked to the owner, the history of the vehicle owner remains available to the insurance company for future insurance quotes, even after the car is sold.

Another blockchain-based solution that links the participating organizations in a safe way when leasing a vehicle to a client, from conducting KYC customer checks (e.g. license and credit check) before leasing the vehicle, storing the blockchain leasing agreement/contract, to automatic payment after the vehicle has been returned.

4.1.9 Loyalty based microtransactions/ infotainment

A blockchain based solution that allows vehicle owners to purchase 'infotainment' services seamlessly or additional customer services (e.g. linking to in-home devices or paying for parking) based on pre-defined contracts and agreements stored and executed on the blockchain.

Loyalty and reward programs can serve as customer incentives. In this use case a blockchain and smart contract-based solution can record customer purchases and issue loyalty points that can be applied as a currency within the stakeholder loyalty network. The points are visualized and updated (e.g., redeemed as a discount) instantly for the whole network.

4.1.10 Automotive financing process

A blockchain-based solution that handles contracts, billing and payments when the owner of an electric vehicle charges their vehicle at a third-party charging station. or discharges their electricity from their EV to the grid to support the stabilisation of the energy network (e.g. transporting energy from rural areas to cities).

Peer-to-peer models offer a business model that connects the involved entities and perform Know Your Customer (KYC) checks prior to leasing a vehicle, stores the leasing contract and automate the payment. Blockchain platforms will leverage secure communications and eliminate data risks. The extracted data can be used for analytics and for monitoring consumer behavior (KYC) in car leasing or rental. A couple of initiatives have studied the mentioned scenarios. For instance, in 2015 Visa and Docusign implemented a blockchain for a car leasing pilot service. Similarly, Daimler AG and Landesbank Baden-Württemberg (LBBW) made use of blockchain to perform financial transactions in a pilot project for monitoring capital market transactions and financial processes.

4.2 SWOT analysis of the blockchain in the automotive industry

As it can be observed in Table 1, blockchain brings numerous advantages. Its main strengths are operational efficiency and resiliency: by removing middlemen, transactions can be simplified and their cost can be lowered (e.g., banking fees).

Table 2: Strengths & Weaknesses

STRENGTHS	WEAKNESSES
• Operational efficiency • Cyber resiliency • No need for intermediaries that do not provide added value • Fast and simple transfers with low fees • Automated transactions by means of smart contracts, loT enabler • Reduction in human errors • Accountability, verified, timestamped, and immutable auditable data • No data loss neither modified nor falsified data • Security and modern cryptography • Non-repudiation Transparency • Global accessibility • Trusted big data analytics platform • Decentralization • Traceability, asset provenance • Dynamic and fluid value exchange • Accountability, proof of ownership and rights	• Immature, early stage of development • Scalability issues • High energy consumption • Low performance • Lack of interoperability • Privacy issues (in some scenarios) • Criminal activity, malicious attacks • Dependent on input information from external oracles • Poor user experience, customer unfamiliarity • In case of users' credentials loss (e.g., a wallet), no intermediary can be contacted • In specific use cases, subject to cryptocurrency volatility • Limitation of smart contract code programming model • Wallet and key management • High-skilled human resources (scarce and costly) • Complexity (blockchain concepts are difficult to be mastered) • Lack of trust in new technology suppliers

	• Core business use cases or processes may not be suitable for the use of blockchain • Poor corporate governance

The major blockchain weaknesses are related to the immature status of the technology (e.g., lack of scalability, high energy consumption, low performance, interoperability risks or privacy issues). In the case of IoT-connected cars or infrastructure, smart contracts will be automatically executed and in some cases, they will depend on the injection of source information from external oracles. Therefore, it is presumable that this scenario will be indeed appealing for criminal activity or malicious attacks.

Blockchain can also enhance the capabilities of a digital twin, which enables digital representations of physical assets to reflect reality through simulations based on information collected from IoT devices. Examples of such improved features can be traceability of electric and electronic devices along their lifecycle, the guarantee of the provenance and authenticity of components, the registration of events from initial product design and approval processes through manufacturing, the verification of the delivery process to customers and the corresponding after sale events.

Table 3: Opportunities and Threats

OPPORTUNITIES	THREATS
• Industrial competitiveness (e.g. reduced transaction costs, enhanced cybersecurity, full loT automation) • Market diversification (e.g. supporting car sharing) • New business-model enabler • Rebalancing information symmetry between stakeholders • Fraud reduction • Reduced systemic risk • Network effect • A huge amount of heterogeneous data pushed into the blockchain by different actors for data analysis (big data applications) • Open-source code • Ease in cross-border trade • Reduction of verification procedures • Digital twin enabler • Circular economy enabler	• Perception of insecurity or unreliability • Technological vulnerabilities • Divergent blockchains. ledger competition • Low adoption from important stakeholders • Unfavorable government policies, legal jurisdiction barriers • Institutional adoption barriers • Medium or long-term investment • Not adequate for external customers, readiness for adoption

Code vulnerabilities in blockchain or smart contracts are a threat to sustainable adoption and can damage brand reputation. An infamous example is the DAO attack of 2016, which exploited a combination of previously reported security vulnerabilities with a cost of around $50 million worth of Ether and a devaluation of the DAO by a third.

Chapter 5 Research Methodology

The methodology used is inspired by The GUEST methodology. The GUEST methodology has been developed by a pool of researchers from the ICE Center of the Politecnico di Torino and BDS, an SME specialized in Business Development.

The GUEST methodology controls the process, from the original idea to its implementation, and provides a conceptual and practical tool to the various stakeholders, enabling them to communicate their vision, difficulties and opportunities within the same structure. The main steps of the methodology are:

1. GO
2. Uniform
3. Evaluate
4. Solve
5. Test

There are some modifications done to the methodology to better suit the research as it was not in the scope of this research. Specifically, the GO phase which involves questionnaires and the researcher to make contact with the company physically. Instead a market analysis and google survey are done to illustrate the nature of the automotive industry. Obviously, Testing is also not included because it is a theoretical paper. There are other modifications as well like the ICE diagram and The Balance Scorecard, etc are also not included.

In this section, the methodology used is explained. The original methodology on which the current methodology is based on is explained in more detail in this paper by Prof. Guido Perboli.

5.1 Business model canvas

The business model is the core of every company and the business plan must show clearly how it works and whether it can generate profit in a sustainable way. It describes the rationale of how an organization creates, delivers and captures value. The main purpose of it is to visualize and define the firm’s business model.

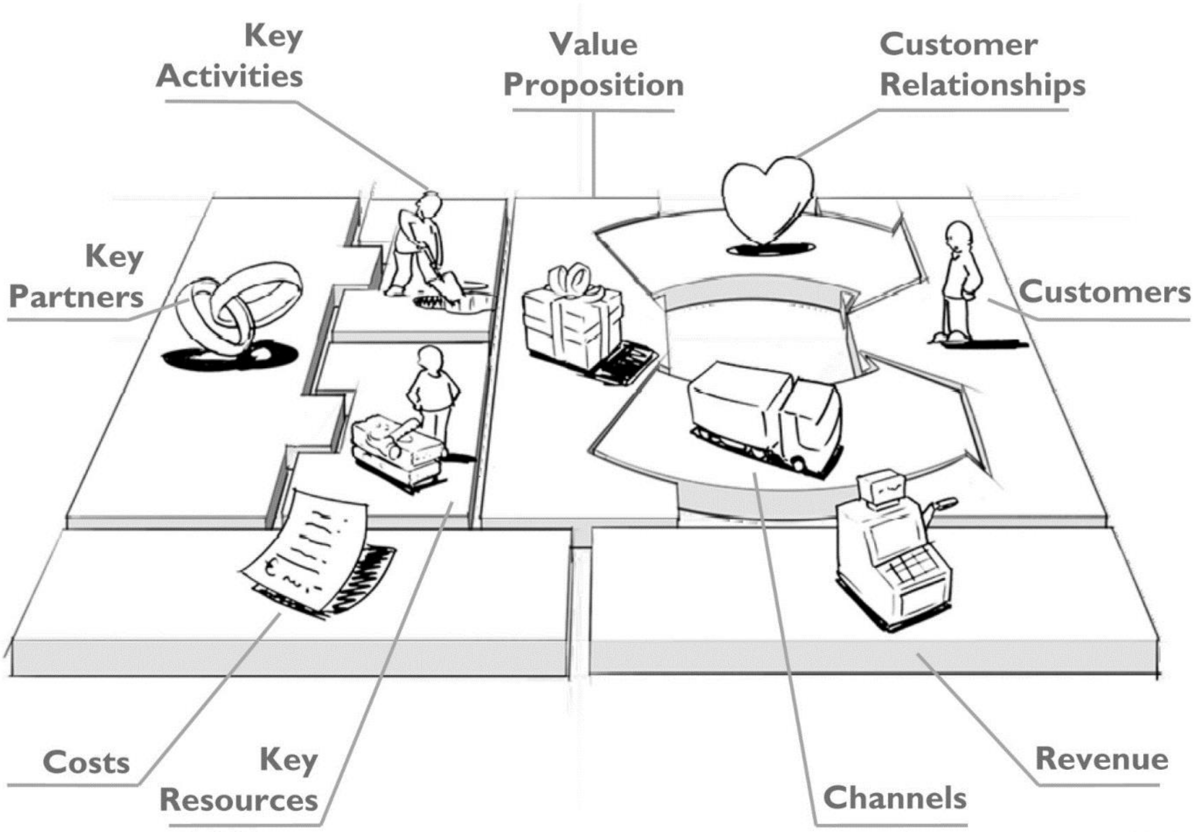

Figure 4: Business Model Canvas

It covers 9 key areas. They are

- The product's value propositions (what it does and promises)
- Customer segments (who it's for)
- Key activities (the steps the team must complete to make it successful)
- Key resources (what personnel, tools, and budget the team will have access to)
- Channels (how the organization will market and sell it)
- Customer relationships (how the team will support and work with its customer base)
- Key partners (how third parties will fit into the plan)
- Cost structure (what it costs to build the product as well as how to sell and support it)
- Revenue streams (how the product will make money)

In the following image, it is illustrated how they work together to provide value to the customers.

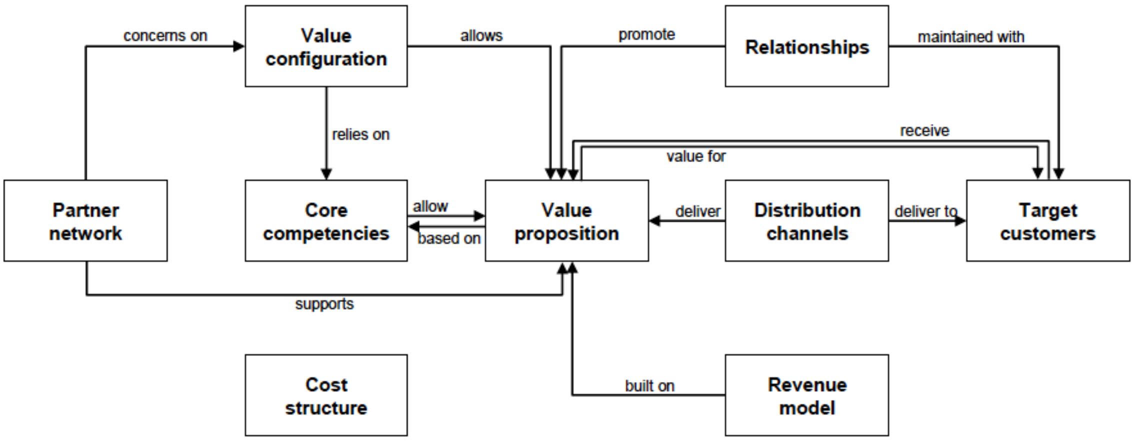

Figure 5: Inter-relationship of Business model canvas

5.1.1 Value Propositions

An organization's value proposition is the blend of products and services it offers to its customers. Osterwalder said that these offerings need to be distinctive and easily distinguished from the competition. Value propositions can be split into two categories:

Quantitative: this emphasizes the price or efficiency of the product or service

Qualitative: this value proposition emphasizes the experience and results the product and its use, produce.

The value proposition offers value through a no. of attributes such as customization, performance, "getting the job done", brand/ status, design, newness, price, cost and risk reduction, accessibility, as well as convenience/ usability.

5.1.2 Customer Segments

The total customer pie is segmented based on the way the goods or services of a company meet a particular need for the segment. The customer segment is an integral component of the business model of an enterprise and is crucial to ensuring that the product specifications are compatible with the features and needs of the segments.

A organization must first know its clients, both by their current and potential needs, to carry out a successful customer segmentation. Then in terms of priority, the company must list its clients, including a list of possible future clients. Finally, by knowing their strengths and weaknesses and exploring other forms of customers that can support the company more if they are to concentrate on them the company should do a detailed evaluation of its customers.

The following are different customer groups.

Mass Market: An company that opts for this type of consumer segment provides itself with a large pool of potential consumers because it believes that its product is a relevant necessity in the general population. Flour may be a possible commodity for such an entity.

Niche Market: This consumer group is focused on its customers' highly specific needs and distinctive characteristics. Louis Vitton is an example of a company with a niche consumer segment.

Segmented: In their key consumer segment, companies following the segmented approach produce more segmentation based on minor differences in the demographics of the customer and, accordingly, their needs.

Diversify: An company with a Diversified Market Segment is flexible in tweaking it to meet the needs of segments with different needs or characteristics in the iterations of its product or service.

Multi-Sided Platform/ Market: This type of segment serves clients that have a friendship with each other, i.e. A broad group of active bloggers need blogging sites to attract advertisers. And to generate cash flow, they need advertisers. Therefore, the blogging site would only be able to provide a profitable business model by having a draw for both segments.

5.1.3 Key Activities

Activities that are essential to generating the value proposition of the business. An entrepreneur must begin by listing the main activities that are important to his business. For the business model to be successful, these activities are the most critical processes that need to occur. Key activities would coincide with sources of sales. Now by adding or removing some and assessing their effects, it is necessary to determine which activities are essential.

5.1.4 Key Resources

These are the organization's properties that are central to how it provides its clients with value. It is possible to categorize resources as human, economical, physical and intellectual. Beginning with the listing of available resources is significant. This gives a better understanding of what end product or service your business requires for the consumer to produce and which resources are dispensable, resulting in cost savings for your business. The organization will determine how much it wants to invest in these key resources to run a successful business until the final list of resources is available.

5.1.5 Channels

As a channel, the mechanism by which a company offers its value proposition to its client segment is defined. There are different choices available to an organization for channels, and the selection is based on the channel that is the cheapest, most successful with the least amount of investment needed. Two basic types of networks exist; company-owned channels such as store fronts or distributors' affiliate channels. A business can opt to choose either one or hire a mixture of both.

5.1.6 Customer Relationships

To build financial success and profitability, a company must choose the kind of partnership it will have with its consumer segment. You may categorize customer relations as follows.

Personal Assistance: The company communicates with the customer directly through an employee in this form of relationship who offers the human touch by supporting the customer pre-sale, during the sale and may also provide after-sales services.

Dedicated Personal Assistance: This type of relationship is defined by a very close relationship between the customer and the business by a dedicated representative who is given a collection of customers and is directly responsible for the customer's entire experience with the business.

Self-Service: Self-Service places the consumer experience on the resources offered by the organization by the client to represent him.

Automated Services: There are tailored self-service partnerships where the customer's past interest is taken into consideration to maximize the overall experience.

Communities: Creating groups of consumers in today's electronic era enables companies to communicate directly with them. This facilitates an improved customer experience as the community enables consumers to share their experiences and to come up with common problems and solutions.

Co-creation: The client has a direct hand in the shape that the product or service of the business will take.

The value of the consumer must be measured in terms of the frequency of its spending on the goods and services of the company. Loyal customers are relationships that the company should continue to invest in because over the year they will generate steady sales.

5.1.7 Key Partners

A company forms relationships with its high-quality suppliers to create efficient, streamlined operations and reduce risks associated with any business model. The network of suppliers and partners that support each other in helping the business generate its value proposition are key partnerships. You may categorize relationships as follows.

- Strategic alliance between competitors (also known as coopetition),
- Joint ventures and
- Relationships between buyers and suppliers.

An entrepreneur must start by defining his main partners, followed by potential plans for partnerships. This can be achieved by analyzing the partnership relationship to judge which relationship characteristics need to be changed and what kind of potential partnerships will be required.

5.1.8 Cost Structure

According to a specific model, this determines the cost of running a company. Businesses may either be cost-driven, i.e. focused on reducing company spending, or value-driven, i.e. focused on providing the client with optimum value.

Some characteristics of common cost structures are given below.

Fixed Costs: costs that remain the same over a period of time

Variable Costs: as the name suggests, these costs vary according to a variance in production

Economies of Scale: costs decrease as production increases

Economies of Scope: costs are decreased by investing in businesses related to the core product.

For an entrepreneur, the first step is to clearly define all costs associated with the business. One of the hallmarks of a strong business model is a realistic view of the company's costs. It is necessary to list all the costs on the canvas after recognition, so they are visually present and then build plans for each cost. Some costs may be minimized by some steps, while others can increase if you decide that an investment in a specific segment can contribute to future gains.

5.1.9 Revenue Streams

A revenue stream is the methodology a company follows to get its customer segments to buy its product or service. A revenue stream can be created through the following ways.

Asset Sale: the company sells the right of ownership over the good to the customer.

Usage Fee: the company charges the customer for the use of its product or service.

Subscription Fee: the company charges the customer for the regular and consistent use of its product or service.

Lending/ Leasing/ Renting: the customer pays to get exclusive access to the product for a time-bound period.

Licensing: the company charges for the use of its intellectual property.

Brokerage Fees: companies or individuals that act as an intermediary between two parties charge a brokerage fee for their services.

Advertising: a company charges for others to advertise their products using their mediums.

It is necessary to remember that an acceptable price for the good and/or service will be arrived at via the elimination phase when setting up revenue streams. It is important to list and compare various iterations of prices. It's important to focus on potential avenues open to you as a company in the end to take a break ad.

5.2 Value proposition canvas

The essence of each company is to understand its client and build a product that is formed according to the needs of the client. That's why it is important for a business to know its client deeply and build a plan based on this information.

The Value Proposition Canvas is a tool which helps in modelling the behavior of customers. It provides insight into

Gains: describe the outcomes customers want to achieve or the concrete benefits they are seeking. Types of gains are:

- **Required gains**: These are gains without which a solution wouldn't work.
- **Expected gains**: These are relatively basic gains that we expect from a solution, even if it could work without them.
- **Desired gains:** These are gains that go beyond what we expect from a solution but would love to have if we could. These are usually gaining that customers would come up with if you asked them.
- **Unexpected gains**: These are gains that go beyond customer expectations and desires. They wouldn't even come up with them if you asked them.

Pains: describe bad outcomes, risks, and obstacles related to customer jobs. They can be:

- **Undesired outcomes, problems, and characteristics**: Pains are functional, social, emotional, or ancillary. This may also involve undesired characteristics customers don't like.
- **Obstacles**: These are things that prevent customers from even getting started with a job or that slow them down
- **Risks**: What could go wrong and have important negative consequences

Jobs: describe what customers are trying to get done in their work and in their lives, as expressed in their own words.

- **Functional jobs**: When your customers try to perform or complete a specific task or solve a specific problem.
- **Social jobs**: When your customers want to look good or gain power or status. These jobs describe how customers want to be perceived by others.
- **Personal/emotional jobs**: When your customers seek a specific emotional state, such as feeling good or secure.
- **Supporting jobs**: Customers also perform supporting jobs in the context of purchasing and consuming value either as consumers or as professionals.

The next step is to create a Value Map which describes what value a company can offer in response to a customer's needs. These are:

Products and Services: It's an enumeration of all the products and services the value proposition builds on. They can be of various types:

- **Physical/tangible**: Goods, such as manufactured products.
- **Intangible**: Products such as copyrights or services such as after-sales assistance.
- **Digital**: Products such as music downloads or services such as online recommendations.

- **Financial**: Products such as investment funds and insurances or services such as the financing of a purchase.

Pain Relievers: Pain relievers describe how exactly your products and services alleviate specific customer pains. Great value propositions concentrate on pains that matter to customers, in particular extreme pains.

Gain Creators: Gain creators describe how the products and services create customer gains. As with pain relievers, gain creators don't need to tackle every gain identified in the customer profile only the most important ones

5.3 Solution canvas

The Solution Canvas (SC) is a tool utilized in the GUEST methodology with the intent of outlining the chosen solution.

The SC is divided into 9 sections, like the BMC:

Decision makers: identifies who makes the decisions listed in the solution presented, their hierarchy and possibly the timing.

Constraints: the actions necessary to implement the solution are detailed in this section, how they will be carried, their target and any technological constraints.

Decisions: this section lists the decisions taken and to be implemented, specifying their characteristics, any hierarchy and methods of implementation.

Information / Resources indicates the source of the information that led to the solution chosen. In this section is also specified the level of detail of the information available and the level of uncertainty, as these two elements have a direct impact on the final objective.

Users / DM Report: it describes the relations that exist between those who took the decisions and who will make use of them.

Users: indicates the stakeholders involved in the solution, those who will benefit from the solution implemented. Users play a vital role, just like the one covered by the Customers in the

Channels: it defines the channels through which different actors are informed of the change due to the solution chosen and the channels through which the solution is implemented.

Goals: explicit objectives to be achieved thanks to the solution defined on the basis of KPIs identified in the previous Evaluate phase.

Costs: in this section must be listed the set-up costs to implement the proposed solution and its maintenance costs. It is also important to stress negative and / or positives effects on other business aspects. In this section, we will also be introduced the 'no cost' solution, or the negative impact that the company would incur not implementing such solution.

Chapter 6 Analysis of Blockchain in IoT connected vehicles (A case study)

After doing extensive research, there are many promising fields in automotive industry as mentioned in 4.1. One of the most promising sectors where blockchain can benefit the most is supply chain. However, as can be seen in the literature review, there are many researches as well as practical applications exist which involve integrating blockchain in supply chain and manufacturing process. In fact, there is a thesis (Colonna, 2018) which follows a similar approach and contains a case study in supply chain. IoT and blockchain are two of the hot topics in any industry let it be industry 4.0, smart cities, etc. IoT is gaining popularity with the rise of autonomous vehicles in automotive industry. However, there are not many research which leverage both IoT and blockchain. Therefore, it was then decided the focus of this case study applying both IoT and Blockchain in automotive industry to create value.

The case study consists of three sections.

1. The current state of the art and potential problems which can be addressed with Blockchain and IoT.
2. An analysis section which discusses how the problems can be addressed value can be created using some of the techniques mentioned in chapter 5.
3. Finally, a proposed solution and evaluation of feasibility

Although a detailed description on the inner workings of blockchain technology is out of the scope of this paper, the interested reader can check out the references. A brief description of technical framework is discussed in the next chapter if the reader wants to get an idea of how IoT and Blockchain can work harmoniously.

6.1 State of the art (Problems)

This case study is done from the perspective of a car manufacturer. How they can leverage technology to create a better experience and overall create value for other stakeholders as well.

6.1.1 Stakeholder analysis

This section provides a comprehensive identification and classification of the current stakeholders of the automotive industry. Next, we introduce specific challenges of each stakeholder that can be faced by the use of blockchain. After reviewing the current state of the automotive industry, it was decided to target stakeholders who are impacted by or can influence the outcome of a blockchain deployment. This includes customers, shareholders, internal and external stakeholders. Figure 5 represents the main analyzed stakeholders.

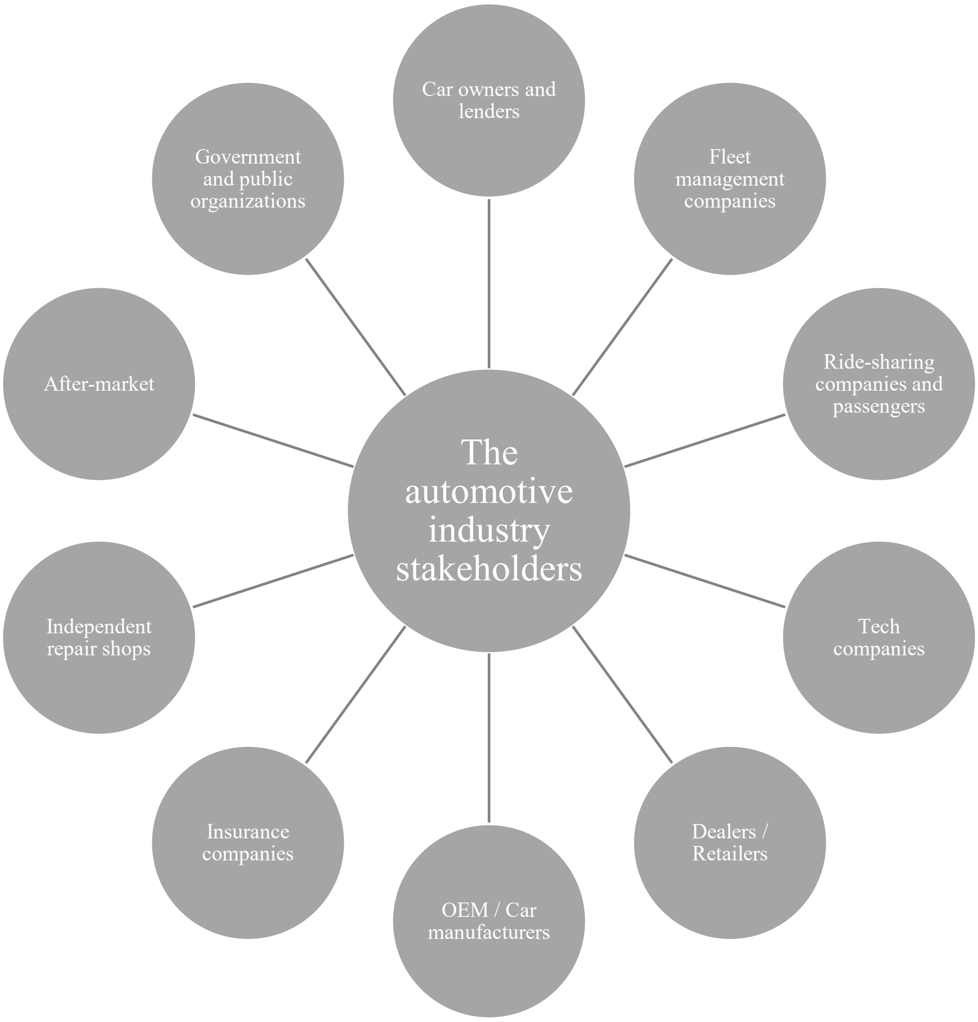

Figure 6: The automotive industry stakeholders

A detailed analysis of the problems faced by these stakeholders which can be solved with blockchain is given in Table 4.

Table 4: Challenges of Stakeholders

STAKEHOLDERS	PROBLEMS
Car owners and lenders	Lack of transparency regarding the car's history Unpredictable car maintenance and repair costs Lack of trust in the outcome of maintenance and repair jobs Absence of informed buying options Absence of car insurance options Lack of trust in autonomous vehicles and IoT-connected vehicles High-level transactional experience to consumers whilst reducing the costs incurred by them

Fleet management companies	Lack of transparency regarding the car's history Unpredictable car maintenance and repair costs Lack of trust in the outcome of maintenance and repair jobs Lack of interoperability with business partners High operational costs, low margin High costs in the car-sharing, ridesharing and ride-hailing economy Lack of trust in autonomous vehicles and IoT-connected vehicles
Ride-sharing companies and passengers	More affordable car rides Better maintained cars Lack of trust in autonomous vehicles and IoT-connected vehicles Lack of a common mobility provider platform Lack of instant payment
Tech companies	Expensive rates for car leasing and rental Lower car-sharing, ridesharing or ride-hailing partnership fees Difficulties to set up business, unfair competition Lack of trust in autonomous vehicles and IoT-connected vehicles Lack of information sharing
Dealers / Retailers	Updated car ownership records Updated repair and maintenance records Updated purchase records Lack of trust in autonomous vehicles and IoT-connected vehicles Lack of information sharing
OEM/ Car manufacturers	Huge warranty claim costs Enforcement of recommended maintenance and repair prices on the dealers Customer complaints due to car dealers' violation of recommended maintenance prices set by car manufacturers Lack of control of the car maintenance performed by authorized dealers Weak customer loyalty

	Cyber-attacks, system failure risks and enhanced security in autonomous vehicles and IoT- connected vehicles connected vehicles Control of the logistics Lack of information sharing
Insurance companies	Inflexible and non-customized policy pricing 5-10% of all claims worldwide are fraudulent Costly and inefficient claim management Inaccurate customer policy pricing Lack of oversight over the quality and pricing for a collision repair
Independent repair shops	Underutilized capacity Customer retention Low margins Lack of brand confidence
After-market	Inefficient stock management Market for counterfeit spare parts Lack of transparency in warranty monitoring and enforcement Low margins Lack of brand confidence
Government and public organizations	Updated state registries (e.g., vehicle maintenance records, ownership rights, vehicle taxes, history of traffic fines) Lack of trust in autonomous vehicles and IoT-connected vehicles Compliance with the current legislation, particularly in terms of driver liability or data protection Enhanced interconnectivity with provision of open-source traffic and infrastructure data through a data cloud and willingness to shift to digital radio and universal network coverage. Greater use of anonymisation and pseudonymisation in data collection and processing and provision of comprehensive information to vehicle owners and drivers about what data is collected and by whom.

	Notifications of road conditions and traffic congestion in real-time Trusted data for accident investigation and mitigating actions
Financial institutions	Updated car ownership records and insurance, maintenance and lien records on cars Non availability of single reference point on all transactions
Telecom and tech companies	Guarantee stable and secured Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication to ensure efficient and safe vehicle coordination and cooperation Lack of trusted connectivity among vehicles and between vehicles and infrastructure
Scrappage / Recycle	Control of greenhouse gas emissions Full traceability of components Long-term sustainability
Academia	Guarantee vehicle safety, security and autonomy More efficient driving, development of optimized Human-Machine Interface (HMI) Handle traffic management of highly and fully automated vehicles under mixed traffic conditions

6.1.2 Common problems

It can be noted in the previous section that many of the stakeholders have common problems. Of course, not every problem of every stakeholder can be addressed by the Blockchain but there are several problems that can benefit from the proposed solution. They are:

6.1.2.1 Lack of transparency

It is one of the most common problems which many stakeholders face. They want transparency like ownership data, history or usage. This enables them to make an informed decision whether they are buying used cars or insuring vehicles, etc.

6.1.2.2 Unpredictable car maintenance

The stakeholders would like to have an estimate of the components of the vehicle and would like a reminder when it is time for service. They don’t want the car to break-down in the middle of nowhere.

6.1.2.3 Traceability of components

The stakeholders would like the assurance that the spare parts are authentic. In fact, the market for counterfeit parts is huge and is one of the biggest problems the automotive industry is facing.

6.1.2.4 Inefficient stock management of spare parts

Demand forecasting for spare parts is very complicated. It depends on a lot of external factors which cannot be contemplated in data. Real-time or near real-time logs of the demand are the need of the hour.

6.1.2.5 Insurance claims

One of the most common problems a car owner faces is insurance claims. It is a never-ending nightmare marred with bureaucracy, formality and inefficiency. The owner is not even sure when he is going to receive the compensation, if at all.

6.1.2.6 Insurance frauds

Another side of the coin is insurance fraud. Every year, there are thousands of cases of insurance frauds so this mandates the insurance companies to be diligent which in turn increases cost and effort. Consequently, it also increases bureaucracy and time to process. That, in turn, causes the aforementioned problems.

6.1.2.7 Autonomous vehicles

Autonomous vehicles are surely touted as the next best thing since sliced bread. However, the reality is the consumers are not really sold on the idea of a vehicle being in control of the driving. Gaining consumers' confidence is a key to realizing the autonomous future.

6.1.2.8 Warranty claim costs

If the vehicle is still under warranty, it is not as easy to get a replacement. Both consumers and the OEMs incur a substantial cost and effort.

6.1.2.9 Control of pollution

Global warming is the truth whether some people believe it or not. Governments are taking measures to reduce air pollution which is a significant contributor to global warming. They need to control the amount of greenhouse gas a vehicle emits. There are strict regulations on how much a vehicle can pollute but the reality is, it is very difficult to enforce.

6.1.2.10 Updated transactions

This problem pertains more to financial institutions and insurance companies. There needs to be a single reference point for all the transactions so as to avoid redundancies and errors.

6.2 Analysis

6.2.1 Value proposition

In this section, a value proposition is developed for most of the relevant stakeholders. It will be difficult to address all the stakeholders and all of their problems. However, some of the main stakeholders will be addressed. Also, their gains, jobs and pains as well as gain creators, product/service and pain relievers will be highlighted.

6.2.1.1 Car owners and lenders

These are one of the most important stakeholders. They constitute the majority of the customer segment and their needs are one of the most important factors. A small survey was conducted using google survey and the reasons were asked for which they are willing to pay more.

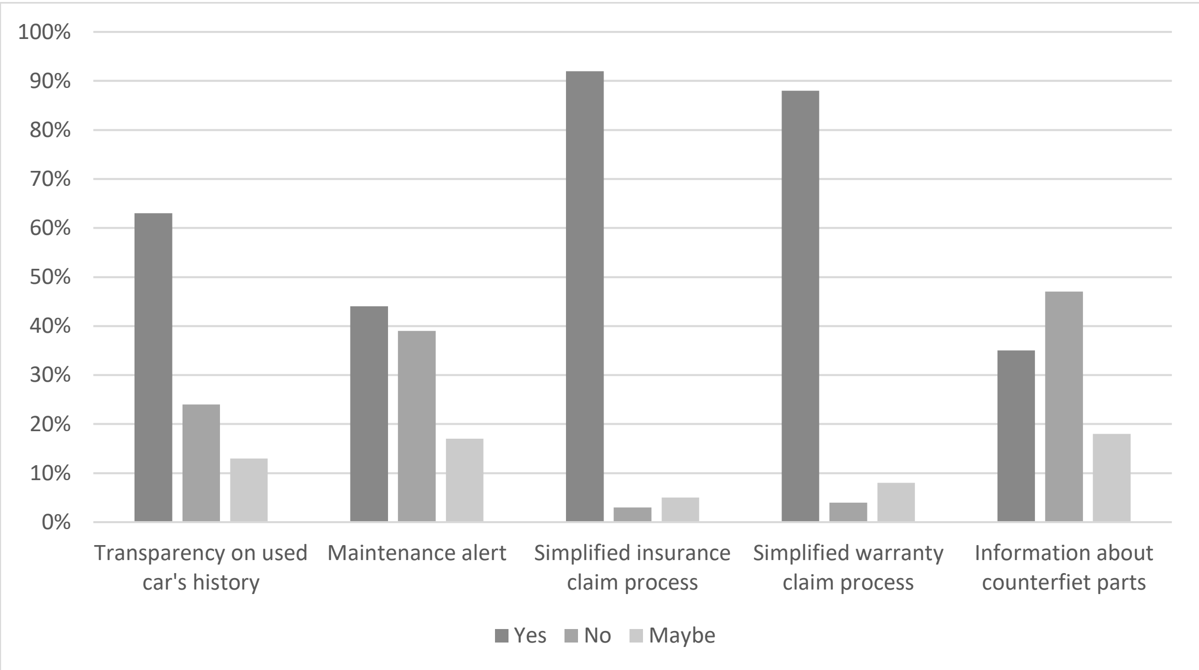

Figure 7: Survey on car owners' willingness to pay

As can be seen from the graph, almost all of the respondents replied yes when asked if they wanted a less complicated insurance and warranty claim process. People are willing to pay more if it guarantees them that in future insurance and warranty will cover them without too much hassle. One of their main problems is insurance companies are too much bureaucratic and often deny them coverage stating some excuses. Similar story with the warranty claims. It is difficult to prove that it was not the customer's mismanagement which led to the failure of the parts. People are also willing to pay more for if they can know the verified history of used vehicles. People have hard time trusting used car market and their lack of trust is well placed. There are many instances of odometer fraud, stolen vehicles and cheap counterfeit products being used. People are on fence for maintenance alert. Still more people prefer to have this convenience. Surprisingly, many people are not willing to pay more for information on counterfeit parts. Perhaps, they just care whether it works not how.

Table 5: Car owners' value proposition

Gains	Simplified insurance and warranty claims, transparency in used cars history, maintenance alerts
Pains	Prices, data sharing
Jobs	They are at mercy of insurance companies, Regular checkup for maintenance, Thorough checking of the used cars
Gain creators	Traceability, immutable data, no possibility of fraudulence
Pain relievers	Prices shared by owners and insurance companies, building of trust
Product / Service	IoT connected devices and sensors which collect data, Blockchain for immutability and transparency.

As can be seen from the above table customers want no hassle when it comes to insurance and warranty claims. These gains are achieved by blockchain where there is no possibility of fraudulence. In other words, warranty and insurance claims are much easier because of the availability of immutable data. Their pains are increased prices and data sharing. These can be alleviated to some extent by making the owners and insurance companies share the price. The reasoning for insurance companies will be discussed in their value proposition. Right now, they are at the mercy of insurance companies and OEMs. Their claims can be rejected even if it is not their fault. The solution which involves IoT connected devices and sensors which collect data and use Blockchain to create a ledger with key features immutability and transparency.

6.2.1.2 Insurance companies

They are also one of the most important stakeholders. It is mandatory to get an insurance for all vehicles and it is a huge industry in itself. As seen in the previous section, car owners want less complicated insurance claims and there is no denying that insurance claims are a nightmare today. With various checks and delays, customer is usually disappointed. However, it is not entirely the insurance companies' fault. They have to be diligent because of insurance frauds. Insurance frauds are one of the main challenges facing automotive industry. In fact — A study (Corum & al, 2015) from The Insurance Research Council (IRC) reports that between $5.6 billion and $7.7 billion in excess compensation for auto accident claims made in the United States in 2012 were added to claim fraud and accumulation. Excess payments accounted for between 13 percent and 17 percent of overall payments under the five major coverages for private passenger car accidents. This is just in United States. In the whole world, it can easily reach hundreds of billions of dollars.

It is evident that insurance companies will charge less to cover vehicles which have absolute transparency and no possibility of tampering data. In other words, the savings can be passed on to the OEM for implementing this solution and this is also a revenue stream.

Table 6: Insurance companies' value proposition

Gains	No need of extensive checks, transparency, reliability
Pains	They have to pay if it is a legitimate accident.
Jobs	They conduct due diligence but still some honest customers lose and fraud customers win.
Gain creators	Traceability, immutable data, no possibility of fraudulence
Pain relievers	Instances of fraud is severely reduced
Product / Service	IoT connected devices and sensors which collect data, Blockchain for immutability and transparency.

As can be seen from the above table insurance companies want transparency and reliability. They will hugely appreciate if it reduces their work of extensive due diligence. These gains are achieved by blockchain where there is no possibility of fraudulence. In other words, insurance checks and due diligence are much easier because of the availability of immutable data. Their pains are they have to pay if it is a legitimate accident. Previously, many deserving candidates were denied coverage but the flipside is there should be way less fraudulent cases. It can be argued that these fraudulent cases far exceed the denied coverage for deserving candidates. In turn, the insurance company will have more revenue whilst having considerably less costs due because one of the main drivers of their cost was these extensive checks which are solved by blockchain. It was mentioned in the previous section that increased prices will be shared by the customers and insurance companies. Since insurance companies will charge less for insuring a car which will reduce their cost, the savings will be passed to the car manufacturer. Right now, they are doing their best but still fraud happens, and honest customers lose. The solution which involves IoT connected devices and sensors which collect data and use Blockchain to create a ledger with key features immutability and transparency will also increase customer satisfaction.

6.2.1.3 Car dealers and repair shops

They are also one of the most important stakeholders. Dealers and repair shops are discussed here together because they have similar pains. Most of the cars are sold by third party dealers. There are some cars which are directly sold by manufacturers showroom. However, that number is comparatively low. Their challenges are discussed in the Stakeholder analysis. A post from Autonews states that one of the main problems dealer face is the lack of customer communication following a sale. When the initial contract is signed, the sales process shouldn't end. A large portion of dealer sales is made up of supplies and accessories., but the challenges are records which are not updated whether it be car ownership, repair and maintenance or any lack of information sharing. Also, the inefficient inventory management is one of the main drivers of cost.

Table 7: Car dealers and repair shops value proposition

Gains	Information about parts, demand forecasting of parts, less counterfeiting of parts, more revenue
Pains	Additional resources needed to monitor these records
Jobs	Demand forecasting (Not accurate), Resource management
Gain creators	Ledgers with accurate data of parts, lean process
Pain relievers	Increase in revenue because of less counterfeiting should compensate that, customer satisfaction
Product / Service	IoT connected devices and sensors which collect data, Blockchain for immutability and transparency, ledger with updated records

As can be seen from the above table updated information about parts help them better manage their inventories. Also, less counterfeit parts should increase their revenue. They need to hire more resource to monitor the data but increased revenue and customer satisfaction should compensate for that. Currently, they are doing their best to forecast the demand but it is inefficient. The solution which involves IoT connected devices and sensors which collect data and use Blockchain to create a ledger with key features immutability and transparency will also increase customer satisfaction.

6.2.1.4 Govt and public organizations

They are also one of the most important stakeholders. One of the main problems they face is to keep the updated registries like Ownership data. Another important thing is they care about the environment, so they want to monitor the emission of greenhouse gases. Many people use old cars or cars with faulty exhaust that pollute way above the recommended levels. Also, it will be helpful if they can find a way when a customer breaks the speed limit or track the parking.

Table 8: Govt and public organizations' value proposition

Gains	Updated registries, real time traffic data, monitoring of emissions
Pains	Additional resources needed to monitor these records
Jobs	They are doing their best but bureaucracy hinders it
Gain creators	Ledgers with updated data, real-time data, transparency
Pain relievers	There is a positive social externality
Product / Service	IoT connected devices and sensors which collect data, Blockchain for immutability and transparency, ledger with updated records

As can be seen from the above table their gains can be easily solved with this blockchain-based solution. They care about social externality like pollution. Any solution which helps them to monitor it will be appreciated. They can give tax incentives for manufacturers to implement this solution if it leads to positive social externality The solution again involves IoT connected devices and sensors which collect data and use Blockchain to create a ledger with key features Real-time data and exhaust emission data are key.

6.2.1.5 Car manufacturers

This whole case study is from the perspective of the car manufacturers. Why they should implement this blockchain-based solution. As can be seen from the previous sections, customers are willing to pay more for simpler insurance and warranty claims, insurance companies will charge less premium if it reduces their cost drastically, dealers and repair shops will also be positively affected because of increased revenue with less counterfeit products and finally Govt would appreciate efforts to mitigate pollution which in turn can result in tax breaks. Car manufacturers will also benefit from reduced counterfeiting, can manage the demand of spare parts better, have data about parts which in turn should improve the quality of cars.

Table 9: Car manufacturer's value proposition

Gains	Better quality cars, Increased revenue, potential tax breaks
Pains	R&D and technology implementation costs
Jobs	Demand forecasting
Gain creators	Differentiation, premium from customers, relaxation from govt
Pain relievers	Increase in revenue from customers and insurance companies, increase in sales because of better products and service, potential tax breaks from the govt
Product / Service	IoT connected devices and sensors which collect data, Blockchain for immutability and transparency, ledger with updated records

Their pain is the most severe. They have to incur a huge R&D cost and components cost like sensors and IoT devices. However, they can charge premium from customers who are willing to pay more. Insurance companies will also charge less premium which should translate to more revenue. Better products and services thanks to targeted repair and demand forecasting should all result in more sales and after sales support which in turn means more revenue. This will be discussed in detail later.

6.2.2 Business model canvas

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Insurance companies Car dealers Repair shops Cloud service providers Government	R&D of the blockchain-based system and IoT integration Monitoring the data Marketing the advantages **Key Resources** Developers & Engineers Shareholders R&D budget	Simpler insurance claims Simpler warranty claims Maintenance alerts Traceability Reliability Immutability No possiblity of fraud Demand forecasting Less counterfieting Less pollution	Dedicated personal assistance (Car owners) Partnerships (Insurance agencies, Govt/Regulators) **Channels** Distributors	Car owners Insurance agencies Government/Regulators

Cost Structure	Revenue Streams
Fixed R&D cost (sunk cost) Variable cost (IoT devices, sensors, etc) Infrastructure cost (Cloud service providers and maintenance costs) Marketing cost	Premium from car owners for the services provided Premium from insurance owners for reducing their huge due diligence costs Tax break from government for reducing pollution

Figure 8: Business Model Canvas

6.2.2.1 Key partners

Insurance companies are one of their key partners as well as their customers. A partnership should be formed to transfer some of the insurance premiums in place of providing service which drastically reduces their cost. Car dealers and repair shops are other partners who benefit from this technology and in turn can increase their customer satisfaction. This is a cloud-based service so a partnership should be struck with cloud service providers such as AWS, and finally a partnership should be formed with government agencies/regulators for improving their registry management as well as reducing pollution.

6.2.2.2 Key activities

First and foremost a department should be formed specifically for developing this blockchain-based solution. After the solution is developed, the data should be monitored and maintained. Also, the potential advantages need to be marketed to the customers.

6.2.2.3 Key resources

The company is venturing into territories which is not its expertise. For this reason, developers and cloud engineers need to be hired who will be their assets. The shareholders will need to be convinced of the disruptive innovation to get the R&D budget. There will lots of resource allocation at first.

6.2.2.4 Value proposition

The value proposition for various actors are discussed in detail in previous section.

6.2.2.5 Customer segments

Car owners constitute the main chunk of customers. They are willing to pay more for the value provided. Insurance companies and Government/regulators are also customer as well as partners. They also contribute to the revenue.

6.2.2.6 Customer relationships

Personal assistance is committed to relationships with car owners. In this case, this form of partnership is characterized by a very close contact between the consumer and the company through a dedicated representative. Partnerships with insurance providers and regulators/governments.

6.2.2.7 Channels

The distributors such as car dealers are nexus for car owners and insurance companies. Usually the car insurance is bought right in the showroom when the car is purchased. This way the company can interact with its customers through dealers.

6.2.2.8 Cost structure

There is initial fixed cost of developing the solution. It is a sunk cost which means it cannot be recovered. Then there is the variable component of the cost which constitutes of sensors and IoT devices. There is the infrastructure cost which consists of maintenance costs and resource costs such as developers. Finally, there is a marketing cost.

6.2.2.9 Revenue streams

The revenue comes from the premium car owners are willing to pay for simpler insurance and warranty claims. Insurance companies will also charge less premium due to huge reduction of their costs. This will be partially transferred to the manufacturer. There will be a tax break from the govt for helping it to keep updated registries and reducing pollution. Also, there are savings from huge warranty claim costs as well as less counterfeit spare parts. There will also be increased sales because of superior features offered, and better after sales support.

6.3 Solution

6.3.1 Solution canvas

Constraints	Decisions	Decision makers	User/DMs Relationships	Users
Clous platforms (AWS) Sensors (IoT, etc) Developers Marketing team	R&D of the blockchain-based system and IoT integration Monitoring the data Marketing the advantages	CEO of OEM Board of directors (need their approval) Regulators	Dedicated personal assistance (Car owners) Partnerships (Insurance agencies, Govt/Regulators)	Car owners Insurance agencies Government/Regulators
	Information/Resource Blockchain & IoT Literature review		**Solution Channel** Distributors	

Costs	Goals
Fixed R&D cost (sunk cost) Variable cost (IoT devices, sensors, etc) Infrastructure cost (Cloud service providers) Maintenance costs (developers' salaries) Marketing cost	Reduce insurance and warranty claim costs Provide traceablity and transparency Product differentiation with better after sales support Reduce pollution

It all starts with the decision makers, in this case the CEO and Board of directors of the OEM. Whatever is working now might be enough but there is huge untapped potential. There should be a meeting with regulators explaining them the possible benefits of this blockchain-based IOT connected vehicles. After a partnership is struck between regulators, A partnership should be proposed to insurance companies. They should be more than willing to give part of their savings if it reduces their huge investigation costs and eliminates insurance frauds. Strong decisions should be made starting with an investment in R&D of the blockchain based system and IoT integration. If the company feels, it is outside its area of expertise, they can either acquire small companies which specialize in this field or outsource it to another firm. However, doing it on its own will yield better results because the company can have better control on the features. New resources should be hired and adequate marketing should be done in order to promote the benefits of this system.

They need to partner with a cloud service provider such as AWS or Microsoft Azure. They provide tailored solution which can be easily scaled up. The required sensors and antennas should be acquired in bulk from suppliers and developers and cloud engineers should be hired to manage this new department. There are different partners who coherently increase the value provided to the customers. Dealers and repair shops will be able to provide better after sales support for these vehicles with accurate maintenance tracking. The better after sales support is enough to warrant a good word of mouth and increased sales of the vehicles. Partners such as insurance companies and regulators who are also customers can charge less premium and provide tax breaks respectively which should further contribute to the revenue.

There is a large initial cost in terms of R&D and infrastructure costs. There are variable costs such as sensors and maintenance and marketing costs. The company should have a clear plan on recovering these. They should not try to break-even as soon as possible but should focus on the long game. The main goal is to create a network externality. It is imperative that the amount charges extra from the consumers should not be more. Even if takes years to break even. Creating a better product and providing good after-sales support is the key. The main objective of the company should be to gain a large user base as the data obtained is invaluable in improving products. There is a general lack of trust from people regarding their data and especially in Europe with GDPR can be a challenge. That's why a complete transparency with public on how their data is used should be clarified. They should be assured that their sensitive data such age, sex, religion, political affiliations or sexual preference are not collected. The data obtained are purely vehicle performance parameters such as engine efficiency, exhaust emission, etc. Data which cannot be misused. Since, it is a ledger, public should have easy access to data related to their vehicles.

6.3.2 Solution external analysis

SWOT analysis is a helpful tool to evaluate the external analysis. The internal Strength and Weakness are same as the SWOT analysis in 5.2. However, the Opportunities and Threats are discussed.

Opportunities

In relation to opportunities for the automotive industry, blockchain allows for gaining industrial competitiveness, for entering into new markets or for developing new types of business models thanks to the use of DAOs and low transactions fees. Blockchain also represents an opportunity to reduce the information asymmetry that today exists among the different stakeholders.

Moreover, in the automotive ecosystem, blockchain can definitely help to prevent fraud and to reduce the possibility of a systemic risk (e.g., the risk of collapse of an entire market caused by intermediaries and/or idiosyncratic events). Specifically, due to the network effect, when a high number of stakeholders are involved, blockchain-based supply chains can be more efficient, since data can be shared nearly instantaneously among different heterogeneous actors. Nonetheless, the impact of such big data-enabled applications depends on the amount and quality of the collected information.

The use of open-source code is also essential in order to increase security and transparency. It is important to note that, although this kind of code is still susceptible to bugs and exploits, it is less prone to malicious modifications from third parties, since it can be monitored constantly by any stakeholder.

Threats

With respect to threats, they are related to several factors. First, technology can be still distrusted by the market, since it can consider it as insecure or unreliable, mainly due to software problems or cryptocurrency volatility.

Another threat if the fact that some stakeholders may think that the proposed system is too complicated, so the adoption rate on a worldwide basis could be low. It must be noted that unfavorable government policies, legal regulations and institutional adoption barriers slow down and threaten the mainstream adoption of blockchain. Potential barriers may arise to the use of smart contracts. A new subset of law, denominated as Lex Cryptographia, that includes rules governed through self-executing smart contracts and DAOs, will have to re-evaluate the interaction between four regulatory forces: the threat of law enforcement, the manipulation of markets (financial incentives and disincentives), social pressure and the centralized intermediaries (i.e., internet service providers).

With respect to Return on Investment (ROI) aspects, it must be indicated that applications based on blockchain technologies are considered as medium or long-term investments and as not adequate for being integrated into every existing process. In fact, most current solutions are still in the prototype stage, but it is likely that more mature applications will reach a broad market in the next years.

Moreover, if blockchain technology becomes a practice, it can have an impact on a company relationship with their customers. However, some customers may refuse to adopt it, as they might still consider personal interaction important. In addition, despite investing in human capital in order to improve customer service, market share may be lost, since companies may start to compete in terms of pricing.

6.4 Financial Analysis

Analyzing the financial aspects is really tricky due to the newness of the technology and unavailability of the data. For this reason, the following analysis is evaluated in the pessimistic scenario. i.e., the worst case scenario where the risk is high, cost is higher and revenue is lower. The financial analysis is speculative for the most part as the revenue depends mostly on the premium negotiated with the other stakeholders. However, a realistic approach is followed. A car manufacturer similar to Fiat is considered. It sells on average 500000 cars in Europe per year. For the sake of simplicity, the cost of capital is not considered.

6.4.1 Project Management

The project is scheduled in MS project. It is scheduled based on real-life projects and the duration allotted is generous. The wage is average wage per hour in Italy. 8 hours per day and 5 days a week working is followed. The resources used are

RESOURCES	MAX UNITS	WAGE (EUR/HOUR)
SOFTWARE DEVELOPER	5	30
PROJECT MANAGER	3	25
TECHNICAL ENGINEER	5	30
PURCHASE AGENT	2	25

The project is scheduled as follows:

	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Cost
1	**Integrating Blockchain in IOT connected vehicles**	**104 days?**	**Mon 01/03/21**	**Thu 22/07/21**			**172,840.00 €**
2	M1 - Effective date	0 days	Mon 01/03/21	Mon 01/03/21			0.00 €
3	C1 - Start of activities	0 days	Wed 10/03/21	Wed 10/03/21			0.00 €
4	Negotiations	60 days	Wed 10/03/21	Tue 01/06/21	3	Project Manager,Purchase Agent	24,000.00 €
5	**Design**	**97 days?**	**Wed 10/03/21**	**Thu 22/07/21**			**134,040.00 €**
6	Determine sensors required	20 days?	Wed 10/03/21	Tue 06/04/21	3	Project Manager[200%],Software developer[200%]	17,600.00 €
7	Data collection	20 days	Wed 10/03/21	Tue 06/04/21	3	Project Manager,Software developer[300%]	18,400.00 €
8	Blockchain network development	40 days	Wed 07/04/21	Tue 01/06/21	7	Project Manager[200%],Software developer[500%]	64,000.00 €
9	Testing	30 days	Wed 02/06/21	Tue 13/07/21	8	Project Manager,Software developer[300%]	27,600.00 €
10	Deployment	7 days	Wed 14/07/21	Thu 22/07/21	9	Project Manager,Software developer[300%]	6,440.00 €
11	**Purchase**	**17 days**	**Wed 07/04/21**	**Thu 29/04/21**			**2,800.00 €**
12	Request for proposals	3 days	Wed 07/04/21	Fri 09/04/21	6	Purchase Agent[200%]	1,200.00 €
13	Waiting period	10 days	Mon 12/04/21	Fri 23/04/21	12		0.00 €
14	Competetive proposal analysis	2 days	Mon 26/04/21	Tue 27/04/21	13	Purchase Agent[200%]	800.00 €
15	Orders	2 days	Wed 28/04/21	Thu 29/04/21	14	Purchase Agent[200%]	800.00 €
16	Logistics	14 days	Fri 30/04/21	Wed 19/05/21	15		0.00 €
17	Assembly	10 days	Thu 20/05/21	Wed 02/06/21	16	Technical Engineer[500%]	12,000.00 €
18	End Project	0 days	Thu 22/07/21	Thu 22/07/21	10		0.00 €

The gantt chart of the project is as follows:

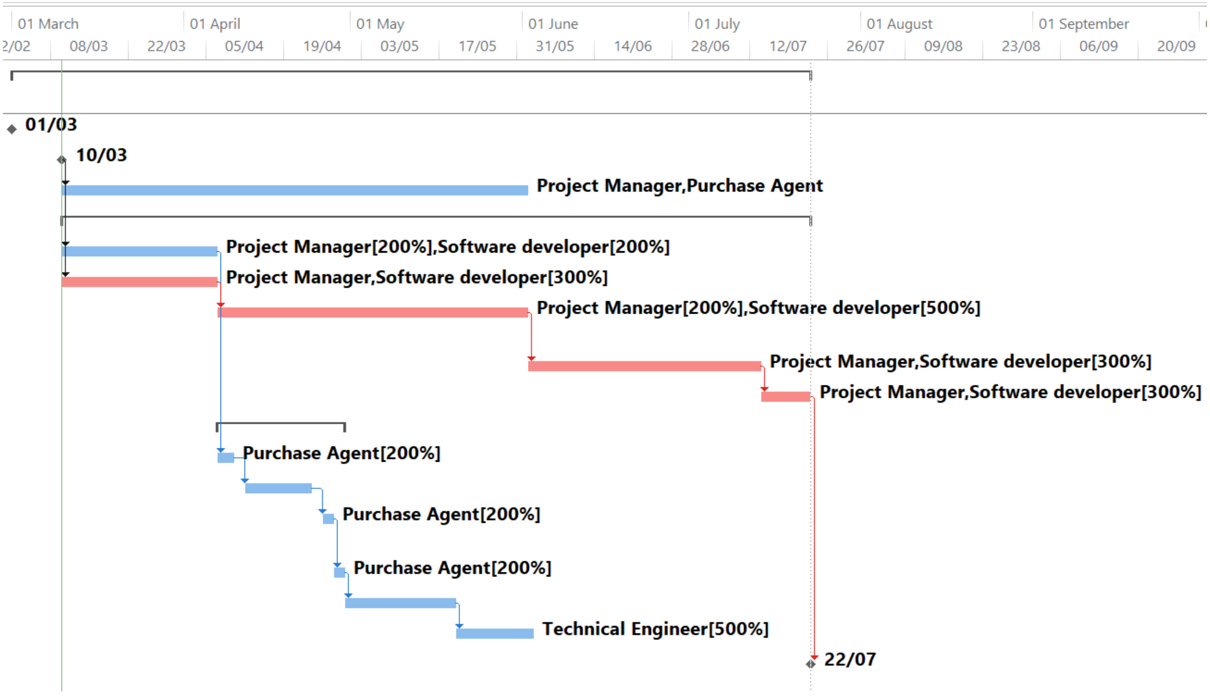

Figure 9: Gantt Chart of the project

In the above Gantt chart there are some tasks which have predecessors as defined in the table before. These constraints are necessary to illustrate that one task cannot be started until the finish of the other task. The tasks in the red are the Critical Path. Any delay in these tasks will delay the whole project altogether.

6.4.2 Costs

The different types of costs are explained in this section. The resource costs are obtained in the previous section. However there are two more costs which need to be taken into account. One is the cost for hosting the network in the cloud which is a recurring cost. The other is a variable costs of the sensors.

The cost for hosting a network can be found on cloud-service providers webpage. The following screenshot shows the pricing of AWS managed blockchain service. The cost is for 1 member and 500gb storage and large peer nodes for high data transfer. The best thing about this is it is easy to scale. So for starters, The service can be deployed with 5 members with more than enough bandwidth and storage for the first year. Blockchain ledger takes less data so the storage can be scaled up if needed. In this case let's consider a blockchain with 1 exabyte of storage and 2000 members which is more than enough for the whole Europe.

Joining a Production Network

Consider an Amazon Managed Blockchain network with members from multiple AWS accounts. In this example, we'll calculate the hourly cost for a single Standard Edition member in the network. This member has a two bc.m5.2xlarge peer nodes for high availability and performance, and each peer node has 500 GiB of storage.

The hourly cost for this network is:

Network member cost: (1 Standard Edition member) x ($0.55 per hour) x (1 hour) = $0.55 per hour

Peer node cost: (1 member) x (2 m5.2xlarge peer nodes per member) x (0.615 per hour) x (1 hour) = $1.23 per hour

Peer node storage cost: (1 member) x (2 peer node per member) x (500 GiB storage per peer node) x ($0.10 per GB-month) x (1 hour) = $0.139 per hour

Data written cost: (1 member) x (100 MB per hour) x (0.10 per GB) = $0.01 per hour

Total production network hourly cost: $1.93

Figure 10: Cost of deploying Blockchain in AWS

The last cost is a variable cost which consists of sensors and antennas. These sensors are really cheap ranging from 5 eur to 20 eur depending on the type of sensors. Even a vehicle with 20 of them should be around 100 eur. There is another cost which is the marketing cost. However, car manufacturers already market their car in any case. So they can just change the advertisements with their previous marketing budget.

The total costs should be:

DEVELOPMENT		174820
NETWORK	1.62*2000*24*365	28.4 million
SENSORS	100*500 thousand	50 million
TOTAL		78.6 million eur/ year

6.4.3 Revenues

The main sources of revenues are discussed in this section. The customers are willing to pay a premium for easy insurance/ warranty claims and information about car's health. Even adding 100 eur one time payment to the car cost should be an easy sell for a customer. This should directly cover the cost of the sensors.

The second stakeholder is the insurance companies. Their pain which is the insurance fraud and all the necessary checks they have to make before compensating which really exhausts their resources. In Europe a car insurance with minimum coverage costs on average 500 euros per year. This revenue depends on how well the commission is negotiated but even 10% per year should be a good deal for insurance companies for alleviating their pains.

The third stakeholder is the government. They need an easier way to monitor all the records of the car as well as pollution metrics. This is something all the governments (at least in Europe) are trying to do. i.e. to reduce emissions. The car manufacturer can negotiate a tax break with the government for helping them control the emissions as well as providing them with accurate data of registration. The average tax for CO2 based vehicles in Europe is 22%. Even if 1% tax reduction is negotiated, then it will be substantial. The average car price for everyday car is 20000 euros

CUSTOMERS	100*500 thousand	50 million
INSURANCE	500 * 0.1 * 500 thousand	25 million
GOVERNMENTS	20000*0.01*500 thousand	100 million
TOTAL		175 million eur/ year

The above revenue is still a pessimistic scenario because there are other indirect revenues which are not considered. Accurate demand forecasting of spare parts and less counterfeits provide additional benefits. Not to mention the better after sales support and word of mouth will increase sales. Granted there are some additional costs as well which were not taken into account for the sake of simplicity such as Transportations costs, Cost of capital, etc. However, even after including those costs the firm should break-even easily and start makind additional profits.

Chapter 7 Technical Framework

The technical details of the blockchain system and working are out of the scope for this paper. However, an overview is presented which will be a good representation of real-life model. The solution is to develop a Real-Time Application (RTA). It aims to solve limitations such as execution time and enhances performance accordingly. Since it is based on the IoT architecture, three layers should mainly be included in the proposed solution; the perception, network, and application layers, as seen in the table and listed below:

1. **The perception layer** is the physical layer. It consists of several sensor-equipped IoT devices designed to recognize and collect environmental information (i.e. physical parameters) and to detect smart objects nearby. Embedded in the perception layer, these sensors gather and interpret information about the vehicle's journey. The Infrastructure Application simulates the function of road-integrated IoT devices, such as radars, traffic lights, electronic roadside signs, etc.
2. **The network layer** links the sensors to other servers, network devices and smart stuff, and also transmits sensor information and processes it. This collection process utilizes the hybrid method before sending it to the server to collect and store data locally. When the Internet link is weak or unreliable, this technique is known to be highly efficient for data collection.
3. **The application layer** It consists of Blockchain and Central Cloud Server applications. It delivers IoT devices with application-specific services. More precisely, in the transport system, the Blockchain application manages communication between vehicles and other actors. The Central Cloud Server is responsible for the collection and interpretation of the data collected and the management of other actors' invitations.

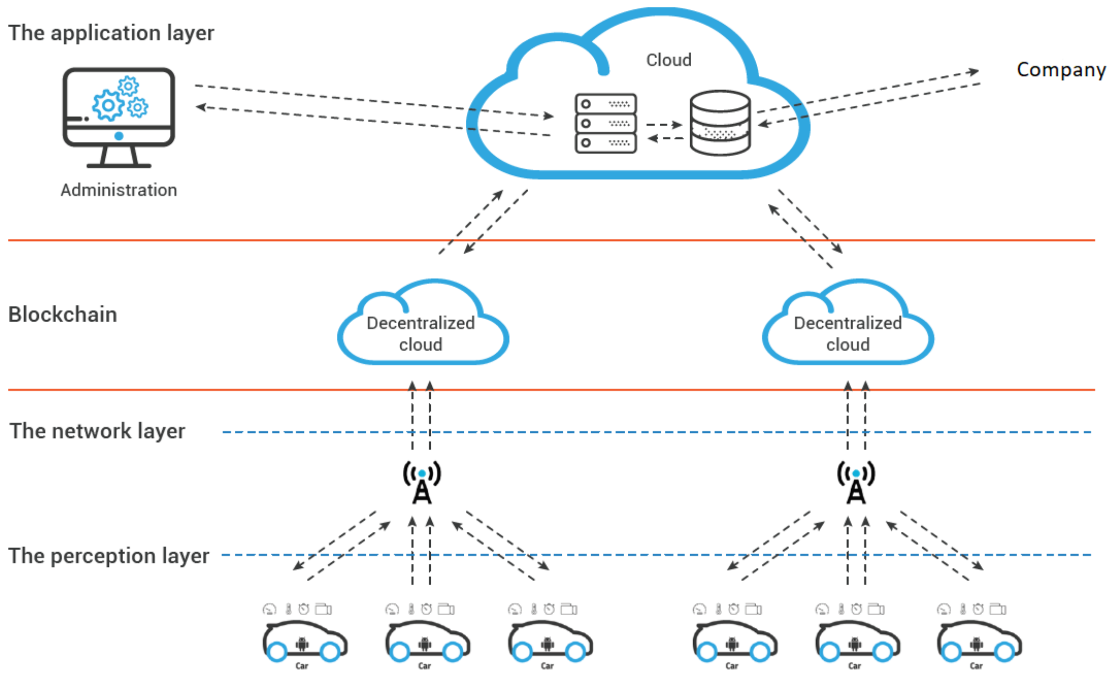

Figure 11: Technical Framework

The figure depicts the proposed solution's architecture and shows the main workflow, which includes three main steps. The cars transmit data to the central server first (1). Second, the central server sends an invitation to link to the Blockchain layer based on the received data. Third, the vehicles can share the data securely with the other IoV participants in the same region.

Layers	Developed Solution	Main Features
Perception layer	IOT sensors inside the vehicle	Collects and analyzes data about the journey, the vehicle, and the components health.
	Application for Infrastructure	Simulate the role of IoT devices incorporated into the roads such as radars, traffic lights, etc.
Network layer		Connects the sensors to networks devices, other servers, and smart devices.
Application layer	Blockchain Application	Managing communication between cars and other actors in the transportation system
	Central Cloud Server	Processes and analysis acquired data Manages invitations of the of other actors

7.1 Blockchain layer

Communication between cars is handled by the Blockchain layer. The car sends collected data via a web service to the central server in each separate time slot. The data contains the current location and the link status to one of the existing layers of the Blockchain. The central server then invites nearby IoT devices to establish communication through an accessible Blockchain cloud. After accepting the invitation, the interaction is created.

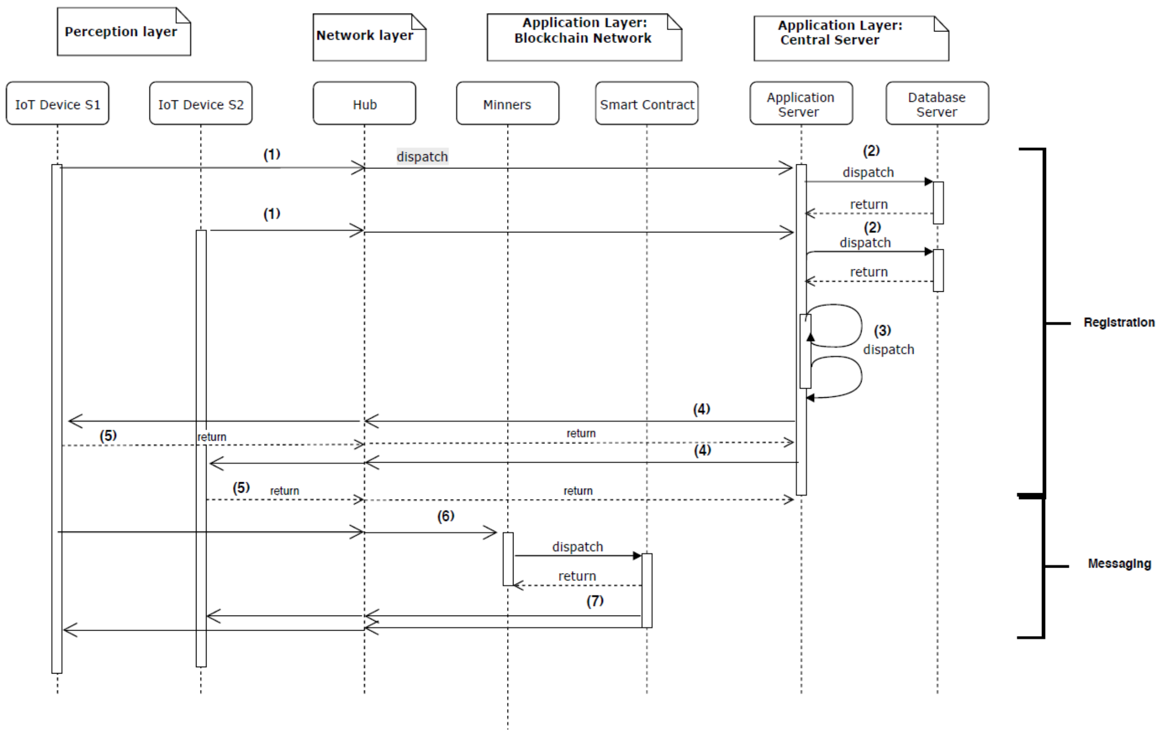

Figure 12: Sequence diagram of nominal scenario of communication between IoT devices

7.2 Function

The nominal communication scenario between IoT devices is defined in this chapter. In the previous figure, the sequence diagram illustrates that the nominal scenario is split into two sub-processes: registration and messaging. In the registration stage, the IoT system sends the collected data to the central server via the Internet for every time slot (15 s) (1). In the database server, the central server saves the stored data (2). In addition, the server scans nearby locations for IoT devices, such as road parts, roundabouts, traffic signals, or others (3). Subsequently, an invitation to connect via one of the available Blockchain layers is sent to the devices in the same location (4). After the invitation is accepted, (5) the second sub-process begins.

The IoT devices are now linked to each other in the messaging stage, and can share data between them. The message is sent by the IoT devices via the Blockchain network. The message is then added to the smart contract after the mining phase (6) so that any computer connected to this server Blockchain layer can receive it (7)

Chapter 8 Conclusion

This thesis was a research-based paper on how blockchain can be used in automotive industry. A literature review was conducted to identify the potential uses and also their limitations. Then various applications are listed in detail. To demonstrate how the blockchain can be implemented in the automotive industry, A case study of one such application, specifically blockchain-enabled IoT connected vehicles are evaluated. The evaluation is based on the GUEST methodology and uses various frameworks to determine how a value can be created for different stakeholders. Their problems are analyzed and a solution is proposed. One could argue that the proposed solution can be built without using blockchain and just using IoT sensors. It is possible; however the goal is to create trust between parties. Transparency and immutability are key words. A centralized solution can be modified, hacked or changed in some ways. Blockchain being a distributed solution is immune to this.

Limitations

There are however some limitations to this research:

- Technical details of inner working of the blockchain is not in the scope of this paper. A brief technical framework is provided which illustrates a general working of this technology in Chapter 7. However, this is an interesting topic for further research in Ph. D where more time and resources are available
- Interview with different actors is not possible due to ongoing Covid situation. Though the pains of the stakeholders are accurately captured with online research and reference is provided wherever necessary.
- The survey done in Car owners and lenders might not be an accurate depiction of the reality but the sample size was diverse enough.
- The financial calculation has many assumptions to simplify process. However, the whole picture is successfully captured.

Future opportunities

- This solution can be combined with AI and machine learning to recognize patterns which will ultimately lead to improved products. For machine learning, Huge dataset is required to train a model which can be obtained from the aforementioned solution.
- The AI-enabled solution can not only be able to alert owners for maintenance for example, but it can also predict accurately in advance so that they can make an informed decision
- This prediction will certainly benefit manufacturers and in supply chain in better demand forecasting.
- Govt can also leverage the predictions to better fight pollution and other social problems

References

T. Alladi, V. Chamola, R. M. Parizi and K. R. Choo, "Blockchain Applications for Industry 4.0 and Industrial IoT: A Review," in IEEE Access, vol. 7, pp. 176935-176951, 2019, doi: 10.1109/ACCESS.2019.2956748.

Abeyratne, Saveen & Monfared, Radmehr. (2016). Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger. International Journal of Research in Engineering and Technology. 05.

Guhathakurta, R. "Blockchain in Automotive Domain: Transparency, Interoperability, & Scalability", IndraStra Global Vol. 004, Issue No: 03 (2018) 0024, **http://www.indrastra.com/2018/03/Blockchain-in-Automotive-Domain-004-03-2018-0024.html** | ISSN 2381-3652

P. Fraga-Lamas and T. M. Fernández-Caramés, "A Review on Blockchain Technologies for an Advanced and Cyber-Resilient Automotive Industry," in IEEE Access, vol. 7, pp. 17578-17598, 2019, doi: 10.1109/ACCESS.2019.2895302.

Atzori, L.; Iera, A.; Morabito, G. The internet of things: A survey. Comput. Netw. 2010, 54, 2787–2805.

Dorri, A.; Steger, M.; Kanhere, S.S.; Jurdak, R. BlockChain: A Distributed Solution to Automotive Security and Privacy. IEEE Commun. Mag. 2017, 55, 119–125. [CrossRef]

Ahmad, F.; Hall, J.; Adnane, A.; Franqueira, V.N.L.. Faith in Vehicles: A Set of Evaluation Criteria for Trust Management in Vehicular Ad-Hoc Network. In Proceedings of the the IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber,

Aloqaily, M.; Otoum, S.; Al Ridhawi, I.; Jararweh, Y. An Intrusion Detection System for Connected Vehicles in Smart Cities. Ad Hoc Networks 2019, 90, 101842. [CrossRef]

Controlling Vehicle Features of Nissan LEAFs across the Globe via Vulnerable APIs. Available online: https://www.troyhunt.com/controlling-vehicle-features-of-nissan/ (accessed on 15 January 2020).

Hackers Discovered It is Possible to Remotely Control Features of Mitsubishi Outlander PHEV by Hacking the Mobile Applications Designed by the Car Vendor. Available online: https://securityaffairs.co/wordpress/48114/hacking/mitsubishi-outlander-phev-hacking.html (accessed on 15 January 2020).

Sharma, P.K.; Moon, S.Y.; Park, J.H. Block-VN: A Distributed Blockchain Based Vehicular Network Architecture in Smart City. JIPS 2017, 13, 184–195.

Mattila, J. The Blockchain Phenomenon—The Disruptive Potential of Distributed Consensus Architectures. Berkeley , CA: University of California, 2016.

Palychata, J. Bitcoin: what you didn't know but always wanted to ask. 2015 Available from: http://securities.bnpparibas.com/insights/bitcoin-and-blockchain-what-you.html

The Economist (US). The next big thing: Blockchain. The Economist, 2015: p. 16.

Swan, M. Blockchain: Blueprint for a new economy. O'Reilly Media, Inc., 2015.

Shrier, D., Wu, W., Pentland, A. Blockchain & Infrastructure (Identity, Data Security). Boston, MA: MIT Connection Science: 2016.

Davidson, S., De Filippi, P., Potts, J. Economics of blockchain. In: Proceedings of Public Choice Conference, 2016. Fort Lauderdale: Public Choice Conference, 2016.

Cachin, C., Vukolić, M. Blockchains Consensus Protocols in the Wild. arXiv preprint arXiv:1707.01873, 2017.

Pîrjan, A., Petrosanu. D.-M., Huth, M., Negoita, M. Research issues regarding the bitcoin and alternative coins digital currencies. Journal of Information Systems & Operations Management 2015:1.

Christidis, K., Devetsikiotis, M. Blockchains and smart contracts for the Internet of Things. IEEE Access 2016;4:2292–2303.

Condos, J., Sorrell, W.H., Donegan, S.L. Blockchain Technology: Opportunities and risks. Vermont: 2016.

Buterin, V. Ethereum: A next-generation smart contract and decentralized application platform, 2014. Available from: https://github.com/ethereum/wiki/wiki/%5BEnglish%5D-White-Paper.

Szabo, N. Smart Contracts. 1994. www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html.

Crosby, M., et al. BlockChain technology: beyond Bitcoin. In: Applied Innovation, 2016: 6. Available from: http://scet.berkeley.edu/wp-content/uploads/AIR-2016-Blockchain.pdf

Morini, M. From 'Blockchain Hype' to a real business case for financial markets, 2016. Available from: https://ssrn.com/abstract=2760184 or http://dx.doi.org/10.2139/ssrn.2760184.

Luu, L., et al. Making smart contracts smarter, 2016. Cryptology ePrint Archive, Report 2016/633, 201 6. eprint/.iacr.org/2016/633.

Zyskind, G., Nathan, O. Decentralizing privacy: Using blockchain to protect personal data. In: Security and Privacy Workshops (SPW). IEEE, 2015.

Wright, A., De Filippi, P. Decentralized blockchain technology and the rise of lex cryptographia. Available at SSRN 2580664, 2015.

https://medium.com/s/story/how-does-the-blockchain-work-98c8cd01d2ae

https://www.mckinsey.com/business-functions/digital-mckinsey/ourinsights/using-blockchain-to-improve-data-management-in-the-publicsector

https://www.forbes.com/sites/samantharadocchia/2018/06/21/3-automotiveconsumer-safety-issues-blockchain-will-help-resolve/#2eea1a486387

https://automotivelogistics.media/intelligence/16979

https://en.wikipedia.org/wiki/Bitcoin

http://www.tesa-scribos:com/eng/markets/automotive_industry/automotiveindustry-component-suppliers-spare-parts-counterfeit-protection-greymarket-protection-and-theft-prevention;7688028;1.html

https://www.forbes.com/sites/samantharadocchia/2018/06/21/3-automotiveconsumer-safety-issues-blockchain-will-help-resolve/#287c75d76387

https://www.ibm.com/blogs/research/2018/02/architecture-hyperledgerfabric/

https://www.edx.org/course/blockchain-for-business-an-introduction-tohyperledger-technologies

https://www.hyperledger.org/

https://medium.com/@philippsandner/application-of-blockchaintechnology-in-the-manufacturing-industry-d03a8ed3ba5e

https://www.insurance-research.org/sites/default/files/downloads/IRC%20Fraud%20News%20Release.pdf

Appendix

Algorithm: a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

Artificial intelligence (AI): the process of constructing an intelligent artefact. Using computers to amplify our human intelligence with AI has the potential to help civilization flourish like never before—as long as we manage to keep the technology beneficial and prevent AI from inflicting any damage.

Augmented Reality (AR): sometimes also referred to as 'mixed reality', AR is the technique of adding computer graphics to a user's view of the physical world.

Big data: a term that describes the large volume of data—both structured and unstructured—that inundates a business on a day-to-day basis. These datasets are so voluminous and complex that traditional data-processing application software is inadequate to deal with them.

Bitcoin: an innovative payment network and a new kind of money. It is a type of cryptocurrency. It is the first decentralized digital currency, because the system works without a central bank or single administrator.

Blockchain: a digital ledger in which transactions made in bitcoin or another cryptocurrency are recorded chronologically. The cryptography underlying blockchain ensures a 'trustless' system, thereby removing the need for intermediaries to manage risk, making data on a blockchain immutable, traceable, and verifiable.

Consensus mechanism: a feature in decentralized networks to determine the preferences of the individual users (or nodes) and to manage decision-making of the whole network. The key to any blockchain: with a consensus algorithm, there is no longer the need for a trusted third party and, as a result, decisions can be created, implemented, and evaluated, without the need for a central authority.

Cryptocurrency: a digital asset designed to work as a medium of exchange that uses cryptography to secure its transactions, control the creation of additional units, and verify the transfer of assets.

Cryptocurrency mining: a race that rewards computer nodes for being first to solve cryptographic puzzles on public blockchain networks. By solving the puzzle, the miner verifies the block and creates a hash pointer to the next block. Once verified, each block in the chain becomes immutable.

Cryptography: protects data from theft or alteration, and can also be used for user authentication. Earlier cryptography was effectively synonymous with encryption but nowadays cryptography is mainly based on mathematical theory and computer science practice.

Decentralized Autonomous Organization (DAO): an organization that is run through rules encoded as computer programs called smart contracts. A DAO's financial transaction record and program rules are maintained on a blockchain. It is an organization without management or employees, run completely by autonomous code.

Decentralized networks: a computing environment in which multiple parties (or nodes) make their own independent decisions. In such a system, there is no single centralized authority that makes decisions on behalf of all the parties.

Digital signatures: a digital code (generated and authenticated by public key encryption) that is attached to an electronically transmitted document to verify its contents and the sender's identity. Digital signatures are based on public key cryptography, also known as asymmetric cryptography.

Distributed application (DApp): blockchain-enabled products and services are commonly referred to as decentralized applications, or DApps. A DApp has at least two distinctive features: (1) any changes to the protocol of the DApp have to be approved by consensus; and (2) the application has to use a cryptographic token, or cryptocurrency, which is generated according to a set algorithm. Bitcoin is probably the best-known DApp.

Distributed Ledger Technology (DLT): a digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple places at the same time. A blockchain is a distributed ledger.

Distributed networks: distributed networking is a distributed computing network system, said to be distributed when the computer programming and the data to be worked on are spread out across more than one computer. Usually, this is implemented over a computer network. Participants in a distributed network are able to verify and authenticate other users' transactions and exchanges. For this reason, the community values its own worth and reputation.

Double-spending problem: this arises when a given set of crypto-tokens is spent in more than one transaction. By solving the double-spending problem, digital or cryptocurrency has now become viable.

Hash Algorithm: each block of data on a blockchain receives a hash ID, as a database key, calculated by a Secure Hash Algorithm. This block hash is fixed. In other words, the hash ID allocated to the block never changes. Hash Algorithms are used in a variety of components of blockchain technology, one of them being the hash ID, which is a unique string of 64 numbers and letters linked to data in each block.

Hash Function: this is any function that can be used to map data of arbitrary size to data of fixed size. The values returned by a Hash Function are called hash values, hash codes, digests, or simply hashes.

Immutability: unchanging over time; and impossible to change.

Machine learning: a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns, and make decisions with minimal human intervention.

Nanotechnology: science, engineering, and technology conducted at the molecular or nanoscale (which is about 1–100 nanometres).

Nodes: computers confirming transactions occurring on the network and maintaining a decentralised consensus across the system.

Peer-to-peer transactions: also referred to as person-to-person transactions (P2P transactions or P2P payments), electronic money transfers made from one person to another through an app.

Private Key Infrastructure (PKI): a set of roles, policies, and procedures needed to create, manage, distribute, use, store, and revoke digital certificates and manage public-key encryption.

Proof of Stake (PoS): a way of validating transactions and achieving a distributed consensus. It is an algorithm and its purpose is to incentivise nodes to confirm transactions. PoS uses someone's stake in a cryptocurrency to ensure good behaviour.

Proof of Work (PoW): a requirement to define an expensive computer calculation, also called mining, that must be performed in order to create a new group of trustless transactions (the so-called block) on a distributed ledger or blockchain.

Quantum computing: incredibly powerful machines that take a new approach to processing information. Built on the principles of quantum mechanics, they exploit complex laws of nature that are always there, but usually remain hidden from view.

Self-sovereign identity: the concept that people and businesses can store their own identity data on their own devices, and provide it efficiently on request. The key benefits of self-sovereign identity are the user only provides the information that is needed by the provider and the provider only receives and stores essential information (and with the identity-owner's express permission).

Smart contracts: programmable applications that can be automated to initiate on satisfaction of certain conditions. These conditions can include complex conditional logic. The smart contract verifies that parties to a transaction can meet their promises, and then the technology manages the exchange so that each promise is satisfied simultaneously, almost certainly eliminating risk for all parties to the transaction.

Timestamp: a sequence of characters or encoded information identifying when a certain event occurred, usually giving date and time of day, sometimes accurate to a small fraction of a second.

Trust protocol: a mechanism whereby trust is managed by technology in a decentralised network. Trust is established through verification or Proof of Work, and is supported by immutability of that work and the consensus of all participants.