POLITECNICO DI TORINO

Automotive Engineering Master of Science Course

Department of Mechanical and Aerospace Engineering

Master of Science Thesis

A BUSINESS MODEL FOR VEHICLE INSURANCE BASED ON BLOCKCHAIN SMART-CONTRACTS

Supervisor:

Professor Anna Filomena Carbone

Student:

Letícia Rubinstein Cavalcanti

enrollment: 239603

ACADEMIC YEAR 2017-2018

Dedication

I dedicate this work to my father Glauco Bronz Cavalcanti, a strong human being with a huge heart, my biggest example in life.

He taught me that "luck" is the perfect combination of being in the *right place* and at the *right time*, but also requires the *right attitude* for that opportunity. Mazal Tov.

Preface

Thesis presented at Politecnico di Torino to conclude the Automotive Engineering Master of Science course as part of the Double Degree Program.

The course was held between the 2016/2017 and 2017/2018 Academic Years and the Thesis presentation was carried out in July 2018.

This work was oriented by Professor Anna Carbone from the Department of Applied Science and Technology (DISAT) and whose proposal was to develop research studies and analyzes about Blockchain Platform for mobility applications. Together, we targeted the application of this technology to the Automotive Insurance Sector.

Turin, 2018-07-19

(Letícia Rubinstein Cavalcanti)

Acknowledgment

I would like to thank my father Glauco B. Cavalcanti for always providing me with all the support so that I could achieve my dreams.

To my mother Rosane Rubinstein for all love, attention and understanding.

To my sister Rebecca E. Cavalcanti and brothers Leonardo R. Cavalcanti and Felipe E. Cavalcanti for inspiring me everyday to be a better person.

To my mother's heart Regina E. Cavalcanti, a strong woman in whom I mirror.

To my eternal friend Regina P. Lima for always giving me the courage to believe in my ideals.

To my partner Raphael Orsini Ardengh for being always by my side regardless of the circumstances.

To my grandparents Sonia S. Rubinstein, Miguel Rubinstein and Regina B. Cavalcanti for always having the wisest and most experienced advice on life. They are my biggest sources of inspiration.

To my long-standing friends for being present in my life every day despite the great physical distance.

To the friends I met while living abroad for having taught me that "home" is about who and not where you are.

To José Carlos G. Pagliuca for being part of my education.

And finally, to Professor Anna Carbone who guided me through all work with great mastery, experience and intelligence. An inspirational professional.

L.R.C.

This Master Thesis has been developed in the framework of the European project FuturICT 2.0 (FuturICT 2.0) that has also provided financial support for my participation at Blockchain & IoT School (BIOTS) at ETH Zurich (CH) in February, 2018.

Figure 1: "The world's largest academic blockchain hackathon just took place (and it was really fun") (FuturICT 2.0)

Summary and Conclusions

This Thesis focuses on the methodology implementation and potential impact of a Blockchain platform designed to be a new business model for vehicle insurance companies. This technology is a strong tool for industries' disruption, here the platform is based on Ethereum and the focus is the Automotive Sector. Within this Industry, the proposal is to reform the way in which vehicle insurance are calculated and marketed. Thus, by matching Blockchain with Internet of Things (IoT), the proposal is a system that measures and analyzes the way each driver behaves in traffic and thereafter automatically issues insurance contracts. In order to measure the impact of this work, some US traffic database were examined. These data relate red light violations, severe vehicle crashes and pedestrian crashes with driver's characteristics. Among them, the target variable was the driver's age, since it is a critical factor when regarding new technology adoption rate. Statistical analyzes showed that the proposed platform had a high impact potential for improving the driver behavior and so reducing infractions and traffic accidents. Not only benefits for society as a whole but consumers would be more satisfied paying a tailor made price for their vehicle insurance, and companies would have reduced operating costs and the possibility to take more precise risk investments by depending on each client's driver behavior.

List of Figures

List of Tables

Contents

Chapter 1

Introduction

1.1 Background

Currently, the fourth Industry Revolution has been boosted due to new digital technologies, among them Blockchain. Despite it became firstly worldwide known due to Bitcoin, the Blockchain proved to have a high potential of impact for other applications, such as platforms related to Health, Transportation, Agriculture, etc. (Unibright).

Among these industries, the Automotive Sector has been one of the main targets. Due to constant technologies' improvement and the volatile consumers' satisfaction perspective, the companies that will thrive and achieve competitive advantage will be the ones that focus on the modernization (Salil Aggarwal, et al.) or even the reinvention of some business models regarding the entire value chain and related services (Deloitte(a)).

Despite the numerous application opportunities, this Thesis focuses on vehicle's insurance business model, since it is a risky and high value-added sector and whose losses and dissatisfaction are significant both for people and companies, so for society in general (Coalition Against Insurance Fraud).

1.2 Problem Formulation

The aim of this work is to design a Blockchain platform that changes the current car insurance business model and has great adoption from society and insurers. For this, the main dissatisfactions were analyzed in order to define respective solutions.

On the drivers' side, premiums paid to the insurer often do not correspond to how the person actually is risk exposed if the analysis is just based on individual basic information. Also, there are perceived bureaucratic delays to activate a service request, even in cases of emergency or theft. In turn, the insurer faces problems such as fraudulent consumers or low risk/return related rates.

Henceforth, the proposed solution is a Blockchain platform that automatically generates insurance contracts in a fast, secure, immutable, transparent, and non-subjective way. Such a platform boosted by Ethereum is technically based on the smart-contracts, that would have as input real-time driver behavior data through telematics and Internet of Things (IoT). So, from pre-programmed rules transparently available on the network, the smart-contracts automatically calculate and charge the tailor made price for each driver with a certain frequency. Since all drivers are connected, in case of an emergency, the system would also trigger the insurer's support and, depending on who the culprit, charge accordingly.

Because Blockchain is by definition immutable, secure and at the same time provides privacy, users rely on the platform as the "trusted third party" responsible for mediating the insurers and drivers' relationship. This would not only solve the aforementioned issues, but also create an incentive system for good traffic behavior, since the price paid for insurance is proportional to how the individual drives.

1.3 Objectives

The main objectives of this Master's Thesis are:

1. Elucidate the many opportunities for Blockchain advent in the Automotive Sec-

tor and how the Industry might change in the next years due to this technology integration in the current business models;

2. Propose a Blockchain platform design, powered by Driver Behavior measurement, that is interesting both for consumers and for insurance companies and hence benefits society in general;

3. Prove that since the Blockchain platform has an adoption rate consistent with what is expected by users, accidents and traffic violations would decrease substantially due to a driver behavior improvement.

The results of those investigated objectives are discussed in section 8.1.

1.4 Approach

To elucidate the Blockchain applications in the Automotive Sector, first was done a research mainly by the sources (Andreas Antonopoulos) and (Jonathan Rohr, et al.) on how does Blockchain technology work. Henceforth, some possible applications were raised within the Automotive Industry, with a categorization inspired by the reports (Deloitte(a)) and (Deloitte(c)) with some projects and start-ups examples currently operating in each area.

To design the platform, studies were first carried out on how to measure the driver behavior, principally based on the studies (EY) and (IMS(c)). Thus, it is explained how telematics powered by Internet of Things (IoT) can collect accurate driver behavior data. Thereafter, this evaluation was crossed with the Blockchain main features to point the main advantages of these technologies combination for the platform.

To calculate the platform's potential impact magnitude, statistical logistic regression models were developed to analyze the correlation between the driver's age, besides other individual features, the traffic accidents and infractions and the Blockchain platform subscription rate. It was considered that the target age group would be individuals interested in joining modern technologies, but also bearers of the own car insurance's responsibility (25-45 years old). The studies were based on the (David Yang, et al.) article about the correlation between red light violation and driver's age. The traffic database examined was obtained in (NHTSA) for Motor Vehicle Occupant and Motorcyclist Fatality and Injury Rates per Population by Age Group (1975-2016) and (NCDOT) for Pedestrian Crashes.

1.5 Limitations

The major limitation of this project is the bureaucratic feature of implementation. This for two main reasons, first because of the volatile and risky insurance market's characteristics, therefore being less likely to abrupt changes. Second, because the regulations of this business are not standardized on a global scale. This means that some laws and fees are different between countries, or even among same country's regions, which makes difficult to implement an integrated digital platform such as the project proposes.

1.6 Structure of the Thesis

This Thesis is organized in the following Chapters:

- Chapter 2 presents the origin of Blockchain, its basic concepts and, briefly, how it works;

- Chapter 3 presents Blockchain applications in order to go into more detail on Bitcoin, Ethereum and Industry 4.0;

- Chapter 4 elucidates Blockchain potential applications in the Automotive Sector related to the value chain, user services and vehicle management and incentives;

- Chapter 5 details the motivation behind the project, exemplifies similar existing ideas and defines how would be the platform methodology of operation;

- Chapter 6 describes the ways in which telematics is used to measure driver behavior and emphasizes how Blockchain could improve the issues arising from the current techniques and measurement parameters;

- Chapter 7 analyzes the correlation between the age of the driver and the respective rate of involvement in traffic accidents and violations in order to develop a statistical logistic regression model that measures the positive impact caused by the influence of the Blockchain platform on driver behavior.

Chapter 2

Blockchain Basic Concepts

Remark: "With blockchain, we can imagine a world in which contracts are embedded in digital code and stored in transparent, shared databases, where they are protected from deletion, tampering, and revision. In this world every agreement, every process, every task, and every payment would have a digital record and signature that could be identified, validated, stored, and shared. Intermediaries like lawyers, brokers, and bankers might no longer be necessary. Individuals, organizations, machines, and algorithms would freely transact and interact with one another with little friction. This is the immense potential of blockchain." (Marco Iansiti, et al.).

2.1 Origin

The Blockchain concept is considered to have its origin through the work described by Stuart Haber and W. Scott Stornetta (Stuart Haber, et al.), where a cryptographically secured chain of blocks it is described. However, the Blockchain technology got more widespread and recognized in 2008 when Satoshi Nakamoto, an unknown identity, created the Bitcoin. This creation is a cryptocurrency that based on a Blockchain network, promised to be the first digital currency that assures reliability without requiring a trusted authority.

Although Blockchain's initial motivation was for financial purposes, this technology stimulated potential applicability on other fields, such as Energy, Agriculture, Healthcare, Legal System, Education and Urban Life. Actually there are a huge amount of new distributed ledger applications.

2.2 Definition

A Blockchain is a peer-to-peer network and public digital ledger in which transactions made with cryptocurrency (the tokens) are recorded chronologically. Briefly, is defined as a decentralized network, since all peers have the same accessing condition to all information. This means that when two peers agree to a transaction, this is public on the network and there is registered in an immutable and eternal way. This ensures the advantage of not having a central network responsible for validating, and managing transactions, giving Blockchain the characteristic of being transparent and reliable (Andreas Antonopoulos). However, all transactions are protected by cryptography, which gives users the privacy and security required. A so-called "block" is a container data structure that aggregates transactions for inclusion in the public ledger.

2.3 Structure

The Blockchain data structure is an ordered list of blocks that contains transactions. Each block within the Blockchain is identified by a hash, generated using the SHA4256 cryptographic hash algorithm on the header of the block as ilustrated in Figure 2.1, Merkle root hash and nonce, followed by a list of transactions (Andreas Antonopoulos). A hash is a one-way function that takes any digital media (strings of binary digits) and runs an algorithm on it to produce a fix length and unique digital output. The math proprieties of this hash function ensure that it is not possible to do the reverse calculation to see which input has generated the actual hash (Jack Shaw).

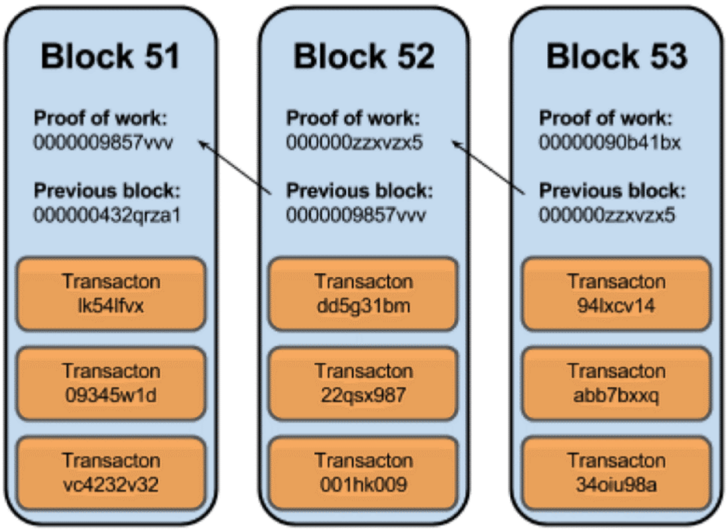

Figure 2.1: Generic Block Sequence (Anitta Patience, et al.)

Each block also references the previous block hash. Therefore, the sequence of hashes linking each block to its previous one creates a chain going back all the way to the first block ever created, known as the genesis block.

Since the previous block hash field is inside the block and thus affects its current hash, this chain effect ensures that once a block has many generations following it, it cannot be changed without requiring large recalculation of all subsequent blocks. Therefore, a long chain ensures that the data stored in the Blockchain is immutable. (Andreas Antonopoulos)

2.3.1 Peer to Peer Network

Since all the data is stored in the Blockchain network and so available for all the peers, there is no need of a central data held monitoring the transactions. While centralize information by a trusted part is more common, data manipulation could be a risk on how transactions and contracts exist nowadays. By decentralizing it, Blockchain makes data transparent in a democratic way.

The existence of a central data carrier has mainly two issues. The first relies on where and with whom user generated data is stored and manipulated, so what global companies such as Google and Facebook could do with all personal information generated by their users. The second would be the concern on how secure located and protected those centrals are, as in the case of a Central Bank for example.

The decentralized ledger has the proponent premise to exclude the need for a central part to manage transactions and agreements. Consequently, this new model has generated much controversy. In addition to the fact that the operating system needs to make many copies and updates, for each peer, each block needs to be validated by the nodes willing to do so. There is also criticism about potential dangers of not having a certified central that ensures security and legality of the transactions and so responsible for certifying stability to the cryptocurrencies' value.

2.3.2 Security

To ensure privacy and security, Blockchain methods include the concept of public and private key cryptography. The public keys are the address on the Blockchain, so the cryptocurrencies could be sent across the network and recorded as belonging to that specific address. On the other hand, the private key is like a password that gives its owner access to their digital assets. Both of those keys are long hashes based on cryptography.

After the transaction occurs, it needs to be certified before validated. This is done by the so-called miners, special nodes on the peer-to-peer network that create the blocks. They receive a reward for those computation that it is generated by the network, so for this and other reasons, computed transactions also require a user fee (Andreas Antonopoulos).

The miners collect transactions that people send each other over the network and only validated transactions are added on the Blockchain. Each miner takes an amount of these transactions and build a new block on the chain to receive the reward. To build a block, each miner must solve a hash puzzle, so the one who has first solved the problem can broadcast the blocks on the network. The block launched also includes the solution to the puzzle, called the nonce, in the block header. Therefore, each block contains multiple transactions, which each contain data. Each of the transactions data must pass through a hash function, generating unique hashes. This process begins in parallel for all transactions and according to a "tree model", the Merkle Tree, narrows to the point where a single hash root is defined as seen in Figure 2.2. This model is called a "Merkle Tree" (David Edwards, et al.).

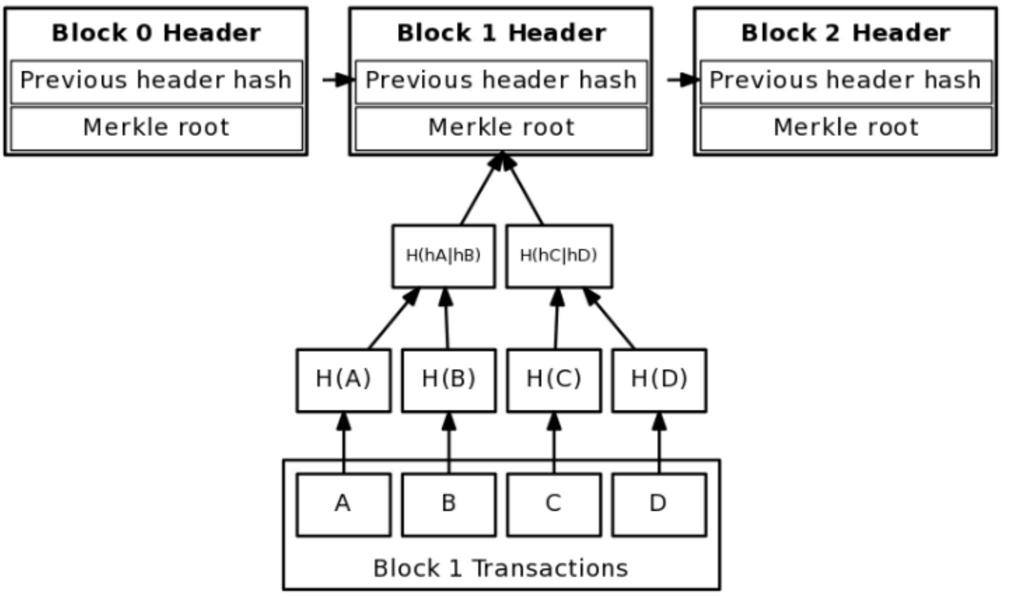

Figure 2.2: Merkle Tree Connecting Block Transactions to Block Header Merkle Root (David Harding)

2.3.3 Tokens

"Blockchains are taking a bite out of capital markets. With less than a hundred lines of code, anyone can generate Blockchain-based tokens and sell them to the public. Over the past year, parties have raised over 3.2 billion through token sales—what some have referred to as initial coin offerings (or ICOs)—with some sales lasting a matter of seconds." (Jonathan Rohr, et al.).

From the formal financial definition, the cryptocurrencies traded on the Blockchain would all be called as tokens and not coins. However, since the tokens can be traded and have aggregated value, they are popularly called as digital coins, the cryptocurrencies.

The most known digital currency is the Bitcoin, but there are many digital coins, usually generated from the Bitcoin open-source original protocol. Users can transfer those cryptocurrencies over the network to do anything that can be done with dollars or euros, like buy and sell goods, send money to organizations, or extend credit. The nonexistence of a central regulation implies that the value of those digital coins are influenced mainly by the market flow.

Also, there are other currencies such as Ether and Ripple, that are not derived from the Bitcoin's open-source protocol. Rather, they have their own Blockchain protocol and their coins are not just used to trading proposes such as Bitcoin. Besides they can also be tradable in the market, they are needed for the users that join the services available on their respective platform (Masterthecrypto).

Therefore, a recent classification used to explain these assets is the division between security and utility tokens. The security tokens derives its value from an external and tradable asset (Josiah Wilmoth), while the utility tokens are useful in specific platforms, they can be exchanged for a product or service. Not just as a monetary value, utility tokens might also represent a title or a reputation, basically any value recognition (Masterthecrypto).

It is called Initial Coin Offering (ICO) when a new cryptocurrency is launched. After the launching of the token what grants the storage and transfer of these assets are the private keys owned by the individuals. As explains (Jonathan Rohr, et al.) "Once the token sale begins, anyone with an internet connection can conceivably buy a token. The sale operates as a worldwide crowdfunding event, where tokens can be purchased en masse, like the way entrepreneurs and artists have used Kickstarter to fund product development. Parties interested in buying a token simply go to an online portal and purchase tokens, which are deposited into a digital currency wallet. Many token sales are "capped." In other words, only a fixed sum of tokens is sold. These token sales—for popular projects or with founders with strong reputations— sell out in a matter of minutes, if not seconds. Once sold, tokens are non-redeemable. The seller generally has no repurchase obligation, and the tokens are not subject to transfer restrictions Rather, they are actively traded on secondary cryptocurrency markets, around the globe, which list tokens and facilitate their trading, much in the same way as a stock exchange lists shares in publicly traded companies. The existence of these exchanges and the ease with which it is possible to buy and sell tokens on an exchange means that even utility tokens—which only may entitle the holder to the use of some service or software—can generate profits if sold on exchanges for more than their purchase price. All proceeds from the token sale go to the organization or group of developers selling the tokens. The nature of these organizations run the gamut. Some are organized as traditional business entities or not-for profit foundations. Others are not formally organized—they consist of a loosely connected group of developers, and the proceeds from the token sale are distributed to those individuals."

Regarding the tokens launching and regulation rules, the maximum number of generated tokens and the way they are distributed is not yet standardized. As an example, Bitcoin was already created with a pre-set maximum limit number and it has been issued according to the mining reward, which temporarily decays, until it reaches the saturation. For the Ripple, all tokens were launched, distributed, and destroyed according to the number of transactions that occur on the platform. On the other hand, Ethereum has been partially initially launched, but also is continuously emitted, since all transactions and smart-contracts require the token to operate (Cryptofinancas).

All of this makes the tokens market very polemic and worldwide discussed. Although it has a huge potential as an asset, the regulation does not have the same standards among the countries, as happens for traditional currencies such as the dollar and the euro. So far, it follows (Jonathan Rohr, et al.) conclusion in this field "For now, Blockchain-based token sales have an immature veneer, causing some to argue that these sales simply represent new tools that will be leveraged by hucksters and unscrupulous charlatans. Digging below the surface, however, reveals that Blockchain-based tokens represent a wide variety of assets, some of which will qualify as securities under U.S. law. Tokens sales are changing how technologists are choosing to fund their ventures and have begun to eclipse traditional financing sources—like venture capital funding—for entrepreneurs exploring Blockchain technology."

2.3.4 Data Storage

A current disadvantage regarding Blockchain technology is the necessity of high amount of data processing and storage. This is due to the transparency and peer-to-peer network characteristics, since the data is validated, updated, and then made available to all nodes. Regarding the historical context, it is estimated that there will be over 20 billion connected devices by 2020, all of which will generate and then require management, storage, and retrieval of a huge amount of data (Gartner). So, this Blockchain's feature could be an issue not only because of requiring too much digital capacity but also the time duration of the transactions could be compromised.

To solve this problem, decentralized storage were built according to Blockchain technology features. Not just being a solution for the capacity issue, this service is also compliant with the Blockchain concept motivation, so to avoid high amount of data concentrated in few private companies, such as Apple (iCloud) or Google (Drive). Some examples of those new storage systems are InterPlanetary File System (IPFS) (IPFS), STORJ Network (STORJ) and Filecoin (Filecoin).

Another advantage is that some of those networks allow anyone to participate as a storage provider, what makes storage resemble a commodity or utility, so then this service could be driven by market pricing instead of by global companies.

Chapter 3

Potential of Blockchain Technology

Remark:

Despite being a recent technology, Blockchain can be categorized according to three major evolutionary phases. The first, referring to the cryptocurrencies coming from the open-source Bitcoin protocol, with an innovative proposal in the financial system. Further, some Blockchain networks were created with diverse goals and protocols, with Ethereum being one of the most popular, a platform based on "smart-contracts" that would allow the creation of decentralized applications for operational uses, not only for financial and speculative terms. Nowadays, these platforms have been implemented in some Industries, to revolutionize areas such as Health, Transportation, Energy and Business. Together with other technologies such as Artificial Intelligence, Internet of Things and Big Data, the Blockchain is collaborating to build the Industry 4.0 (Unibright).

3.1 Bitcoin

“The Bitcoin system, unlike traditional banking and payment systems, is based on the decentralized trust. Instead of a central trusted authority, in Bitcoin, trust is achieved as an emergent property from the interactions of different participants in the Bitcoin system." (Andreas Antonopoulos).

3.1.1 Transactions

The Bitcoin system is composed by the users with their respective wallets containing the keys, propagated transactions and the miners, nodes responsible to validate the transactions on the network.

The users have public and private keys. Briefly, a private key is the owner signature used to send the cryptocurrencies to other users, so it is convenient to keep it secret. On the other hand, public key is broadcasted out to the network and has the owner authenticity verified by the miners. After that, the public key is sent to the address desired by the transaction generator. A remark is that both the private and the public keys are hash functions, so one-way functions as illustrated in Figures 3.1 and 3.2.

Figure 3.1: Blockchain Transaction (Leon Di)

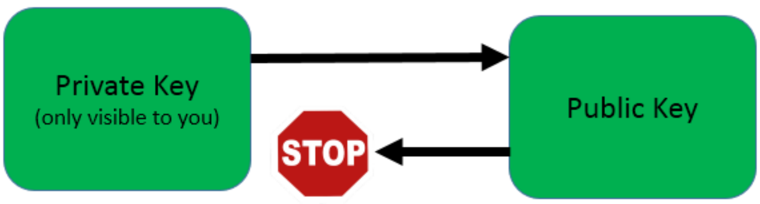

Figure 3.2: Private and Public Keys (Leon Di)

In a Bitcoin transaction there is a standard fee added to the inputs, a payment collected by the miner responsible for including the stated transaction in the ledger. As seen before in Figure 2.1, any new transaction references the previous one with the respective hashes, therefore compounding a chain of blocks.

Another powerful feature is that nodes can be active through any type of connection such as wired, WIFI, mobile, etc., independent on where the peers are located (Andreas Antonopoulos). However, one of the most common criticisms of Bitcoin is the miner's validation delay meanwhile the number of transactions is increasing exponentially. An average time to mine a block is ten minutes, but to be validated it needs at least six miner's confirmations, so approximately one hour to be reliably broadcasted in the Blockchain (Steven Buchko). Therefore, it is a disadvantageous when compared to bank transaction, whether one can make a purchase with a credit card or debit card in seconds. However, it is argued that for small transactions on Blockchain it would not be necessary to wait for all the six confirmations, with no more risk than a credit card payment made without an ID or a signature, as people currently accept.

3.1.2 Mining

The mining process has two main purposes in Bitcoin. First, miners oversee validating all the transactions compliant with the Bitcoin's consensus rules, so providing security. Second, miners create new Bitcoins in each block, following a pre-defined issuance schedule.

There are four main methods of finding consensus in a Blockchain: the practical byzantine fault tolerance algorithm (PBFT), the proof-of-work algorithm (PoW) ,the proof-of-stake algorithm (PoS), and the delegated proof-of-stake algorithm (DPoS) (Chris Hammerschmidt). In fact, the Bitcoin's protocol states for the proof-of-work (PoW). Basically, a miner uses a large amount of electricity to solve mathematical problems, described as "puzzles". When a new transaction is launched into the network, miners compete for those who can solve these puzzles faster. A successful miner would collect reward in the form of new Bitcoin and transaction fees and so the block is published on the network. As mentioned, not just one, but usually six miner's confirmations are required. This methodology guarantees security without a central authority.

Those "puzzles" are based on cryptography and its difficulty is adjusted by the network according to the amount and expert level of the miners trying to solve the same challenge. "Finding such a solution, the so-called Proof-of-Work (PoW), requires quadrillions of hashing operations per second across the entire Bitcoin network. The algorithm of Proof-of-Work involves repeatedly hashing the header of the block and a random number with the SHA256 cryptographic algorithm until a solution matching a predetermined pattern emerges." (Andreas Antonopoulos).

Before, to be a miner the peer could use its own computer Central Processing Unit (CPU) or a high-speed video processor card, however currently it would need a special Bitcoin hardware since it has become a very electricity-consuming activity. In addition, it has taken industrial and entrepreneurial proportions, there are many Bitcoin mining pools, groups and corporations of Bitcoin miners working together and thus sharing the rewards.

3.2 Ethereum

"Ethereum is a decentralized platform that runs smart-contracts: applications that run exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference. These apps run on a custom built Blockchain, an enormously powerful shared global infrastructure that can move value around and represent the ownership of property. This enables developers to create markets, store registries of debts or promises, move funds in accordance with instructions given long in the past (like a will or a futures contract) and many other things that have not been invented yet, all without a middleman or counterparty risk.” (Ethereum)

3.2.1 Origin

Ethereum was created in 2013 by Vitalik Buterin, a young programmer who at the time was only 19 years old. Thereafter, during the North American Bitcoin Conference (Miami, 2014), Vitalik officially presented his idea and so Gavin Wood got interested in the project and together then published the Ethereum Yellow Paper containing the specifications for the Virtual Ethereum Machine (EVM). Regarding the fundraising for the project, were launched several crowdfunding campaigns and so the funds and project development was managed by the Ethereum Foundation, a Swiss non-profit organization in Zug (Switzerland)(CoinBR).

In November 2014, it was organized the *DEVcon0* event (Berlin), which brought together Ethereum developers to discuss the issues involving this new technology with the aim to make it more secure and widespread. From 2015, the *DEVgrants* program was created to offer resources from contributors to both the platform and related projects. The idea was to attract developers, investors, and companies to contribute to Ethereum worldwide recognition, improve its applicability and technological development. In the same year, another platform acceleration program was created. In this case, a reward was offered for those who could detect any vulnerability of the software (CoinBR).

An analogy made by the Ethereum founders is that when the Internet arose, one could not imagine the possible applicability as it is nowadays. Therefore, Ethereum is only four years old, the future applications could be many, and it is still very uncertain, probably its greatest utility has not yet been drafted.

3.2.2 Structure

Ethereum is a digital platform based on smart-contracts whose focus is the decentralized applications (Dapps) implementation. Such applications have the premise of offering services and utilities without the need for intermediaries connected to a central network, as Blockchain's proposal foresees. These smart-contracts are responsible for storing data, sending, and receiving transactions and enable a safe and immutable negotiation without a bureaucratic and high-cost service as currently demanded by usual contractual regulations.

To illustrate, this technology can be compared to basic services which do not require an intermediary, such as a food vending machine. Instead of buying a snack in a bar, the person can choose to use this machine, where it is enough to put a coin then the system will process if the value entered was sufficient and provide the snack, without the need of employees and the bar infrastructure (CoinBR).

Also Ethereum has a Blockchain architecture as the one described for the Bitcoin, however there are some fundamental differences. Ethereum is a platform designed for everyone to create applications or tokens with the smart-contracts and the official coin used in this digital environment is the Ether. So, contrary to Bitcoin, the Ether has a direct application and it can represent not just a tradable currency, but also valuable utilities, as described in (Ethereum) "Tokens in the Ethereum ecosystem can represent any fungible tradable good: coins, loyalty points, gold certificates, IOUs, in-game items, etc. Since all tokens implement some basic features in a standard way, this also means that your token will be instantly compatible with the Ethereum wallet and any other client or contract that uses the same standards."

Ethereum is becoming popular and has many social-economical advantageous. One is the acceleration and democratized on small business, since anyone can create a Decentralized Autonomous Organization (DAO) and issue a token to crowdfund a project, what is also a great incentive for innovative creations. Since usually donors prefer don't invest in projects with small founder's background, in Ethereum this crowdfunding would be ideal, because if the founders don't accomplish the goals, the donations are returned, so reducing the risk for donors, since the only loss would be the gas fees paid for computation. Otherwise, if the funded project evolves, donors have access to all operations in real time and in a transparent manner, also by the decentralized ownership of Blockchain. The results are then clearer and more accessible, and the risk of investment is lower.

Ethereum removes mistrust barriers between contractual parties. Because Ethereum is, by Blockchain concept design, fairness and immutable, it is an alternatively solution for contractual problems that are currently solved at high costs, long time, and subjective trust, such as properties and services transference, voting systems and financial operations. All these applications can be created on a network where users keep their funds and personal data all the time.

Moreover, since it is a distributed ledger it is not possible to be censored by an organ or authority. Nowadays developers need to pay to submit their application to Apple (Store), for example, and still risk having it removed according to the company justification. Another positive argument is that in the digital world, what is centralized becomes easier to attack by hackers because it offers a single point as a target.

So far, decentralized applications have the potential to replace services such as Airbnb, Facebook, and Spotify, due the advantage of directly transferring value to the owners since there is no involved companies' commission. As an example, when people use social networks, besides having a lot of personal information and contributing with their own interactive content (photos, comments, and events) this generates more value for the company (Facebook, Instagram, Twitter etc.). Although, with a decentralized platform, this could be converted into value for users through tokens that they could easily create and launch in the market.

3.2.3 Smart-Contracts

"A smart contract is an agreement whose execution is both automatable and enforceable. Automatable by computer, although some parts may require human input and control. Enforceable by either legal enforcement of rights and obligations or tamper-proof execution" (Christopher Clack, et al.). Simply, is a code that pre-defines the conditions to which the parties agree, and then certain actions are automatically executed (Lukas Kairys).

Besides the transparency and democratization proposed by smart-contracts, another advantage is the non-subjectivity. For example, for a vehicle insurance contract it is quite difficult to predict and reference all the factors involved in a car crash. Such as, who was blamed, whether it was due to driver irresponsibility or exogenous factors and compensation's conditions for each case. It is quite common that from that point on, a long-term bureaucracy occurs, both because the insured would like to obtain the maximum benefits of the contract, and because the insurer would be interested in having less possible expenses. However, if this agreement was established with a smart-contract on the Ethereum network, so that the vehicles, the drivers and the insurance company were involved, by the time the car crash occurred, it would be possible to compute all the variables (such as checking the speed and the behavior of the driver, the severity of the accident and climatic conditions, among others) there would be no place for subjectivity and money would or would not be debited from the parties automatically.

Similarly to Bitcoin network with miners and transactions, the users willing to execute a smart-contract need to pay a fee, a proportional amount of "gas", for its computation. A part for being a reward incentive to the miners, this fee also prevents users to write excessive number of programs and line codes, so incentives the network to be efficient.

Regarding the programming language where the smart-contracts were build, the most well-known is called Solidity, developed based on JavaScript. However, from the beginning there was seven different based programming languages, like Go, C++, Python, Java and more (Ethereum).

3.2.4 Decentralized Application (DApp)

Decentralized Applications are the projects generated in Ethereum platform. For illustrative purposes, if large applications like Uber and Airbnb were built in Ethereum, there would be no need for all data to be stored and controlled by the respective companies, so users would always be in control of their personal data. Thus, possible conflicts between service providers and consumers (in this case, drivers and passengers, guests, and owners) would not be more mediated with subjectivity and delay by a company service. There are already many applications being created every day, and they can be found in the official Ethereum deposit (State of Dapps). Such transparency as well as codes publicy available (Ethereum) serve as encouragement and support for many developers, which speeds up the process of disseminating knowledge and creating useful applications in various industries.

A very interesting example of decentralized application is one called ETHERISC (Christoph Mussenbrock, et al.), a decentralized insurance business model. It operates mainly in three areas: Flight Delay App, Crop Insurance and Social Insurance. The drivers of this projects are efficiency and automation at lower costs operation and transparency both for costumers and investors.

Briefly explaining the *Flight Delay App* (see the Demo in Figure 3.3) can issue policies and pay out valid claims automatically. It is enough for the registered users to enter their personal and flight data in the network and to buy the insurance, without needing a direct contact with the airline company. If the delay does not occur, the network computes the information and discards the user's insurance. In the other hand, if there has been a delay, the application automatically deposits the money to the users, without the need to request the company. In this fast, transparent, and efficient way, it avoids costs of operations and also prevents the user or the company from having a conduct that is not faithful to the contract.

As stated at (Etherisc), "Based on our research and experience with the Flight Delay Dapp, insurance applications with fixed risk pools do not scale. Cryptographic

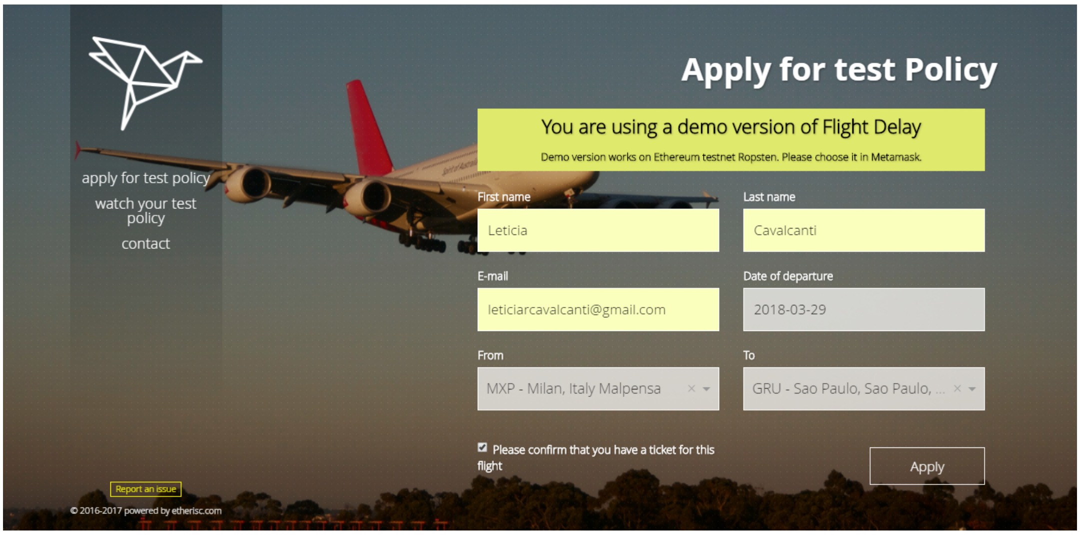

Figure 3.3: Flight Delay Dapp Demo (Etherisc)

tokens enable highly customized economics. Our goal is to tokenize reinsurance risks and make them available on a global ”open access" marketplace. This strategy provides both flexibility and scale for decentralized insurance risk pools, enables new types of insurance products, makes the product extremely safe for customers, and democratizes access to reinsurance investments” Those innovative decentralized projects have a high potential impact on society. Although this is one out of thousands applications, whether in the Aeronautics Sector, but also in the Health, Social, Energy, Transportation, Pharmaceutical and related sectors. Further, it will be discussed special applications within the Automotive Sector in specific.

3.2.5 Decentralized Autonomous Organization (DAO)

Briefly, a digital Decentralized Autonomous Organization (DAO) relies on smart-contracts and pre-programmed rules that describe what can happen in the system. It is a self-governing organization, so not influenced by external forces. It is a new propose of business model, likely the mentioned Ethereum crowdfunding, which was considered one of the biggest crowdfunding campaigns that have ever been launched.

The DAO was launched in April 2016 and its tokens were emitted throw a crowdsale that by the end of May 2016 raised more than 150 million dolars, from more than 11,000 investors (Wikipedia). Since then, the DAO tokens were tradable on various cryptocurrency exchanges, while the code is open-source and could be developed in different languages throw Ethereum, so anyone could create a business organization and emit tokens for fund raising. However, because it relies inside the Blockchain network, it is not directly related to any country and this raises a lot of discussions about legislations and regulations that should be related to an organization, with or not profit driven. An example is the Dash crypto-currency (Dash), first decentralized, autonomous organization to be created, since it is operated in a decentralized budget governance and budgeting system.

3.3 Industry 4.0

The Industry 4.0 concept is based on revolutionary modern technologies such as Artificial Intelligence, Blockchain Networks, Internet of Things, Machine Learning and more as illustrated in Figure 3.4. Thus, the concept of a fourth Industrial Revolution that requires a huge volume of digital data efficient storage management has been developed. One of the biggest challenges is the integration of these technologies between companies, transports, and people, so that a seemingly simple and integrated system is built but with a very complex backend (Bernard Marr). Another concern is how such data generated and stored should be managed. Both in terms of efficiency and logical correlation, as well as privacy and copyright. Therefore, it is inevitable that the largest companies are insistently investing in the implementation of these technologies.

The application of such technologies can be directly in the manufacture process and product development, as in the new logistics of interactions between employees and machines, but also can change the management system and data analysis of the company. There are many levels within the industries that can be revolutionized.

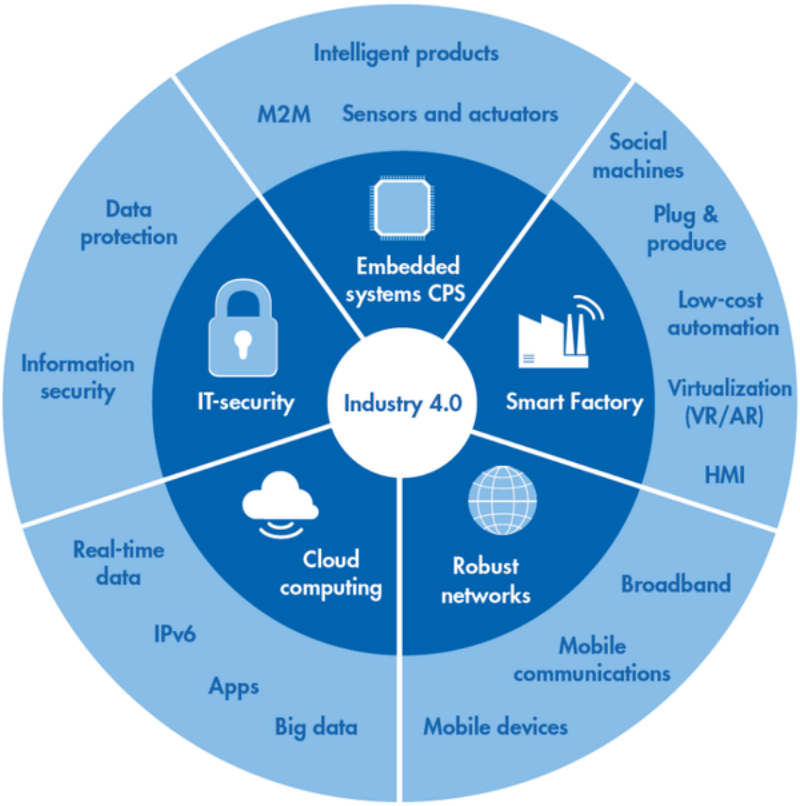

Figure 3.4: Industry 4.0 (Messe Leipzig)

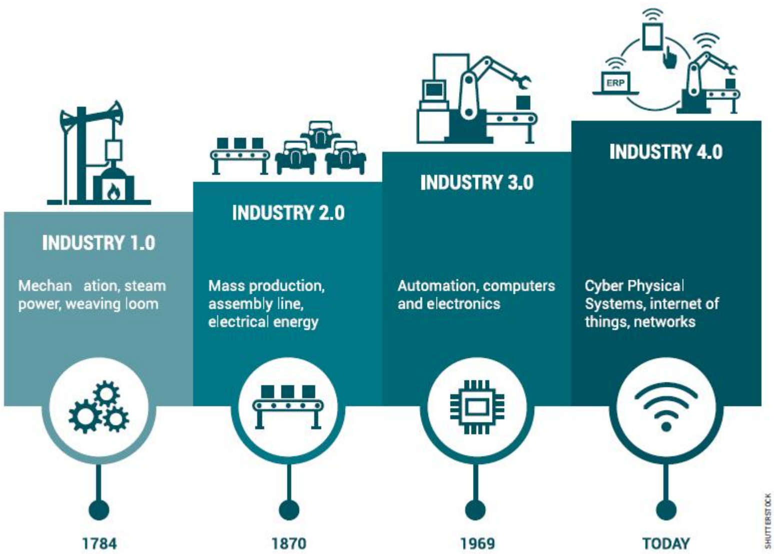

Figure 3.5: Industrial Revolutions Timeline (Aidan Coleman)

An example of a combined technology application is Blockchain's interaction with Internet of Things (IoT), as stated (Khwaja Shaik) "The rapid advance of Blockchain technology and the Internet of Things (IoT) are felt throughout our daily lives. A Gartner study estimates Blockchain will add 3.1 trillion dolars in business value by 2030, and in another analysis the global IoT market is expected to grow from 157B dolars in 2016 to 457B dolars by 2020. We are about to see more change than we could imagine with Blockchain and IoT."

Some platforms, like The Watson IoT Platform (IBM) enables the user and the IoT devices to add data to a private Blockchain, so the data is shared among only the business partners involved with the transaction. Therefore, the partners would be able to access and supply Internet of Thing (IoT) data without the need of a company centralization, what makes the data treatment more transparent and dynamic within such many IoT devices that may be connected to the network. Further, the platform proposed in this Thesis will also suggest a combination between Internet of Things (IoT) and Blockchain technology.

Chapter 4

Automotive Sector

Remark:

"Imagine a world where foreign aid didn't get consumed in the bureaucracy but went directly to the beneficiary under a smart-contract? Rather than a 60 billion dolars car-service aggregation, why couldn't we have a distributed app on the Blockchain that manages all these vehicles and handles everything from reputation to payments? Ultimately, they'll be autonomous vehicles moving around" (Don Tapscott). The Blockchain technology promises to change the whole Automotive Industry.

4.1 Introduction

To emphasize the importance of modern technologies applications, like Blockchain, in the Automotive Sector, it was extracted the following forecast data from McKinsey (Salil Aggarwal, et al.) report: "Several factors are contributing to the growing amount of available car data. An increasing number of sensors – present in vehicles and integrated into mobility infrastructure – means that information can be gathered on nearly every way a driver uses a car, how that car functions (or malfunctions), and everywhere it goes. Organizations that use this connected technology to optimize their products and services based on data or to develop new, in-vehicle experiences for drivers and passengers will be the ones to create a significant competitive advantage for themselves. This market – comprised of more than 30 car-data-enabled use cases representing new features and services – is projected to reach USD 450 billion to 750 billion worldwide by 2030. Three value creation models underlie these use cases: revenue generation, cost reduction, and enhanced safety and security."

It is a fact that today's society has become increasingly digital and that has influenced several industries, among them Automotive. People tend to be connected to several digital devices in an integrated way. Also, there is a worldwide worry about environment and security issues and so there is a large investment in electrical and autonomous vehicles development. Following this trend, the focus on improve standard vehicles and integrate them with the driver's digital devices has been a certain attractive topic.

A vehicle is a very complex machine whose thousands of data generated are poorly explored. Thus, there is an ambition to monetize and add value to all this information generated by the vehicles. There is a trend of competitive advantage among the companies in the Automotive Sector that are most able to digitize and integrate the vehicle systems. Such an advantage can be at levels of Original Equipment Manufacturers (OEMs), suppliers, dealers, financiers and end consumers, the opportunities are many.

Although Blockchain itself has great innovative potential, when it is combined with Internet of Things (IoT), Artificial Intelligent (AI) and Big Data can further boost applications development, such as smart mobility solutions linked to location-based vehicles services. In the following sections, some existing ideas and Blockchain application projects will be elucidated to promote a better understanding about its potential impact.

Based on a study report from Deloitte LLP (Deloitte(a)), Blockchain applications in Automotive Industry can be segmented in three sessions. First, linked to the vehicle's value chain, second, focused on the vehicle's digital information and third, directly related to the consumer, such as payments and services.

4.2 Value Chain

Across the path from the company to the supply chain there are many opportunities to improve efficiency and support validation within the process.

4.2.1 Supplier's Identity Validation

The proposal would be to transfer the agreements between carmakers and suppliers to the Blockchain network, for example by means of smart-contracts. In this case, suppliers' data would be saved in the network, and validated in an immutable way. Further, all agreements and transactions of this provider are subsequently registered in the network, so that it is possible to trace its profile continuously. Such a solution has the potential to reduce the time and expenses from contractual bureaucracies that a carmaker faces with its suppliers. In addition, it would bring more transparency and confidence for the carmaker to be able to follow up overall historical transactions and agreements made with its suppliers throw the platform. In this way, it would be more difficult to get a fraud or a contractual problem between the parties.

An example of this propose is Deloitte's Smart ID platform (Deloitte(c)). The platform offers an automatically identity linked processes such as customer registration or the so-called Know Your Customer (KYC). Any entity can be represented digitally, using attributes to represent key information, such as legal entity reference and beneficial ownership. Also, the platform is efficient in receiving and verifying customer information for staying up to date with changes on an ongoing basis. In this case, the relation between the organization and the costumer could be agreements within the vehicle supply chain.

4.2.2 Spare Parts Provenance

A Blockchain network could be useful to capture, store and update information on vehicle spare parts. This enable the service center, car manufacturer and customer to trace the origin of spare parts through the supply chain to the original manufacturer data and location. This improves the quality and reliability of the vehicle, from its production to the entire life cycle. Of course, this information is interesting to the car manufacturer but also for the end-costumer, for example when one is interested on buying a vehicle in the used market, the costumer could access all information about original and replaced spare parts that composes that vehicle.

A good example to illustrate this new business model is the startup Ambrosus (Ambrosus). In this case, the focus is to trace the production and commercialization of food and medicine products with the aim to build a community-driven ecosystem to assure the quality, safety, and origins of products, so to improve distribution processes and allow consumers to easily see where their products come from and what is really inside them, a very relevant information specifically when talking about those kinds of products.

Fake Parts

The core is to identify spare parts placed in the supply chain by not verified suppliers, what certainly compromises the final vehicle's quality and reliability.

A Blockchain platform could be useful to identify some parts sold as original even if they are not. In fact, could happen that some suppliers who receive molds and specifications for manufacturing parts for a company, in addition to delivering, use this information to sell similar parts to other companies without the permission of the owner of the technology.

Parallel Market

This issue could be illustrated with the following example: A piece destined from Italy to Germany at the price of 100 dollars is instead bought by a Spanish distributor where it had been sold for half of the price. The aim would be to use Blockchain to verify the negotiations and agreements between the suppliers and the carmaker. That could be done in Ethereum, for example, with the verification of the smart-contracts by the network.

4.2.3 Integrated Supply Chain

The proposal is a platform that integrates all automotive organizations and provides an end-to-end supply chain solution. It could be possible to order or sell, track, and pay for the orders, validate, and store the related documentations and set agreements throughout the chain, for example between seller and shipping company and seller and buyer or seller and custom authorities. It would be a revolutionary business model, as illustrated in the Figures 4.1 and 4.2, so the idea is to build an integrated and decentralized system.

Figure 4.1: Automotive Supply Chain Nowadays (Deloitte(b))

The current supply chain model limits many Original Equipment Manufacturers (OEMs) control and visibility beyond tiers, what could be the cause of meaningful lack of insights for quality improvement and cost reductions. By incorporating

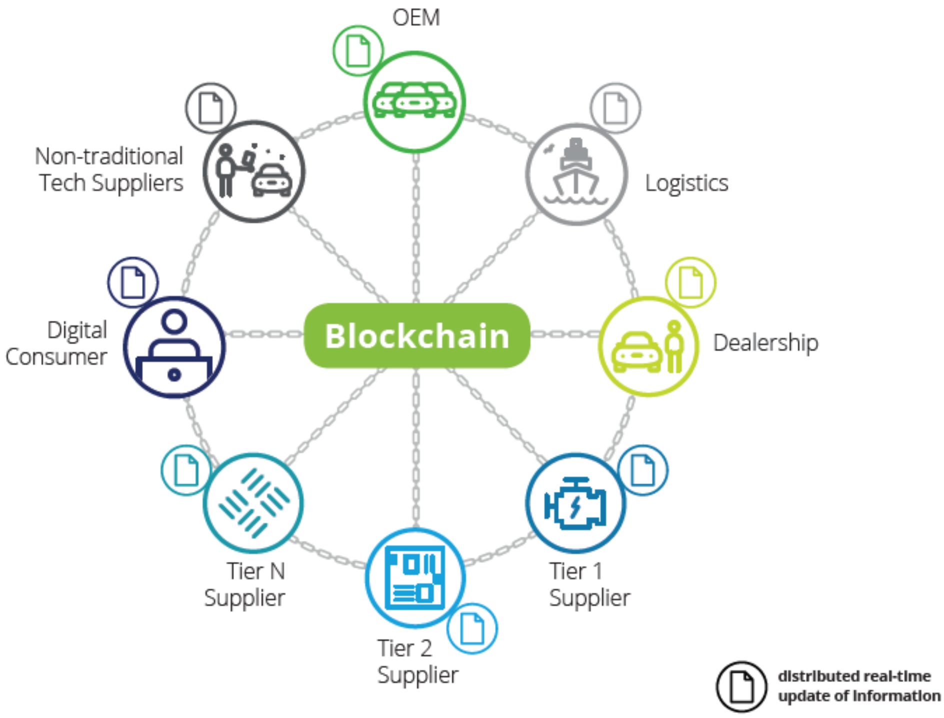

Figure 4.2: Automotive Supply Chain in the Future (Deloitte(b))

this new Blockchain based model, Michael Woodword, Partner at Deloitte UK (Deloitte(b)), believes that analytics may be improved, and trading relationships may become more transparent, enabling "an amplification of trust that is an imperative for supplier relationship management". The concept is based on Deloitte's TraceChain project, a Hyperledger based solution for traceability of goods and assets that enhances transparency and visibility into the chain of custody for complex global supply chains (Hyperledger).

Focus on the open market platform, the Figure 4.3 is a simple example of how it could works. First, an Original Equipment Manufacturers (OEMs) could create a request to purchase raw materials with specific criteria such as price, delivery date and origin. Second, some suppliers using the platform would be notified at the time of the request and could submit bids including details of their conditions. Third, the OEM can choose either automatically for a supplier that meets all his requirements or to select a new one that fits better. Further, clauses could be added to these smart-contracts to trigger specific events, such as a delay that results in an automatically charged penalty to the supplier prior to delivery, with no need to discussing between the parties. This would also give the stakeholders a better oversight of which player is responsible for bottlenecks in the supply chain and save time and bureaucracy costs when the agreement is not completed correctly.

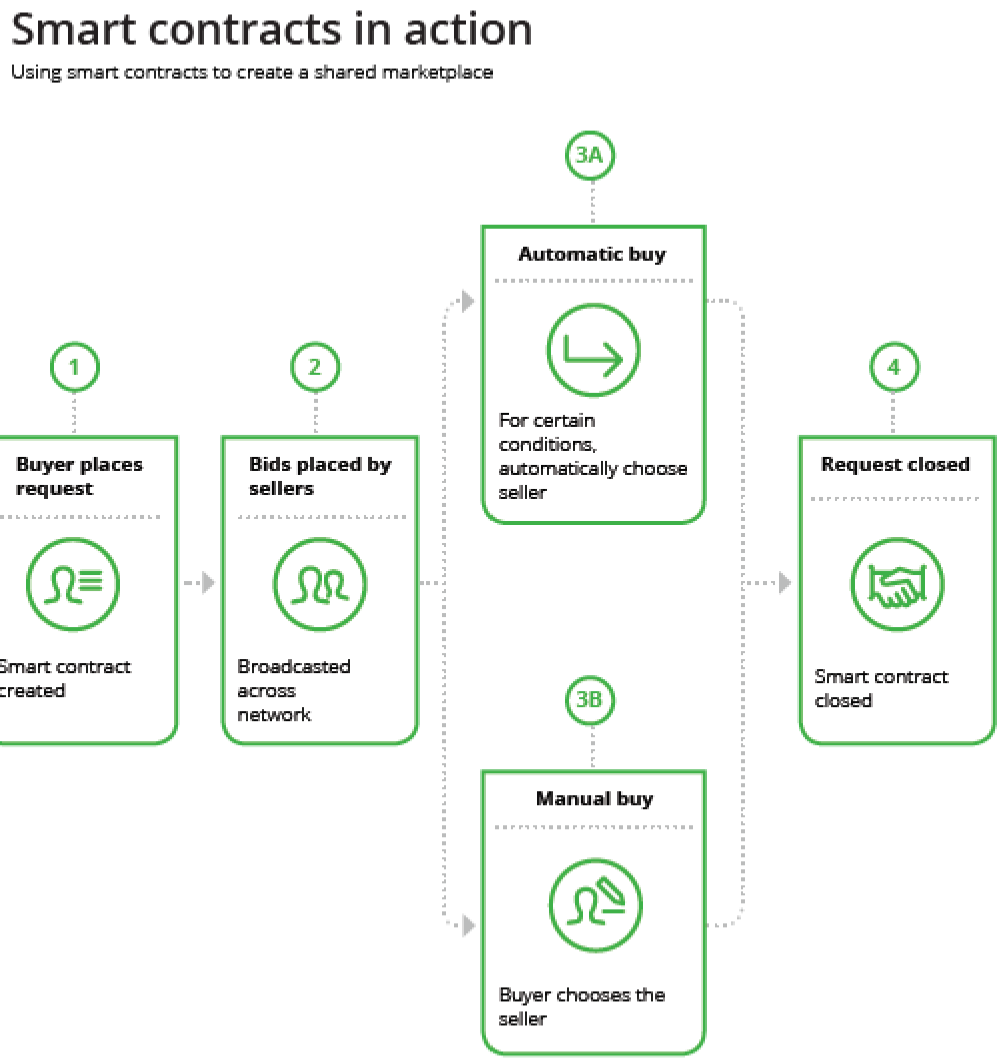

Figure 4.3: Smart contracts in action (Deloitte(b))

4.2.4 Vehicles Recall

This is a extended application derived from tracking vehicle parts and verification of the manufacturer and dealers within the supply chain. Therefore, put together all previous concepts that enables car manufacturers to target vehicles that contain defective parts and so issue specific recalls or services bulletins for them. This application can also track the status of the recall, what would improve consumer satisfaction and reduce the high costs involved whenever a carmaker sets a vehicle recall.

A good illustration is the recall of one of the most famous car companies nowadays, Tesla. The company recalled 123,000 Model S cars due to an issue that could affect steering. The recall was issued on March 29 (2018) and included Model S cars around the world that were built before April 2016. Tesla said it would fit the new power-steering component after engineers had observed "excessive corrosion in the power steering bolts, though only in very cold climates, particularly those that often use calcium or magnesium road salts, rather than sodium chloride (table salt)." (Trevor Mogg)

Of course, this is not a company, but an industry problem, as stated “Despite the undoubted reliability of modern-day cars, recalls by major automakers seem to have been coming in thick and fast in recent years. Just a couple of weeks ago, Ford called in 1.3 million Fusion and Lincoln MKZ vehicles over a steering issue, while Toyota, Hyundai, and BMW have also been forced to take similar action this year. And this week’s recall isn’t the first for Tesla. Twice in the last two years it’s called in a number of Model X SUVs, and in 2015 it recalled all Model S cars to inspect the front seat-belt assembly. But it’s airbag maker Takata that takes the unwanted crown for the biggest recall to date after a dangerous fault emerged in recent years that affected 50 million vehicles from 12 automakers.” (Trevor Mogg)

In that case, if such vehicles were connected to the Blockchain network, the company could have access to this vehicle issue in a more quickly and efficiently way. Since the problem focuses on vehicles that drive under specific climatic and road conditions, it would be enough to check where the risk zones for this vehicle are and who is the vehicle's owner. Also, to schedule the reform of so many vehicles, Blockchain could be useful for organizing, satisfying the customer, and balancing this work from the company's workforce that stops producing new vehicles to dedicate to maintenance of the recall.

4.3 Vehicle Management and Incentives

In parallel with the supply chain approach described, there are also projects being developed that aims a better relationship with the consumer and that improve value chain tiers.

4.3.1 Dealer and Costumer Incentives

As explained, besides the tokens have a monetary value, it could represent a title, a reputation or a good of consumption, basically any assets of value inside a Blockchain platform. Based on that, a loyalty system could be developed to incentive a vehicle brand commercialization. For example, a vehicle dealer could supplement purchase of parts with customer loyalty tokens at a discount that are recorded in an Original Equipment Manufacturers (OEMs) Blockchain network. In this way, the negotiations are more transparent for both parties and the brand differentiates itself regarding the costumer prospect of satisfaction.

This idea is based on a project called Loyyal's loyalty (Sean Dennis, et al.), a platform that uses Blockchain and smart-contracts to enable instant redemption of loyalty points, removing delays, costs, and poor integration with other systems.

4.3.2 Extended Vehicle Ledger

A Blockchain based solution that securely stores, updates, traces, and shares vehicle data (including telematics) across Original Equipment Manufacturers (OEMs) and with external parties in real time.

The idea is an open book where all the information of a vehicle's life-cycle is registered and, due to Blockchain features, in an inviolable way. That way, when a consumer wants to buy a vehicle, he or she could have information on all its parts and respective production path. In addition, for a used car, it would be possible to have the right information of where and by whom that vehicle was owned, without fraud or omission, as it occurs mainly in the used car market. So far, would be possible to target with better prediction a vehicle's value. This technology could complement or replace the physical log book.

A project designed for that is the carVertical's (CarVertical), a "Blockchain-based solution that gathers as much information as possible about cars' history from different sources like centralized country registries, police and Interpol databases, insurance, leasing, claims handling service databases, privately owned registries, paid APIs, other sources and puts it into blockchain registry". Any person or company who wants to check car's data via carVertical product can be sure due to Blockchain features that no one manipulated its mileage, all insured accidents are logged and general data about the car is extensive.

To illustrate one of the issues that motivates this idea, "Odometer frauds in second hand cars poses a massive problem, which affects a considerable number of used cars in Europe – the estimates go as high as 30%, costing European consumers approximately between €5.6 to 9.6 billion per year. The odometer fraud is an artificial lowering of the mileage of a car. It is technically simple, cheap to do, and aims to inflate a vehicle's value by several thousand euros." (Zdechovský) To simply solve this billion euros problem, a car owner can log its mileage on the Blockchain so when the vehicle is sold, the person receives a certificate that confirms the information. Done that, there is an immutable registry with the vehicle's mileages without a central one being the holder. This would be a stimulus for users to always buy and register their negotiations in the network and would make it difficult to sell not certified vehicles.

The interesting irony of this concept is the data organization and integration in a decentralized network. In the current business model, the many vehicles information is fragmented into big companies of assemblers, insurance companies, and sales dealers among others. So, in addition to being difficult to access by consumers, the vehicles information is subject to changes by their holders without a trustful central control. The idea of adding such data in Blockchain, therefore, centralizes all information necessary for a vehicle in a network, without this being owned by any authority. Therefore, such data can be used safely even in more specific projects, such as changing the vehicle's commercialization structure or the insurers' business model. This second opportunity example will still be much explored.

4.3.3 Mobility

Recently, urban mobility services have been changing a lot their structure. This market was early monopolized by taxis, so that people could just wait for a taxi to pass them on the street or call the company to request for a car.

With smartphones popularity, a mobile online channel was created to make this request faster and more efficient. However, one of the biggest complaints was the abusive prices of this transportation mean and the distrust that the driver could have chosen a more time-consuming way to increase the route's price.

In the last decade, many alternative models of mobility services have emerged. The first were the applications that enabled a person to be a driver without the bureaucracy and initial investment of buying the license plate and the rights of a taxi. Among these services, the most widespread was Uber (Uber). Prices for mobility service felt sharply and made it possible for more people to perform the driver's profession. Requests and payments are all made by the application and the path is monitored with a GPS that estimates the price of the service based on the distance, users demand and duration. In this way, despite the great controversy that generated with the taxis companies, this was a milestone to mobility services structure.

Meanwhile, other mobility-focused projects and start-ups entered the market, so ride-sharing became popular, such as BlaBlaCar (Blablacar), where users registered in the network were able to offer car rides in their own vehicles, which of course has a lower price than requesting a driver. In addition, car-sharing companies such as Enjoy (Enjoy) allow a person to find this car's company on the street through the mobile application, unlock it through a register and pay the service for time duration and mileage. In this case, neither a driver nor a vehicle owner is required. In addition, there are companies that offer this service and only provide electric vehicles, as in the case of BlueTorino (BlueTorino) company.

Therefore, the revolution in the mobility Industry has been massive. That makes a lot of sense, given a little exploited market with monopoly and the growing traffic problem that increasingly populous cities have faced. There are also projects focus on autonomous car that would provide a mobility service, the idea is to order the car through the application and it would take the person to the destination guided by the best GPS route, without the need for a person to guide or e vehicle owner (Boston Consulting Group).

The business models driven by new technology are many and within them entrepreneurial companies are also. The idea of using Blockchain in this field would be to exclude the need for a central, such as companies, responsible for validating drivers' identity and payment's transactions. Using a Blockchain application, would be possible for anyone to register more quickly and securely, as well as validate a payment. Such stored data could include vehicle location, keys to unlock the car, agreement terms and user payment information. The solution would update the user's record with a register of that trip.

Some examples of such services offered in a Blockchain platform are here quoted. The one called CarTaxi (CarTaxi) was first launched in Russian market, it is a service for car towing. It brings together all tow trucks to one online network and provides for fast and safe vehicles transportation at any time and from anywhere, it is like the "Uber" of car towing. Another innovative mobility solution is the peer-to-peer platform Darenta (Darenta), a car rental marketplace connecting people who need to rent a car with private owners.

Another decentralized transportation platform is LaZooz (Lazooz), a real-time ride-sharing, enabling private cars to share their journey with others traveling in the same direction, so a concept similar to BlaBlaCar (Blablacar), but developed in Blockchain. It works with a "Fair Share" rewarding mechanism for developers, users, and backers. With a similar propose, a platform called Arcade City (Arcade City) was launched. Besides being also a ride-sharing service, it transparently provides rider and driver information about the other party to each transaction, including a strong reputation and ratings system where riders and drivers 'level up' after community-vetted good behavior on the platform. This is done through the Arcade Token (ACRD) (Arcade City) that drivers and riders earn for actions that grow the network. Those tokens unlock premium features and other benefits in the network.

Also great project, not that service specific but active in mobility ecosystem, was developed by Toyota Research Institute (TRI) (Chris Ballinger, et al.) with four global partners. It focus on three mobility areas: data sharing, peer-to-peer transactions, and Usage-Based Insurance (UBI). The aim is to securely share and monetize driver's information in a secure marketplace. "Blockchain-based tools have the potential to empower vehicle owners to monetize their asset by selling rides, cargo space or even use of the vehicle itself. The Blockchain can store data about the vehicle's usage, such as travel routes, distance and time, and information about vehicle owners, drivers, and passengers to craft a "smart contract" that verifies the transaction. Further, all those driving data stored in the Blockchain can let vehicle owners to be eligible to lower their insurance costs through data analysis of safe driving habits, feedback to improve safety, and transparency to reduce fraud." (Chris Ballinger, et al.). A global project with such influential partnerships in the Automotive Industry has caught a lot of attention to this application area of Blockchain (Corporate News).

4.4 User Services

There are also applications in vehicle services, such as means of payment, car insurance and financing.

A vehicle insurance platform will be the focus of this work. As an introduction, a Blockchain based solution could enable firms to create personalized vehicle insurance contracts based on actual driving behavior and automate payment and financial settlement following an insurance claim. Based on projects aimed to store vehicle data, like the (Chris Ballinger, et al.) previous described, driving behavior features such as speeding, mileage, damaged parts, collisions, driving frequency and others, could be recorded in a reliable and immutable way in the network, also for future insurance quotes after the car is sold.

There is also research on leasing vehicles market‘s application. The aim is to integrate payments, identity confirmation and driver licensing validation on a Blockchain platform so that they would be done faster but at the same time trustworthy. That’s the goal, for example, of a partnership between DocuSign and Visa, which have a Blockchain pilot designed to introduce greater speed and automation to the car-leasing process (Joe McKendrick).

A project called Car eWallet (CareWallet) was announced by a jointly ZF, UBS and IBM who aimed for a platform where a variety of vehicle‘s services payments is allowed. From car-sharing to in vehicle purchase to dealership repairs, the payments transactions are processed autonomously via the Blockchain. The idea is suggested by the name, so having a mobile wallet for the car. In this sense, the concept enables cars to autonomously pay for services like parking or charging. “The Car eWallet is the response to a self-driving future.” (CareWallet).

In this sense, a Blockchain ecosystem Uservice (Useservice) token pre-sale was launched. The aim of the project is to unite and optimize all processes related to the purchasing, operation, and maintenance of the car (News BTC). This is another integrated idea where services and payments are made with smart-contracts.

Specific about charging services, Innogy SE announced that is has launched hundreds of Blockchain-powered charging stations for electric cars across Germany through its e-mobility startup ventures Share&Charge (ShareandCharge). This platform is still under development, and the aim is to drivers use the Share&Charge wallet to pay for accessing all charging public and private registered energy poles.

As noticed, Blockchain applications in the Automotive Industry are many. They may be related to the production or to marketing and commercialization of the vehicle and in the follow-up of its life cycle. Otherwise, they can provide additional services and payments commitment to the vehicle's owner. However, although there are many options, it is an emerging and promising market, it should be analyzed with caution to target the best possible investments.

Chapter 5

Pilot Project

Remark: This project aims to promote a new model of Blockchain's application in the Automotive Industry. The idea is a Blockchain platform that uses driver behavior data to set car insurance price. This purpose has already been mentioned previously, but it is still little explored, there are so far no major projects focused on this. However, there are already companies focused on collecting driver behavior data generated by the vehicle system, and many use Internet of Things (IoT) technology for that. Therefore, as will be studied and discussed, this IoT and Blockchain combination that uses driver behavior data to issue tailor made insurance contracts has proved to be possible and quite valuable.

5.1 Project Pilot Applications

Currently, some insurance companies are investing in obtaining driver behavior data to increase their statistical database to offer better prices to their customers (Kylie Jane Wakefield). Usually, there is an intermediary responsible for collecting and processing the data that will be sold to insurers. For the company, more data available means less risk because it is possible to differentiate people within the same risk group. Currently, an adult has the risk level accessed by individual characteristics like the age, car model, living area and licensing time, besides other factors. So, the purpose is to differentiate two people with similar characteristics by how they actually behave in traffic. This can be measured from their average speed and acceleration, the vehicle's frequency use or accidents registered events for example.

The platform would work according to the main following steps:

1. Internet of Things (IoT) devices are installed in the vehicles and connected with its telematic systems, so as the person drives, information is collected;

2. Driver Behavior data is stored in Blockchain network in real time;

3. According to the behavior of the driver, smart-contracts generate tokens of reputation, which will be called *DBTOKEN*s (Driver Behavior Tokens). That way, if the smart-contracts receive the information that the person drove responsibly, some *DBTOKEN*s are proportionally generated in an interface available to the user and to the insurance company;

4. It is available to the driver in the decentralized mobile application (DApp) how many *DBTOKEN*s he or she has received over time, in the same way the person can access information from other drivers. This creates a system of encouraging a good driving behavior;

5. The platform accesses the basic information of the driver (age, car model etc) and compares it with the *DBTOKEN*s amounts the user has. Then smart-contracts generate new insurance contractual proposals that would automatically debit the driver's account premium on a frequent time base.

Blockchain is a key tool to this platform's development, because it guarantees confidence. Since the data is immutable, neither the driver nor the company can change them for their own benefit, both trust the network and the other peers involved. The system is transparent, not only the company, but also all peers can monitor the situation and in addition becomes a system to incentive good driver behavior. Although this platform requires huge data processing, Blockchain has been developing rapidly, so the computation of all these data has the potential to be quite fast. It eliminates an outsourced service and a data centralization, so that the drivers are still holding their personal information and the company could access it in a controlled way.

The main advantage to users is the ability to monetize their behavior and thus buy fairer prices for their car insurance, since a good behavior is rewarded accordingly. In addition, the insurance company would have a richer statistical base from accessing much more information about its customers. A better statistical base tends to increase the company's profitability, since it comes from purchasing risks. Also, this service does not have to be outsourced and many operating costs could be reduced, given that the platform will generate lots insurance contracts automatically through the smart-contracts, just under company supervision. Therefore, smart-contracts have great potential for reducing labor expenses, improve service quality and reduce labor processing time. So far, the project has positive potential for both stakeholders and costumers.

5.2 Motivation

"Auto insurers like Progressive, Allstate, and State Farm are using IoT to monitor drivers' habits, including changes in speed, how often they drive, and the time of day they drive, according to a 2015 BI Intelligence report. By 2020, more than 50 million U.S. drivers will have tried Usage-Based-Insurance (UBI), per Business Insider estimates. By granting insurance companies permission to monitor their driving habits, drivers gain access to better premium rates. Embedded blockchain technology can add an additional layer of security and ensure trust concerns are addressed proactively." (Shetty Rakesh)

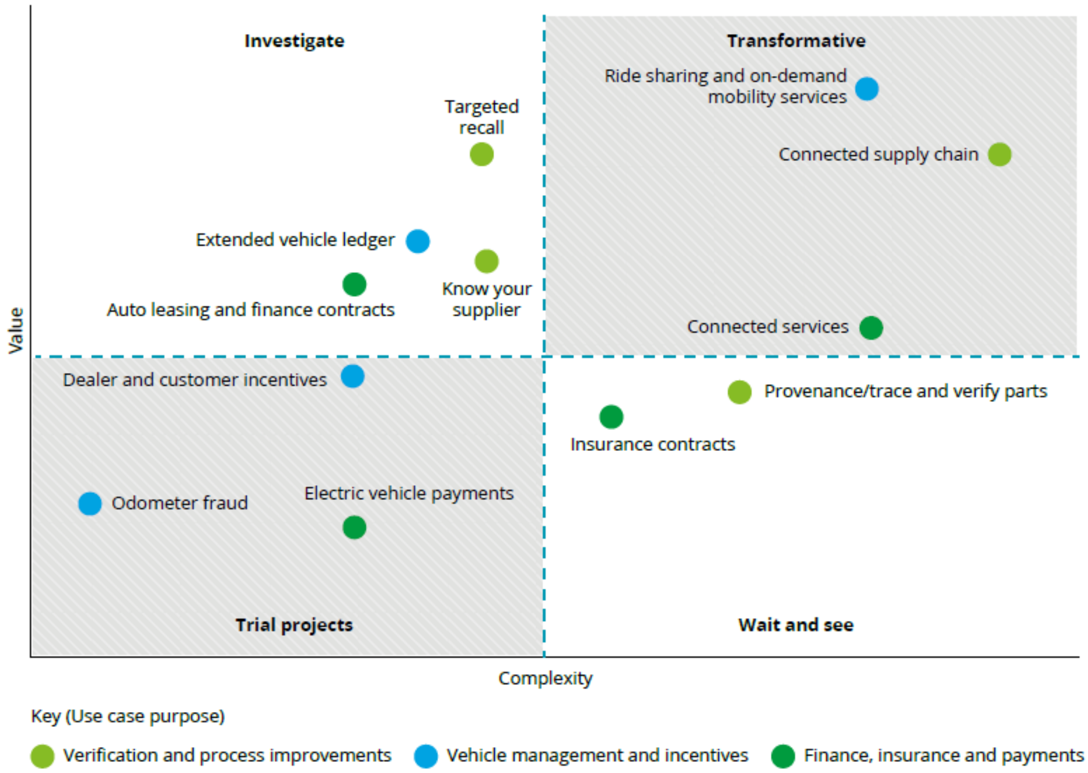

Figure 5.1: Value and Complexity/Ease of Blockchain Implementation (Deloitte(a))

In Figure 5.1 follows a summary of the previously discussed study carried out by Deloitte (Deloitte(a)) about the current areas of research and applications of Blockchain technology in the Automotive Sector. Note that the "Insurance Contracts" are still in an area of low value high complexity. This is mainly because it involves a bureaucratic aspect whose management depends on each countries' legislation. Also, because there are many users' personal data involved and is inserted in an expensive and risky market, which are the main insurace characteristics. Also, by considering the Blockchain and Internet of Things (IoT) combination, the insurance application could be boosted.

Thus, the objective is to develop a study on how to measure the driver's behavior, mainly with Internet of Things (IoT) devices, what are the greatest related advantages and risks, as well as the adoption rate of this new platform and insurance business model by companies and society.

5.3 Blockchain Insurance Applications

As illustrated in section 3.2.4, a good insurance application example is ETHERISC (Christoph Mussenbrock, et al.) that has three main projects. The first, (see Figure 3.3), is the *Flight Delay App*, which can issue policies and pay out valid claims completely autonomously. The second is the *Crop Insurance*, where the user can select a crop product, the field's location and apply for a policy by sending Ether with a smart-contract. In case of a drought or flood, the user gets an automated instant payout. The least application is the *Social Insurance*, a model designed to provide basic coverage for rare, disastrous life events such as death or heavy illness. The aim is to be a first, immediate emergency payment which helps to get through critical times available for everyone.

A Car Insurance project was exposed in a workshop during *D1Conference* by André Wolke and Sebastian Bürgel, both from the Validity Labs. Sebastian demoed a sample car insurance app built as smart-contract on Blockchain, explained the protocol behind it and shared this project on GitHub as open source (Validity Lab). The aim of the workshop was to discuss the potential Blockchain benefits and to demonstrate how accessible is to "Build a Sample Car Insurance App on Blockchain in 30 Minutes" as it was called (Etherisc).

Another application is the Aigang (AIX) Token (Aigang), described as a Decentralized Autonomous Organization (DAO) insurance protocol Crowd-sourced insurance pools that would enable community, companies, developers build insurance prediction markets and insurance products themselves, using this protocol infrastructure.

Also, there is the token Insurepal (InsurePal) illustrated in Figure 3.4 and defined in (InsurePal) as follows: "The InsurePal (InsurePal) platform will act as a global provider of various insurance module based on social proof mechanics. For the end user, the

InsurePal decentralized app will serve as an entry point to our insurance ecosystem, whereas to the third-business parties the solution will allow white label partnerships to re-sell social proof insurance." There is an application for Car Insurance in Insurepal (InsurePal), but it works based on social proof endorsements. So to have an insurance price reduction, the driver needs a trusted endorser who would financially guarantee his/hers exemplary behavior. Briefly, if the driver does not get involved in an accident, this individual pays a reduced premium and the endorser is rewarded with tokens. On the other hand, if the driver causes an accident, the endorser would need to pay for that.

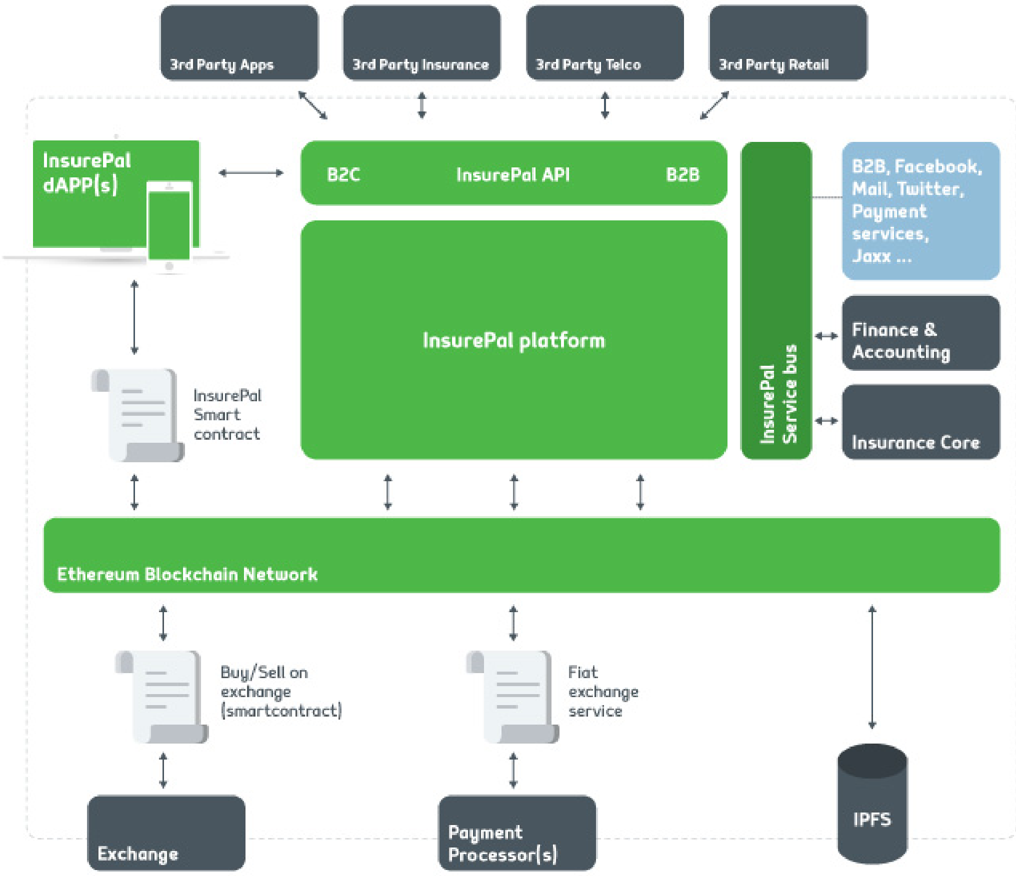

Figure 5.2: Insurepal Platform (InsurePal)

Another point of view to improve insurance with Blockchain applications is the opportunity to build short-term insurance contracts. For an insurance company build a one-year standard contract, it needs to collect and analyze a large amount of data about the target driver. It would be very useful if a person could prove to a car rental company, for example, that he or she drives in a safe way. This might be possible if also car rentals and mobility services, such as ride sharing and car sharing, are connected to this proposed Blockchain platform. Therefore, they could generate a smart-contract within a short time and propose a suitable premium for the insurance, as suggested by John Gerryts, co-founder and CEO at Oaken Innovations "Insurance has always been built with 12 months in mind. Now, we're building insurance products for five minutes or 20 minutes." (Bailey Reutzel). This would also help those services to save operation costs and reduce their financial risk, but also incentive more people to use those new sharing mobility services that is a tendency.

Chapter 6

Driver Behavior

Remark: "Telematics-based UBI growth is being propelled by technology advances, which continue to substantially improve the cost, convenience, and effectiveness of using telematics devices. It is through the use of telematics that insurers are able to collect driving data enabling them to monitor and connect a driver's individual risk with premium. Data has traditionally been one of insurance industry's greatest and more valuable assets. The ubiquity of wireless connectivity, the increasing sophistication of in-vehicle electronics and machine-to-machine (M2M) communication is presenting the auto insurance industry with a historic transformational challenge. Insurers are investing on their ability to collect, store, manage and analyze vast amounts of variable data to solve complex problems in order to remain competitive and profitable. Auto insurance is fast becoming a big data industry, with telematics-based UBI poised to potentially change the business of insurance as we know it." (EY).

6.1 Definition, Origin and Motivation

The driver behavior's analysis as an input to define the car insurance's premium is advantageous both for the insurer and for the user. About the company side, there is a general database that classifies drivers into risk groups defined by age, gender, car model, driver license validity, most frequent traffic zones, among other factors. A more visual example would be analyzing two people from the same age and driving the same car but taking in account that one usually drives while talking on the phone, statistically this person has a higher probability to cause an accident, due to a lack of attention. In this way, the company would have access to a wider statistical base and thus optimize the balance between the premium charged and the risk level to be assured, generating a potential increase in profit.

From the driver's perspective, the insured would be charged according to his or her behavior as a driver, which means that the person can influence the insurance premium price. This factor causes a feeling of control and generates greater confidence to the user, who would feel motivated to take less risks while driving. Besides a possible decrease in the amount paid by the driver, a great advantage is the increase of the safety and prudence of this person in traffic.

Telematics is the technology branch that deals with long-distance transmission of computerized information (Oxford Dictionaries). The integration between the mobile communications, vehicle monitoring systems and location technology can serve as the platform for Usage-Based-Insurance (UBI). Pay per use insurance, pay as you drive (PAYD) insurance, pay how you drive (PHYD) are all terms used for programs that offer drivers the option of having premiums tailored to their individual driving patterns (Insurance Information Institute). The pay as you drive (PAYD) offers a discount calculated according to the number of driven kilometers evolution, while the pay how you drive (PHYD) calculates the insurance premium based on how people drive and has started with basic metrics such as average speed and the frequency of abrupt braking.

The first Usage-Based-Insurance (UBI) features focused on pay as you drive (PAYD) and was launched at the beginning of this century. Further, due to the increased interest on this market, the pay how you drive (PHYD) was then developed. Currently, because of Internet of Thing (IoT) technology, modern smartphones, and massive research on electric and autonomous vehicles, UBI is rapidly modernizing.

“The first UBI programs began to surface in the U.S. about a decade ago, when Progressive Insurance Company and General Motors Assurance Company (GMAC) began to offer mileage-linked discounts through combined GPS technology and cellular systems that tracked miles driven” (NAIC). First, when automotive telematics and Usage-Based Insurance (UBI) emerged, most insurance providers used wireless devices that were plugged into a vehicle’s on-board diagnostics to receive information about a driver’s on-road behavior (IMS(c)). However, with smartphones, special sensors, and Original Equipment Manufacturer (OEM) new technology implementation, the UBI programs are improving.

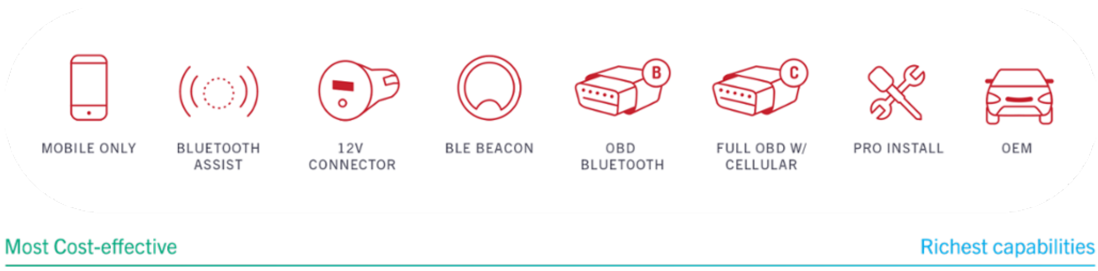

Figure 6.1: Driver Behavior Measurement Device’s Comparison (IMS(c))

For more detailed analysis, it is convenient to segment the driver behavior measurement technologies (EY). The measurements could be done from a dongle, so a plug-in device which the insurer installs into the vehicle themselves, from a smartphone working as stand-alone device or linked to vehicles’ systems; or alternatively from a Black Box, permanently affixed into the vehicle. Also, a modern option is to manufacture the vehicle with this technology already embedded in its system.

6.2 How Does Driver Behavior is Measured

Basically, targeted information such as average speed and miles traveled, among much others, is transmitted wireless directly to insurance companies to design the driver habit's profile over a certain time, and then the policy is re-evaluated accordingly. In the case there is greater integration and development of the technology, as shown in Figure 6.2, the driver can also have access to this data through his smartphone device to receive the feedback.

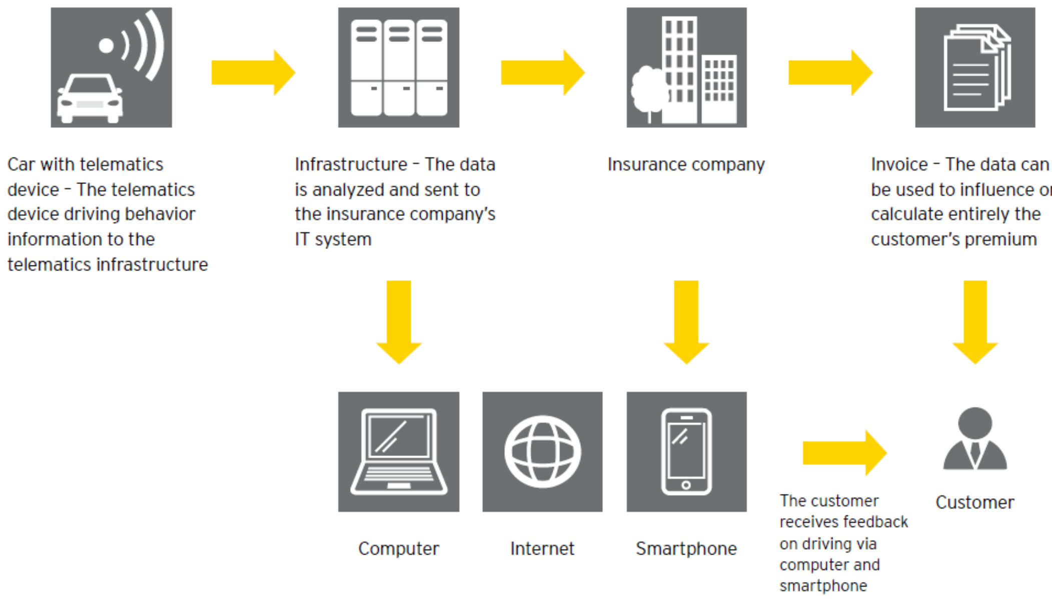

Figure 6.2: How Does Telematic Driver Behavior Works (EY)

The idea is to take social-economical advantage by means of aggregating value to the large amount of little explored data generated by the vehicles. Not only Usage-based-Insurance (UBI), but other services can be explored as illustrated in Figure 6.3

6.2.1 Black Box

The Black Box is namely after a mandatory device inside the airplanes, whose function is to record all generated data, including the conversation between the pilot and

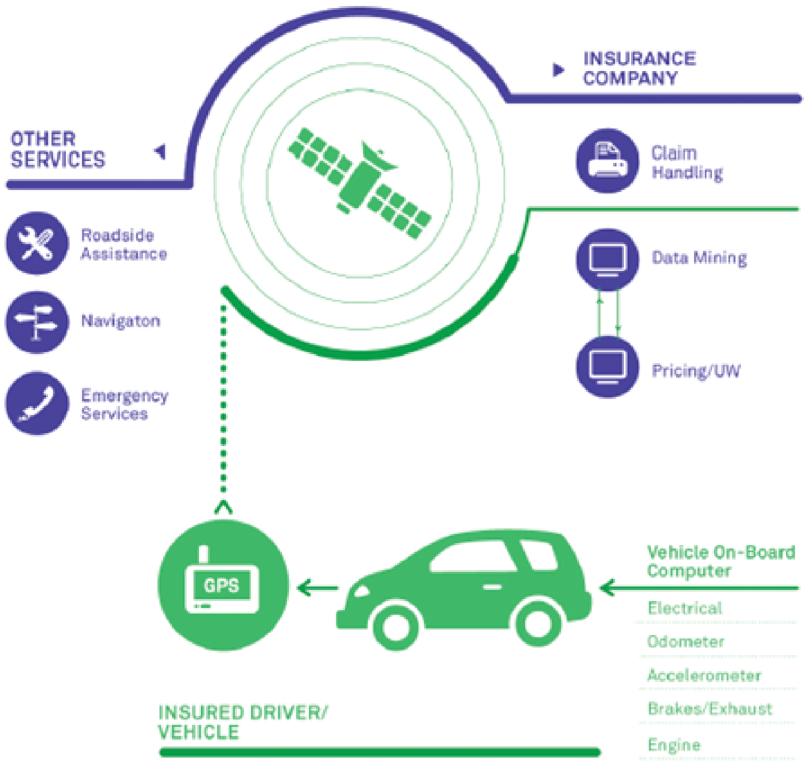

Figure 6.3: Exploring Vehicle's Telematics (Jon Tindall)

the base on Earth, the performance of the operating systems and of course, possible technical problems. When an aircraft accident occurs, it is through the analysis of the Black Box that the root causes' diagnosis and the procedures taken are evaluated. Since it was one of the first pay how you drive (PHYD) launched technologies, it became popular at first for younger drivers, because it is considered a high-risk group, and because the parents had interest on tracking how their dependents where driving.

The device is installed in the car by professionals, so it is not portable or easily removed. The great advantage is to be one of the most secure, meticulous, and reliable methods to measure driver behavior, while the disadvantages are the cost of installation and maintenance. In addition to car's sensors, the Black Box is connected to the Electronic Control Unit (ECU) and is therefore able to access general car data, such as accelerometer measurements and engine performance's use.

In general, there are four main elements that composes the Black Box. One is the GPS system, which tracks where and when the driver is traveling, also informs the type of road on he or she is driving. Another is the called motion sensor, which provides information about the level of braking and average speed mainly. There is also the SIM card, that as the ones installed inside the smartphones, is responsible for sending those data to the database. Finally, there is a computer software, which controls how the information is analyzed and transmitted. The components of the boxes may vary by manufacturer, there are currently several patents and technology being developed, however, these are the main device components.

Therefore, the telematics box could provide information about what times of the day the person usually drives, especially important for more dangerous hours like late night, the discontinuity with which the driver sets different average speeds, how sharply is the brake or acceleration, if the driving journeys are usually long or shorts and total miles driven.

In addition, insurers claim that installing the Black Box have further benefits. One is track the car in case of theft, since vehicle's location can be accessed and the Black Box is not apparent in the vehicle, so that the thief can hardly detect it. Also, in case of an accident, the insurer can immediate detect a non-standard behavior data and can provide emergency assistance as quickly as possible, without the person having to make the request. Also, for non-emergencies accidents that causes conflicts in transit it is possible to have evidences that the driver was not reckless and therefore was not to blame for the accident, if that is the case.

Insurers can convert information from the Black Box to an online portal so that the driver can get feedback on how he or she is driving on a regular basis, to provide an incentive system and a so-called transparency on the collected and analyzed data.

6.2.2 Dongles

Unlike the Black Boxes, Dongles are plug-in small boxes that are easily attached to the On-Board Diagnosis (OBD) vehicle's system and automatically turns on with vehicle's ignition. Compared to the Black Box, it is an easier and cheaper installation device, but less reliable due to easy removal, even if unintentional. This OBD technology is classified as a self-diagnostic system present in light-duty vehicles and trucks manufactured from 1996 in Europe and USA. (IMS(d)) as can be seen the OBD subsribers increase in figure 6.4. Basically, since the vehicle has the OBD-II (second and latest OBD version) technology installed, the Dongle is an adapter which is plugged into the OBD port of vehicles to provide diagnostics data to a Bluetooth-connected computing device, such as a smartphone and a telematics control unit (TCU), that would be the insurance company database.

"Although not originally designed with vehicle telematics in mind, OBD-II provides access to data indicating vehicle speed, engine rpms, calculated fuel consumption, general trip data, and other information (in addition to the diagnostic data for which the port was designed). All of the relevant information can be transmitted into a telematics data collection system" (IMS(b))

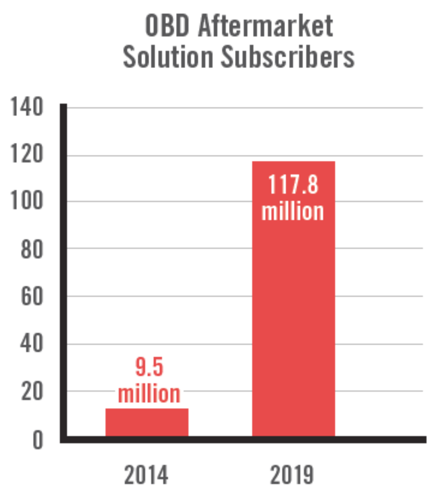

Figure 6.4: OBD-II Aftermarket Solution Subscribers (IMS(b))

6.2.3 Smartphones

With technological advances, more modern solutions were launched alternatively to OBD-II, mostly smartphone apps, or hybrid solutions like Bluetooth-based OBD or beacon devices paired with a smartphone, as stated in "Hybrid Bluetooth solutions represent another approach that has gained popularity in the marketplace. A hybrid solution combines a Bluetooth based device (such as OBD-II with Bluetooth or a Bluetooth beacon) paired with a smartphone to relay data using its wireless connection and data plan." (IMS(b)).

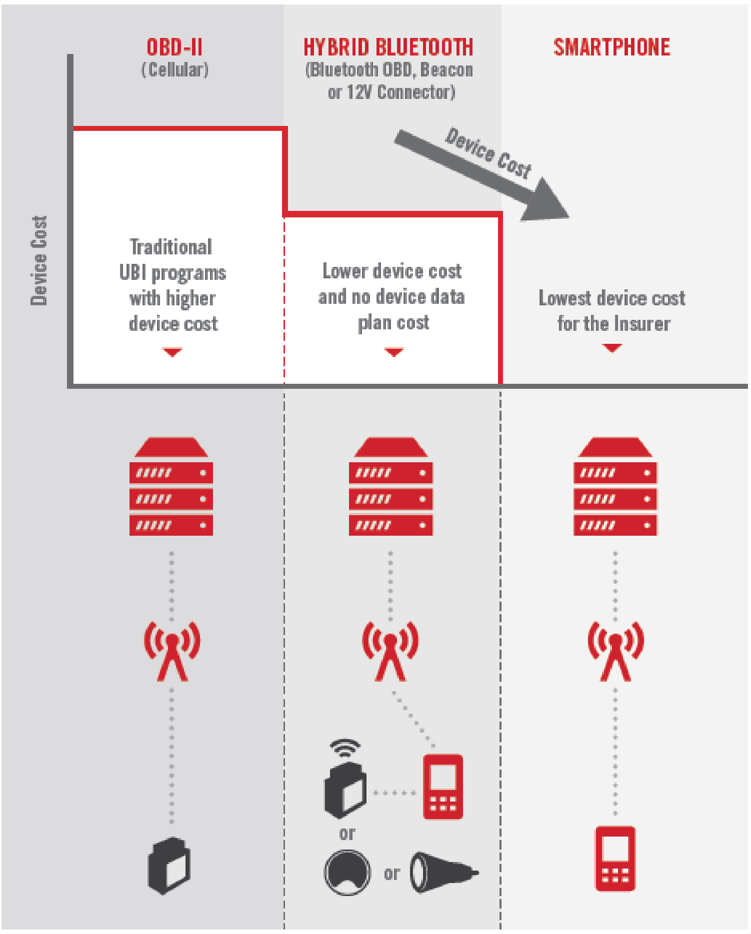

Figure 6.5: Techonology Costs and Basic In-Vehicle Enabler Options for Telematics Solution (IMS(b))

Smartphone apps as stand-alone devices to measure the driver behavior are the latest tool in telematics. The modern ones are usually equipped with a broad type of sensors, such as GPS, accelerometers, and gyroscopes and they have large data storage capacity, or almost infinite if connected to a cloud platform. The big advantage is the absence of installation need or data connectivity costs for insurers with smartphones equipped with UBI programs. The weakness relies on mainly the quality and reliability of data measurement that smartphone's sensors can provide. Also, unlike the standard OBD-II system, the smartphone's apps rely on several different operating systems and platforms. However, due to the cost effectiveness as shown in Figure 6.5 and higher smartphones adoption rate, probably the technology will soon allow more reliable sensors and an efficient way to standardize the information collected.

Among device solutions connected to OBD-II, hybrid technology or smartphones apps, there are four main factors to be taken into consideration by the user. Those are data quality, continuity of the data record, user experience and accident data (IMS(b)).

Regarding data quality for smartphone, hybrid Bluetooth, and OBD-II solutions, continuous and calibrated measurements must be captured from the smartphone or vehicle sensors. Considering an OBD-II device, vehicle speed can be precisely measured with the Vehicle Speed Sensor (VSS) in the automobile, while with a smartphone this is done throw a GPS-based speed, so requires a strong GPS signal being received. About the continuity of data record, there are two important points to be stressed about using smartphones. The first is the case when the person does not carry the cell phone in the car or in which the cell phone runs out of battery, which would be plausible given the continued use of the device while driving. In this case, the data collection is interrupted, which detracts from the continuity of the measurements, naturally. One advantage is that the phone is related mainly to a person and not to a specific car. In this case, even if the person drives different cars (for example, a young person driving the parents' car), the information is still tied to that person, not to the vehicle, unlike for OBD-II measurements. However, this is a feature that may be subject to fraud, since the identification of the driver with the vehicle and the cell phone may be ambiguous.

For the user experience, this is basically the driver's preference among devices, considering the use of the interface and the trade-off between the ease of this technology being integrated with the smartphone and the need for it to collect the data.

Finally, the accident data means the measurement difference between devices when it comes to an accident. The device connected to the OBD-II has better performance in this case because its position is fixed. For the smartphone, it can be in places inside the car whose impact is damped and therefore the acceleration of the car is underestimated by the sensors, generating false information that could be useful in the case of activating an emergency service.

To conclude, "In the past, telematics solutions based on OBD-II were leading the market in terms of sheer numbers but are now on the decline. Smartphone technology has greatly improved and is satisfying certain market requirements and quickly advancing as a preferred approach. Hybrid Bluetooth solutions are also gaining popularity because of their ability to enhance smartphone telematics while offsetting hardware costs." (IMS(b)).

6.2.4 Embedded Vehicle Technology

"As of the end of 2013, there were 11 car manufacturers with embedded telematics equipment in vehicles" (NAIC). This embedded module connected to the vehicle's Electronic Control Unit (ECU) can record and transmit data about the vehicle performance. Although the higher cost for the consumer, it can provide more value to some vehicle's costs like maintenance, possible recalls, and potentially low insurance premiums.

Although this seems to be the solution with greater reliability and security, it is still a telematics reality a little distant and not standardized. Potentially with the driver behavior valuation, Original Equipment Manufacturers (OEMs) would be incentivized to invest more in this technology as shows the forecast in Figure 6.6. Naturally, due to a better interface, the collected information would be transferred to the end-user mainly through the smartphone. The vehicle electronical system in general include multimedia entertainment, vehicle status monitoring, and some safety and security features.

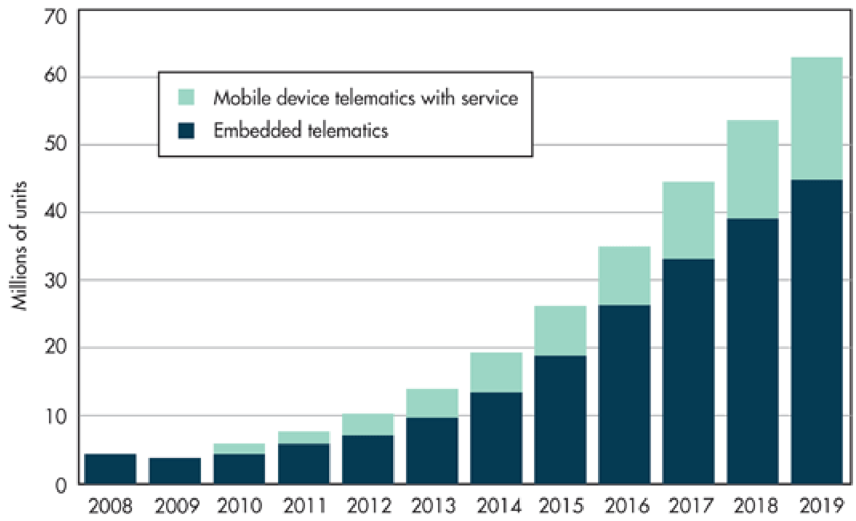

Figure 6.6: Techonology Costs and Basic In-Vehicle Enabler Options for Telematics Solution (Lou Frenzel)

6.3 Current Applications

As a context illustration, “There are currently 753 Billion USD automobile insurance premiums sold around the world today. It is estimated that there are currently 3.6 billion dolars or 0.04% linked to a Usage-Based Insurance rating system. This equates to under 6 million policies. There are approximately 160 programs or active trials underway around the world, in 34 countries. This indicates that despite increasingly frequent media announcements around Usage-Based Insurance, the industry is still in its infancy. Industry analysts predict that by 2020, 4% of auto insurance policies in the world will be rated with telematics, 13% in Europe and just under 18% in North America." (Baseline Telematics).

The countries whose insurance companies are most involved in Usage-Based insurance (UBI) are USA, Japan, Australia, UK, Spain, and Italy. As an example, there is a company in USA called Allstate that has developed a UBI program called Drivewise from early 2010, with a better version integrated with a mobile app from 2014. This Drivewise app measures mainly the driver‘s speed, braking and time of day, calculates the possible premium discount and provides feedback on each trip to the user. From 2016, this program is available in 48 of 50 states and so it is getting more popular (Wikipedia).

In Italy, since 2005, Sara Assicurazioni created the first pay-as-you-go insurance policy for vehicles in the country, the SaraFree program. It started with a GPS device provided to the costumer which allows customers to pay according to the number of kilometers run with their vehicle. "Customers benefit from the same level of insurance coverage while saving up to 55% on the price of a traditional insurance policy. Moreover, the GPS application enables to reconstruct the dynamic of an accident, to assess responsibilities objectively, and to contest unjust fines by proving the position and speed of the vehicle at any given time." (Eusiry).

A strong argument to why companies should invest in this technology and new Usage-Based Insurance (UBI) business model, is by competitive advantage. The insurance business market will inevitably go through some changes and this is just the beginning. In this case, the companies able to follow this trend might be market leaders. An interesting new business model is about start ups and Information Technology (IT) companies that offers outsources services to insurers. In this case, the reliability and privacy quote are even more complex, since besides the insurance company and the telematics data collection device, there is also a third part involved.

However, this might be an advantage when related to the technology development, as there are companies focus directly on this area. A good example is a company called Intelligent Mechatronic Systems (IMS) (IMS(a)), that said to be pioneering in connected car technology that enables drivers to be safer, smarter, and greener. "IMS' award-winning and industry-acclaimed DriveSync connected car platform is built on 15 years of R&D experience enabling connected car and telematics solutions that are backed by over 200 patents and patents pending. From insurance and government, to fleets and everyday drivers, IMS solutions are used across industries worldwide." (IMS(a)).

A great advantage of this DriveSync platform (Figure 6.7) is the adaptability and integration with most telematics devices, from smartphones app and hybrid solutions to Internet of Things (IoT) connected devices in On-Board Diagnosis (OBD-II). Also, it connects drivers to their cars, to other motorists and to surrounding infrastructure.

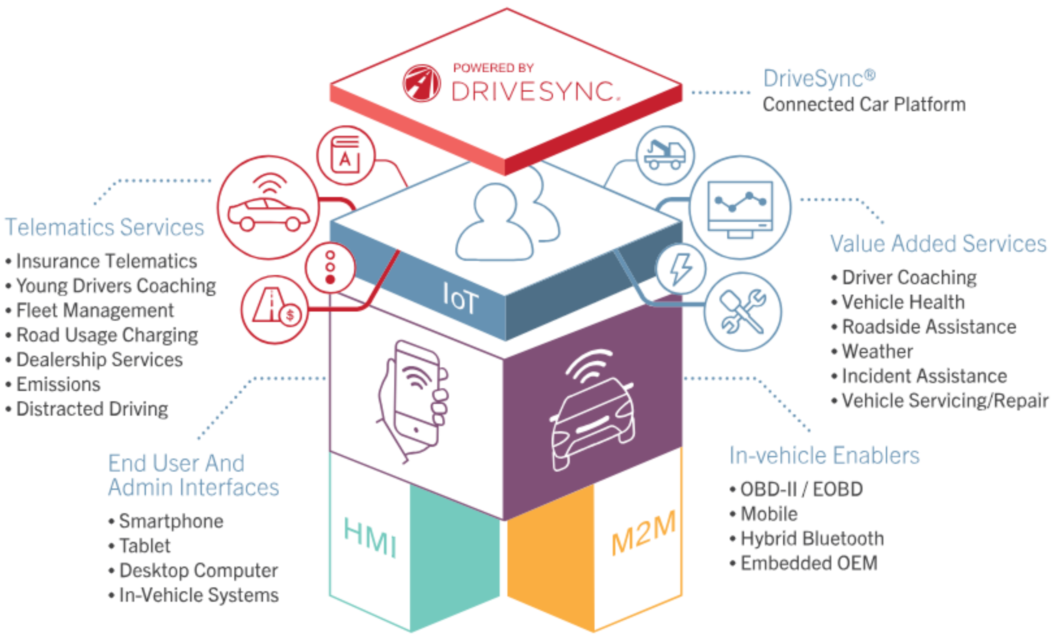

Figure 6.7: DriveSync Connected Car Platform (IMS(c))

In addition, the trend is for carmakers start making partnerships with insurers to integrate this new business model. As an example, Hyundai has announced a partnership with data analytic company Verisk, “a major data broker for the insurance industry, with self-stated 3.3 million cars and more than 36.5 billion miles of driving data in its records” (David Muller). The carmaker announced that from 2018 all vehicles will provide a Blue Link connected-car service, which can measure a huge range of data, even like climate control and in-car maintenance scheduling. The information collected is automatically transferred to the associated insurer via wireless, but despite being a promising service, in an interview Hyundai was asked about the terms of privacy, of course. The carmaker then said that would only share user’s data outside the Hyundai-Verisk with the customer consent (David Muller).

The privacy issue is indeed one of the biggest obstacles to the implementation of this business model. Therefore, Blockchain with its transparency and privacy properties has the potential to leverage this technology, a topic that will be discussed later in this work.

6.4 Driver Behavior Measurement Parameters

The metrics used to define a good driver behavior could be questionable. A coherent solution for the proposed platform, since it will be developed in Blockchain, is to analyze the driver behavior based on internal and external benchmarking. So, in addition to evaluate the driver’s historic it also makes sense to compare it with other drivers, since due to a decentralized and efficient database, it is possible to access how the entire Blockchain community behaves in traffic.

Also, it is an incentive to a prudent traffic behavior, since the metric is in continuous improvement, the better people drive, more an individual must improve to reach the target. An example of this application follows from the study (EY) which illustrates the four basic metrics for analyzing driver behavior in Figures 6.8, 6.9, 6.10 and 6.11.

In addition to these basic measures, it is possible to add extra sensors and cameras, being all interconnected devices. For example, one can detect if the driver is using the smartphone while driving, a current source of distraction. Other sensors could detect the drivers alcohol level, fatigue and traffic attention.

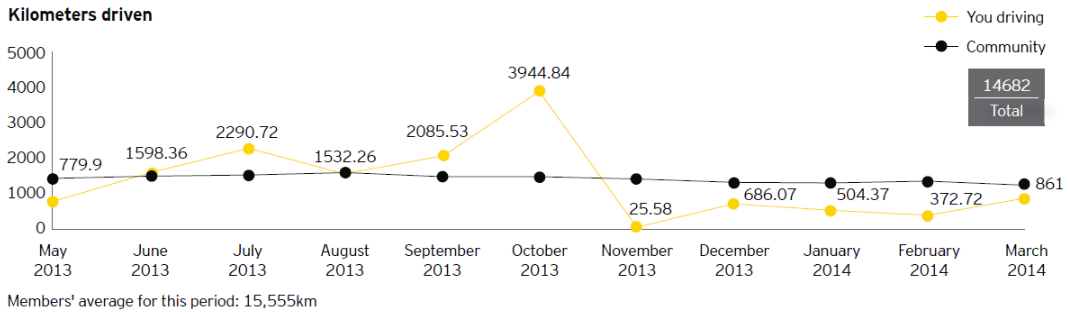

Figure 6.8: Kilometers Driven (EY)

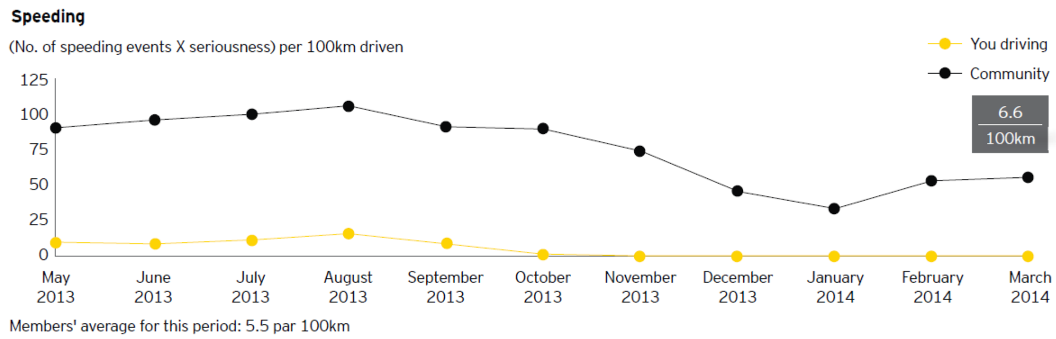

Figure 6.9: Speeding (EY)

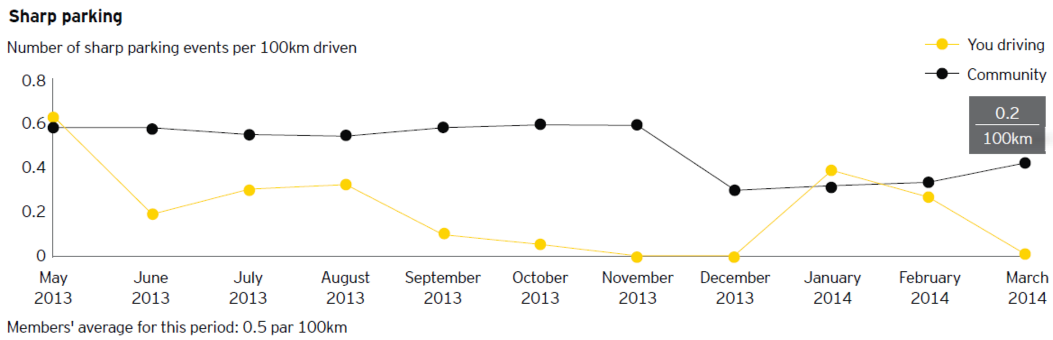

Figure 6.10: Sharp Parking (EY)

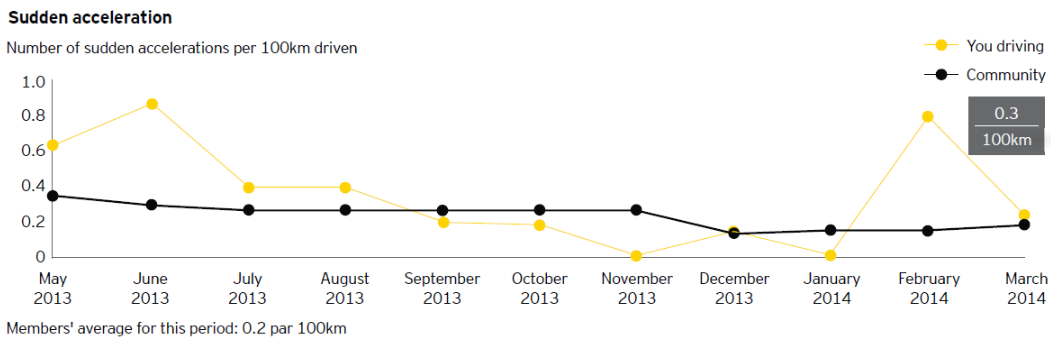

Figure 6.11: Sudden Acceleration (EY)

Through the vehicle's own sensors, it is possible to detect the frequency with which the person drives, so the pay as you drive (PAYD), the quality and requirements of its general maintenance and fuel consumption. Also exogenous information like recognizing if the driver is violating some traffic rules or the whether and road's condition are pretty relevant and can be measured.

Another sensors can detect if the car is mechanical balanced, if the driver practices fast lane changes, drives off road or practice other dangerous maneuvers, it is just a matter of technology improvement and integration into the basic system to better define the driver behavior as can be seen some examples in Figure 6.12

6.5 Motivations of Using Telematics

As discussed, driver behavior analysis through telematics technology has great potential for disrupting the current car insurance business model in an integrated way such as shows the Figure 6.13.

It would benefit the costumers, insurance companies and the society. From the costumer point of view, the person could receive rewards such as premium discounts or access to partner benefits, like garages, maintenance services and gas stations. Also, demonstrating safe driving habits could be a personal advantage for legal judgment and personal defense in case of an accident. Parallel services that require data

Figure 6.12: Usage-Based Insurance Telematics (IMS(c))

like vehicle maintenance diagnosis, emergency calls and even recovery stolen vehicles might be empowered by telematics integration.

From the insurers side, it is emphasized the improvement of risk assessment of the costumers to lower premium expenses by enhancing pricing accuracy. Also reduce fraudulent requests and reduce claim costs could increase profit a lot. By lowering the premiums and improving costumer's satisfaction, the company could be a market leader and increase customer retention with a more friendly and collaborative approach with its consumers.

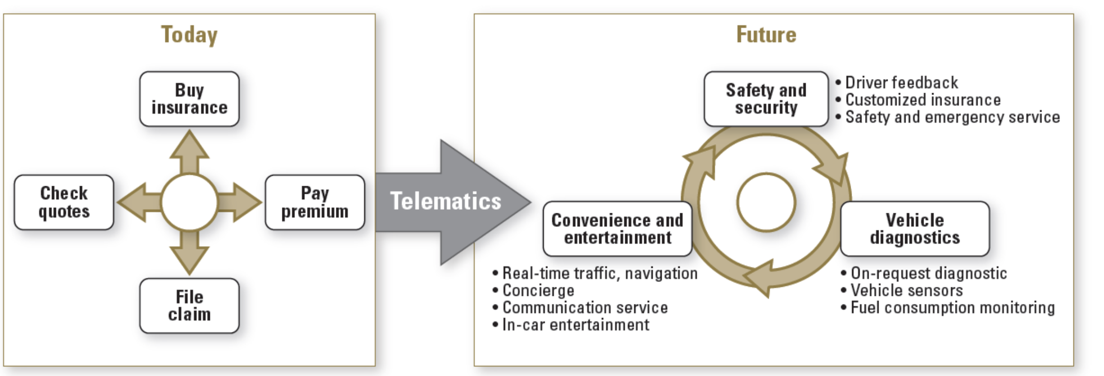

Figure 6.13: Fundamental Change in Auto Insurance Industry (AT Kearney)

Finally, analyzing society related benefits, the tendency of this incentive system is that accidents frequency and its severity diminishes, since people would be motivated to drive in a safer way. Also, the fact that the insurer has immediate access to emergency requests would potentially reduce the rescue time and improve the city traffic.

6.6 Blockchain and Vehicle Telematics

One of the major concerns that most people have with Usage-Based Insurance (UBI) is privacy. The insurance companies must ensure that the driver behavior and vehicle information meet with the privacy legislation. This is one of the challenges that Blockchain aims to tackle. The issue of privacy is quite complex, both from the user perspective to feel exposed, and from the company's possibility of being sued. A decentralized and encrypted network would protect both the user and the company in this sense. This concern from the company side has been a big issue in the information age, as follows the Cambridge Analytica's scandal in April 2018 (Nicholas Confessore). In apprendix D is provided the EU General Data Protection Regulation (GDPR), that contains the updated privacy rules from 2018.

In this case, neither party has control over the data generated, it will be stored on the Blockchain network and will serve as input for pre-programmed smart-contracts.

Thus, the company does not need to have access to the users' data, only to the output of the smart-contract. If the company decides to have access to this specific data, it can request the user's private key, a temporal hash, that gives access to the information generated by that specific user. In this way, the insured person grants controlled access to the company.

Another problem is the amount of data generated. Although this means a more complete and therefore secure statistical basis, the insurer needs to handle this amount of data generated by every car connected. As mentioned, this market is growing and the Usage-Based Insurance (UBI) means a competitive advantage for the insurer. Given that, increasingly telematics data will be generated. One solution that some insurers have adopted is to hire start-ups or outsourced services that are responsible for capturing and processing such data. Although one of the Blockchain criticisms is also the storage capacity and the delay in data processing, many solutions have been emerging. As mentioned in section 2.3.4, it is possible to support smart-contracts in specific Blockchain networks for data storage, such as InterPlanetary File System (IPFS) (IPFS). There are still many challenges, but there is a potential positive cooperation between the UBI and Blockchain technology.

In this sense, also the issue about real time information could be improved. The insurer provides a feedback to its users periodically. This requires a time to process and synthesize the information of the thousands of drivers subscribed into the system. In case these data are transferred to Blockchain, smart-contracts would be responsible for the inputs' analysis and conclusions. This means a potential real-time feedback, since the limitation would be the operating capacity of the system rather than the pace at which the insurer operates the data. It may still be a challenge, but the Blockchain's development tendency indicates that it is a tool with increasingly data-processing capacity. Another positive consequences of this real-time feature are the greater ease of driver assistance in case of accidents. As soon as an accident occurs, a medical team or tow truck could be automatically requested for assistance and the payment can be instantly charged by one of the parties involved or by the insurer itself, this would be the "Truested Third Party" as in Figure 6.14.

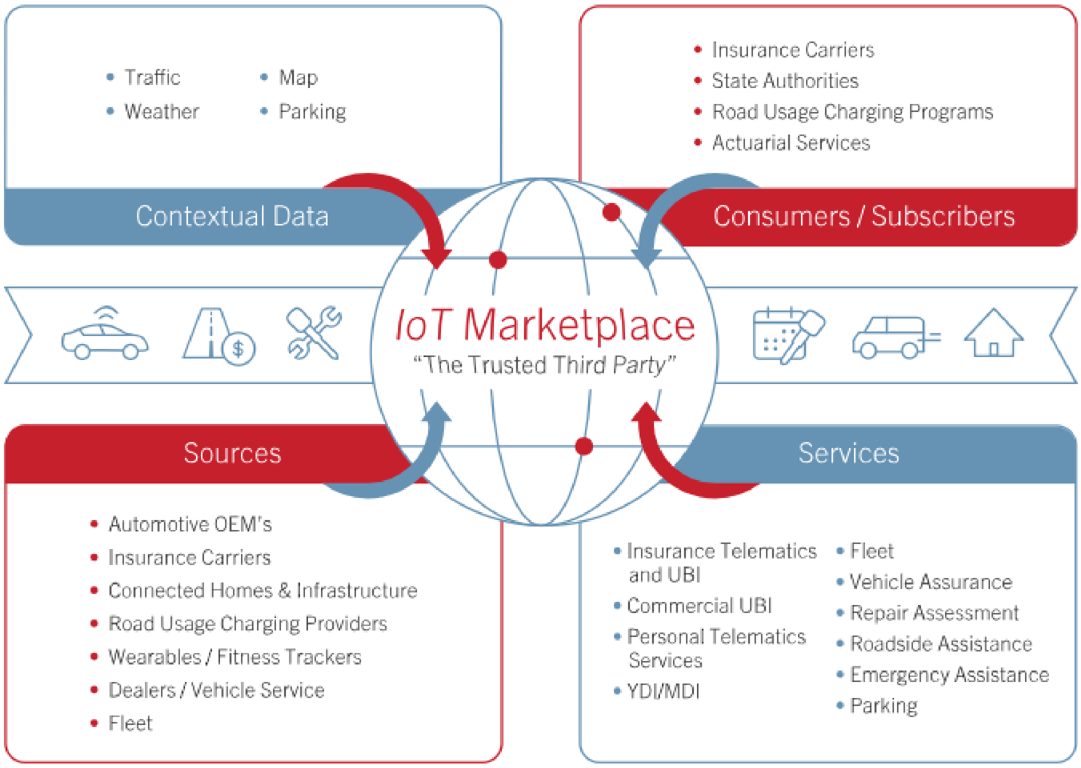

Figure 6.14: The Trusted Third Party (IMS(d))

Regarding this easy payment feature, as states Genaldi Man, the CEO of Kasko2Go, a Blockchain technology-based car insurance startup that focus on the fraud detection problem, “Transactions become instant and cheap due to the rejection of many counterparties and the replacement of complex infrastructure. Previously, it could take several weeks from the insured event to make a payment, but now it’s done in minutes.” Stewart Rogers.

Another Blockchain technology advantage is the non-subjectivity of the data collected analysis by the company. Currently, much data is collected and transmitted to the insurer or outsourced service that will then be responsible for evaluating and determining whether the driver deserves the discount on the insurance premium. Although most insurers offer an online portal or mobile application in which the drivers can monitor their performance, this assessment is subjective to how the company judges the criteria, a methodology not completely transparent to the user.

Blockchain would benefit from greater transparency of such data treatment and the standardization of criteria among insurers. The platform is based on smart-contracts, what means that they are pre-programmed and open source tools whose function is to convert vehicle information into reputation tokens for the driver. Both parties can visualize the code by which the contract defines the number of tokens and this pattern remains the same for all insurers and users, so there is no room for questioning the validity of the analyzed information.

Naturally, this would also improve fraud detection and risk prevention. To illustrate the impact of this issue, the Coalition Against Insurance Fraud estimates the cost of fraudulent claims in the U.S. in the range of $80 billion on an annually bases (Coalition Against Insurance Fraud). That's because with Blockchain network, it is possible to verify the authenticity of customers, policies, and transactions (such as claims) by providing a complete historical record.

In addition, the Blockchain network has the characteristic of being immutable, a great advantage for the insurer and its users. This is because, once the person registers in the network and the information is validated, all their generated data is stored in a permanently, secure, organized and in a very difficult to be changed way. Thus, throughout both vehicle and driver life, regardless of whether the user wants to buy a car insurance, at the age of 18 or 90, in Asia or South America, the insurer can access all the individual's history. So the information would be always linked to the person and not to the insurer, for the lifetime.

Further motivations to invest in this Blockchain platform are the many other applications and benefits that this would bring together. The goal is to have millions of data from all vehicles, drivers, and routes in a transparent, secure, decentralized, and real time Blockchain network. One of the future developments might be the autonomous cars, because thousands of information would be frequently updated in the network, a smart car would then have all the data needed to guide itself accurately and safely.

Chapter 7

Driver Behavior Statistical Analysis

Remark: The objective of this section is, through a realistic traffic database, to analyze the driver behavior and the correlation between this parameter with the person characteristics to establish a risk pattern. According to that, it is suggested a new model in which an “influence” variable is added. This variable represents a scenario where the driver behavior is positively influenced using the Blockchain application proposed in this work.

7.1 Red Light Violation Case Study

The report "Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras" (David Yang, et al.) was used as the basis for this statistical model development. This report, sponsored by the US Department of Transportation National Highway Traffic Safety Administration, had approximately 47,000 red light violation records from 11 intersections in the City of Sacramento (California) collected between May 1999 and June 2003. The purpose of this study was to analyze exogenous and endogenous factors influencing the driver to commit a red light violation.

So, two logistic regression models were developed, each one for a chosen dependent variable. The first one considered whether the driver's speed when violating the red signal was greater or lower than the posted speed limit. The second one referred to the elapsed time since red light onset (less than 2 seconds or greater than 2 seconds). In both statistical analyses the following factors were considered: age of the driver, time of violation, gender, age of the vehicle and location of the signaled intersection. The Table in 7.1 illustrates these variables in the case of the measured speed as a dependent parameter (analogous to elapsed time since red light onset as a dependent variable).

However, after many iterations, the final model contained only the age of the driver, time of the violation and location for the signalized intersection as explanatory variables, since factors as the gender and the age of the vehicle driven did not show significant influence.

Use of (David Yang, et al.) as a reference had at least three main advantages: The first is the highlight of "Age" as a variable that strongly influences driver behavior. The second is the statistical methodology based on the presented, logistic regression modeling, adopted for this project. The third is the consideration that traffic signal violations often result in car accidents of various injury rates, an impact scenario further considered in this work.

As can be seen in (David Yang, et al.), the driver age and the number of red light violations are inversely related parameters. This means that the older is the driver, the less likely he or she is to commit this traffic infraction. As stated, "Analyzed results for the 'Age' variable are consistent with our expectation. Research results from other studies have found that younger motorists drive more aggressively and are more likely to take driving risks compared to older drivers. Hence, we would expect that there are more younger drivers who would attempt to 'beat the red light' by going through the intersection at high speeds that are greater than the posted speed limit"(David Yang, et al.).

Variable Description	Variable Code	Variable Type	Data Format	SAS Code
Speed of the Vehicle at Time of Violation, MPH	*Speed2*	*Dependent*	*Violation Speed ≤ Posted Speed Limit*	*0*
			Violation Speed > Posted Speed Limit	*1*
Age of the Red Light Violator	Age	Explanatory	Younger, 15 to 29 Years Old	1
			Middle-Age, 30 to 59 Years Old	2
			Older, 60 Years or Older	3
Gender of the Red Light Violator	Gender	Explanatory	Male	0
			Female	1
Time of the Red Light Violation	Time 1	Explanatory	6 a.m. to 9 a.m.	1
	Time 2		10 a.m. to 3 p.m.	2
	Time 3		4 p.m. to 7 p.m.	3
	Time 4		8 p.m. to 5 a.m.	4
Age of the Vehicle Driven by Violator	VehYr	Explanatory	Old, Made in or Before 1993	1
			Medium, Made from 1994 to 1999	2
			New, Made in or After 2000	3
Location Code for the Signalized Intersection	LocCode 1	Explanatory	Fair Oaks Boulevard and Howe Avenue	1
	LocCode 2		El Camino Avenue and Evergreen Street	2
	LocCode 3		Arden Way and Exposition Boulevard	3
	LocCode 4		Mack Road and La Mancha Way/Valley Hi Drive	4
	LocCode 5		Mack Road and Center Parkway	5
	LocCode 6		30th Street and Capitol Avenue	6
	LocCode 7		J Street and Alhambra Boulevard	7
	LocCode 8		Broadway and 21st Street	8
	LocCode 9		W Street and 16th Street [Highway 50 Exit at 16th Street]	9
	LocCode 10		Howe Avenue and College Town Drive	10
	LocCode 11		Power Inn Road and Folsom Boulevard	11

Figure 7.1: Dependent and Explanatory Variables Used in Logistic Regression Analysis (David Yang, et al., **Table 16**)

Moreover, the driver's age is a relevant factor when it comes to the adaptability and propensity to use modern technologies, such as a mobile Blockchain application it is. So, for the application influence factor it will be considered a young age group, but whose individuals are already old enough to pay for their own car insurance, which results in a long-term increase in the interest on a discounted premium. Thus, the most positively influenced age group are individuals aged 25 to 45 years, although all the age groups will be better evaluated later. Also, the (Insurance Information Institute) provides a research from (Towers Watson) that states "Sixty percent of those who are interested in Usage-Based Insurance (UBI) indicate they are willing to change their behavior, suggesting a large appetite for behavior-changing features, which underscores the value of pursuing the development of effective driver coaching. The most promising observation is that the willingness to change is highest among younger drivers, drivers who drive the most and owners of newer vehicles (Figure 7.2). These are higher-risk segments, with above average expected insurance losses. This suggests that if the industry can effectively deliver driver coaching, this would have the biggest impact on the riskiest drivers, resulting in an improvement in road safety."

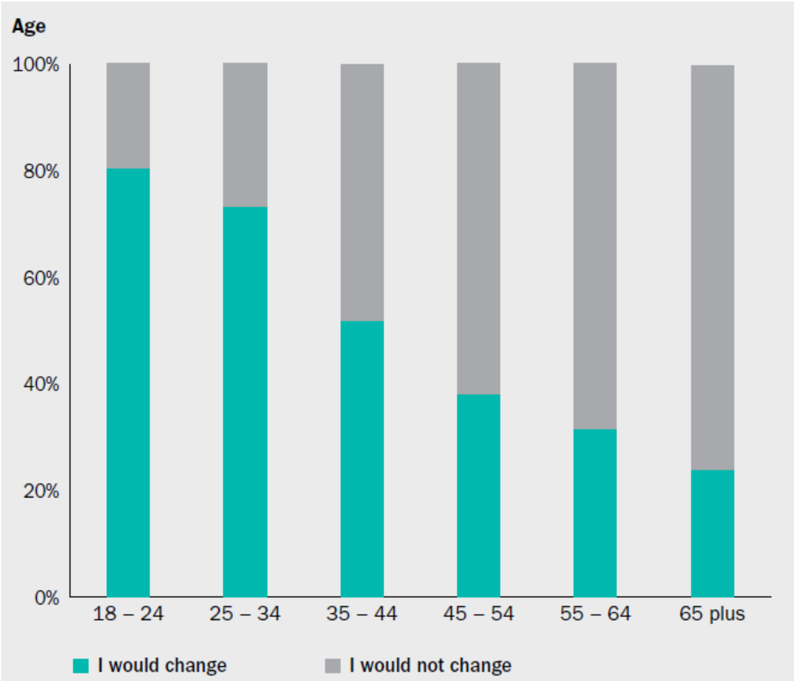

Figure 7.2: Higher risk segments tend to be more willing to change behavior, potentially resulting in lower loss costs (Towers Watson)

To emphasize the importance of the age factor, the *Motor Vehicle Occupant and Motorcyclist Fatality and Injury Rates* database was examined throughout the United States, not only in Sacramento (California). These data are publicly provided by the National Highway Traffic Safety Administration's Annual Safety Tables Report (NHTSA).

In Figure 7.3 there is a graph generated by the *Fatality Rate per 100,000 Population*. The database is provided in Appendix A in Tables A.1 and A.2.

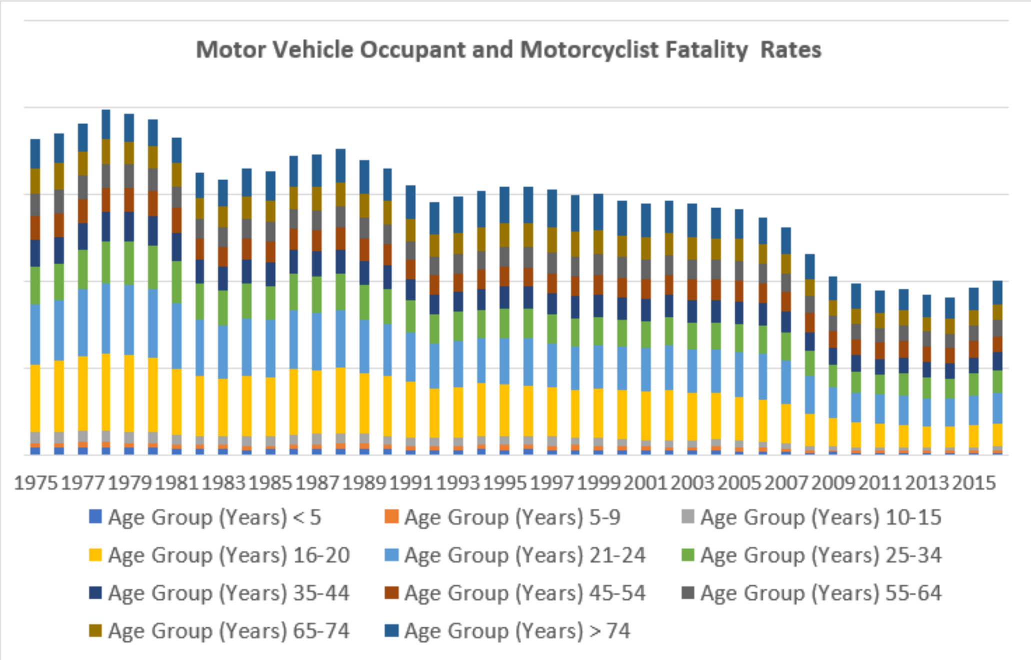

Figure 7.3: Motor Vehicle Occupant and Motorcyclist Fatality Rates

Note that the age influence in the driver behavior is a pattern for the whole country, as well as for different traffic infractions and its consequences, such as a fatal injury. It is also mentioned in (David Yang, et al.), that red light infractions and car accidents are directly related, "Overall, the crash rate is estimated at about 5 crashes per 1,000 red light violations based on this Sacramento data set." and so, vehicle crashes injury levels and pedestrian crashes will be further evaluated considering also the driver's age as an explanatory variable.

7.2 Blockchain Application vs. Red Light Violation

To better understand the motorists' age influence on the driver behavior, the reference (David Yang, et al.) presents the data in Table 7.1, where the *RLVs* is the number of red light violations, *LDs* is the number of licensed drivers in California (2001) and *MVMT* are the total vehicle miles of travel in the U.S., in millions (1996).

Table 7.1: Distribution of Red Light Violation Records by Age (David Yang, et al. **Table 7**)

Age Group	No. of RLVs	% of RLVs	No. of LDs	% of LDs	% of RLVs/ % of LDs	Total MVMT	% of MVMT	% of RLVs/ % of MVMT
<or = 19	1.668	4,27%	883.858	4,09%	1,05	83.169	3,96%	1,08
20-29	9.769	25,02%	3.925.985	18,16%	1,38	412.282	19,65%	1,27
30-39	9.448	24,20%	4.997.068	23,11%	1,05	539.014	25,68%	0,94
40-49	8.390	21,49%	4.797.117	22,18%	0,97	503.354	23,99%	0,90
50-59	5.381	13,78%	3.401.805	15,73%	0,88	288.915	13,77%	1,00
60-69	2.410	6,17%	1.883.240	8,71%	0,71	170.488	8,12%	0,76
>or = 70	1.979	5,07%	1.734.720	8,02%	0,63	101.386	4,83%	1,05
Sub-Total	39.045	***	***	***	***	***	***	***
Missing Data	7.952	***	***	***	***	***	***	***
Total	46.997	100%	21.623.793	100%	***	2.098.608	100%	***

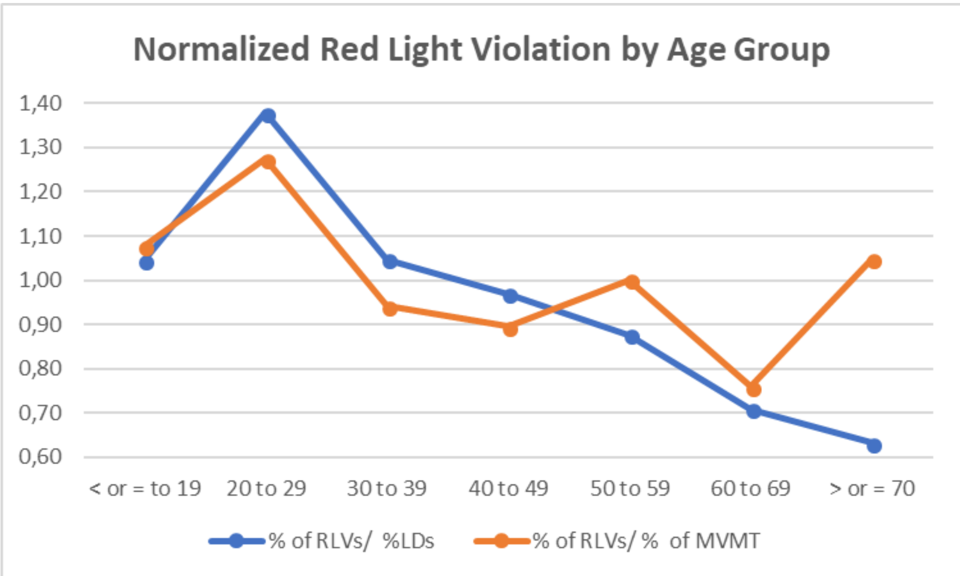

Figure 7.4: Normalized Red Light Violation Values by Age Group - (David Yang, et al., **Figure 2**)

Based on Table 7.1 and Figure 7.4, it is noted a peak for drivers between 20 and 29 years old, a group that falls within the target group influenced by the Blockchain application. Then, three scenarios were designed in which this technology influences the behavior of this target age group. Firstly, an influencing factor related to the driver's age was established in an optimistic scenario (*High Influence Scenario*). These values will serve as a basis for other influence scenarios analysis, not only for red light violation, but also for other driver behavior indicators, like vehicles crashes. The influence factor is proportional to the traffic infraction severity, for example, since vehicles with more traveled mileage are less relevant as indicators of driver behavior compared to red light violation, the value of this influence factor was obtained as one-third of the red light violation factor.

The Results of this hypothetical scenario are presented in Table 7.2. It means that, for the 20-29 age group, the number of red light violations (RLVs) would reduce in 50%, so from 9.769 infractions (Table 7.1) to 4.885 (Table 7.3). Analogously for the same age group, the total vehicle miles of travel (MVMT) are reduced by 17%, so approximately one-third of 50%. Naturally, the number of licensed drivers (LDs) remains the same.

Following this logic, it was designed a *Medium Influence Scenario* which calculations are in Table B.1 and a *Low Influence Scenario* from Table B.2, respectively to the influence degree of the Blockchain application on driver behavior. By definition, the ratio between the red light violation (RLV) and vehicles miles of travel (MVMT) is constant among the three scenarios. The difference relies on the Application Factor of RLV that was set as 1.5 times lower for the *Medium Scenario* and 2 times lower for the *Low Scenario*, both in respect to the referenced *High Scenario*.

Finally, when comparing the real scenario with the three hypothetical ones, so comparing Figure 7.4 with FIgures 7.7, 7.6 and 7.5), it was established to use the *Medium Influence Scenario* as a basis. Such influence factors due to the Blockchain application will be a reference for the statistical modeling of more severe traffic occurrences, such as cars and pedestrian crashes.

Table 7.2: Factors of High Blockchain Application Influence in the Driver Behavior

App. Factor RLV	App. Factor MVMT	Age Group
-30%	-10%	<or = 19
-50%	-17%	20-29
-60%	-20%	30-39
-50%	-17%	40-49
-30%	-10%	50-59
-10%	-3%	60-69
-1%	0%	>or = 70

Table 7.3: High Influence Scenario

Age Group	**No. of RLVs**	**% of RLVs**	No. of LDs	% of LDs	**% of RLVs/ % of LDs**	**Total MVMT**	**% of MVMT**	**% of RLVs/ % of MVMT**
<or = 19	**1.168**	**5,33%**	883.858	4,09%	**1,30**	**74.852**	**4,17%**	**1,28**
20 to 29	**4.885**	**22,28%**	3.925.985	18,16%	**1,23**	**343.568**	**19,14%**	**1,16**
30 to 39	**3.779**	**17,24%**	4.997.068	23,11%	**0,75**	**431.211**	**24,02%**	**0,72**
40 to 49	**4.195**	**19,14%**	4.797.117	22,18%	**0,86**	**419.462**	**23,37%**	**0,82**
50 to 59	**3.767**	**17,18%**	3.401.805	15,73%	**1,09**	**260.024**	**14,49%**	**1,19**
60 to 69	**2.169**	**9,89%**	1.883.240	8,71%	**1,14**	**164.805**	**9,18%**	**1,08**
>or = 70	**1.959**	**8,94%**	1.734.720	8,02%	**1,11**	**101.048**	**5,63%**	**1,59**
Sub-Total	**21.921**	***	***	***	***	***	***	***
Missing Data	**7.952**	***	***	***	***	***	***	***
Total	**29.873**	**100,00%**	21.623.793	100,00%	***	**1.794.970**	**100,00%**	***

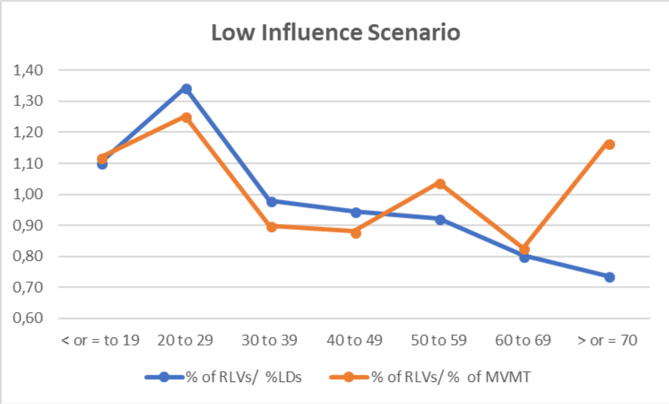

Figure 7.5: Low Influence Scenario

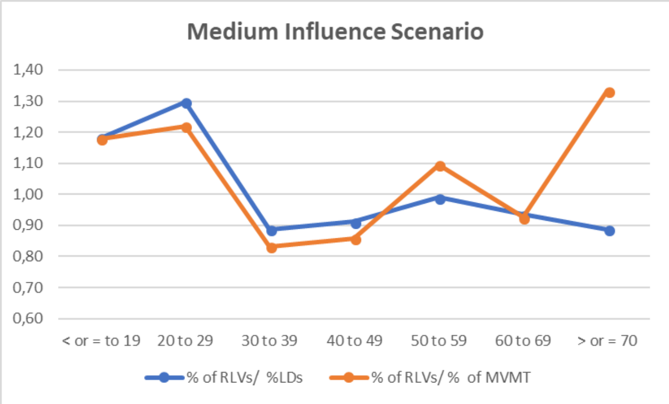

Figure 7.6: Medium Influence Scenario

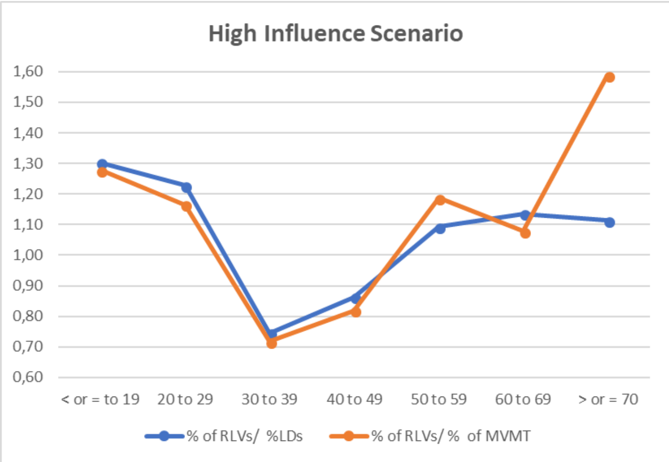

Figure 7.7: High Influence Scenario

7.3 Statistical Modeling of Car Accidents Data

As mentioned, one of the outputs from (David Yang, et al.), is the statistical modeling method applied to analyze the red light violation data, so the logistic regression model. From the modeling description: "Two logistic models were developed to examine the influence of age, gender, violation time, vehicle year and violation location on two dependent variables: (1) vehicle speed at the time of violation and (2) elapsed time between the onset of red signal and the time of violation".

Logistic regression correlates more than one explanatory variable with a binary response dependent variable to obtain Odds Ratios (Sandro Sperandei), the definition is "The Odds Ratio is used when one of two possible events or outcomes are measured, and there is a supposed causative factor. The Odds Ratio is a versatile and robust statistic" (Mary McHugh).

The odds of an event is simply the fraction between the probability of that event occurring and the probability of not occurring, as represents the equation 7.1 (David Yang, et al.). From this definition, Odds Ratios are the ratio of probabilities of two events' occurrence, that is, it represents how much more probable is an events' occurrence in respect to another.

$$O_i = \frac{p_i}{1 - p_i} \tag{7.1}$$

Furthermore, this work focus on traffic injury accidents. Thus, an Odds Ratios model was developed to evaluate the *Driver Involvement Rates per 100,000 Licensed Drivers by Age, Sex, and Crash Severity (2015)*, data available publicly (NHTSA). This database presents driver rates of fatal crashes, injury crashes and property-damage-only crashes segmented by age and gender of the driver and are presented in Appendix C.

The data relate the age and gender variables to the driver's involvement rate within three levels of crash severity occurrences. In order to simplify the analysis, only the age variable was considered. This is due to two main reasons, first for the fact that the gender was not proved as a significant variable in the reference (David Yang, et al.) and secondly from the initial hypothesis that the driver's adoption respective to the proposed Blockchain application does not depend on the genre.

The analysis tool was the weighted Odds Ratio (William Haenszel, et al.), (Sandro Sperandei) with the aim of correlating the crash severity with the driver's age. The results obtained comparing the Fatal and Injury Crashes are presented in Table 7.4

Table 7.4: Driver's Involvement Rate in Fatal and Injury Crashes

Driver's Age	Involvement Rate	Drivers in Fatal Crashes	Drivers in Injury Crashes	Totals	Total	**Odds Ratio**
16-20	Involved	117	118	235	379258	**89,76**
	Not Involved	4141	374882	379023		
21-24	Involved	144	144	288	359015	**72,68**
	Not Involved	4871	353856	358727		
25-34	Involved	384	384	768	693993	**71,14**
	Not Involved	9609	683616	693225		
35-44	Involved	362	362	724	542768	**72,19**
	Not Involved	7406	534638	542044		
45-54	Involved	395	395	790	494915	**64,71**
	Not Involved	7519	486605	494125		
55-64	Involved	377	377	754	392525	**62,72**
	Not Involved	6148	385623	391771		
65-74	Involved	250	251	501	205794	**56,7**
	Not Involved	3544	201749	205293		
>74	Involved	151	151	302	114762	**42,83**
	Not Involved	2611	111849	114460		

The important conclusion from that analysis is that driver's age follows a trend similar to that presented in (David Yang, et al.), that is, the younger the driver, the more likely to be involved in severe crash accidents. Comparisons were also made on Fatal versus Property-Damage-Only crashes and Injury versus Property-Damage-Only crashes and so the outputs follow the same reasoning.

As a result for data in Table 7.4, the weighted Odds Ratio (William Haenszel, et al.), (Sandro Sperandei) equals to **64,64**. It means that the weighted chance of involvement associated with fatal crash is **64,64** times the chance of involvement with injury crash when considering the various age ranges as a parameter.

In order to correlate a potential improvement of this scenario with the positive influence proposed by the Blockchain platform, a similar reasoning to that applied in section 7.4.2 was developed.

Table 7.5: Correlation Between the Factors Influencing The Application and Driver Behavior

App. Factor RLV	Age ranges RLV	**Age ranges Crashes**	App. Factor Injury Crashes	App. Factor Fatal Crashes
-20%	<or = 19	**16-20**	-30%	-40%
-33%	20-29	**21-24**	-50%	-67%
-40%	30-39	**25-34**	-55%	-73%
-33%	40-49	**35-44**	-53%	-70%
-20%	50-59	**45-54**	-41%	-55%
-7%	60-69	**55-64**	-26%	-34%
-1%	>or = 70	**65-74**	-13%	-18%
		>74	-1%	-1%

The Blockchain application proposes penalties in terms of the *DBTOKENs*, proportionally to the consequences severity degree due to a a bad driver behavior. This means that, while a red light violation would penalize the user at 1 *DBTOKEN*, liability for involvement in a car accident would penalize at 30 *DBTOKEN*s. As a consequence, it is assumed that more severe penalties result in greater application influence on the driver behavior. Of course, the driver behavior is influenced by a huge number of correlated factors, and it is complex to categorize the data in this way, but for the sake of illustration, the **Application Influence Factor for Injury Crashes** was considered 1,5 times the **Influence Factor for Red Light Violation** in the *Medium Influence Scenario*. Analogously, the **Influence Factor on Fatal Crashes** is 2 times the Red Light Violation factor. As a result, the Odds Ratios changed from the ones in Table 7.4 to the exposed in Table 7.6 and so the reductions percentages can be seen in Table 7.7 and represents by how much the respective involvement rate would be reduced in a scenario influenced by the Blockchain platform.

Table 7.6: Driver's Involvement Rate in Fatal and Injury Crashes When Influenced by the Blockchain Platform

Driver's Age	Involvement Rate	Drivers in Fatal Crashes	Drivers in Injury Crashes	Totals	Total	**Odds Ratio**
16-20	Involved	70	83	153	379259	**76,09**
	Not Involved	4188	374918	379106		
21-24	Involved	48	72	120	359015	**47,53**
	Not Involved	4967	353928	358895		
25-34	Involved	102	173	275	693993	**40,97**
	Not Involved	9891	683827	693718		
35-44	Involved	109	172	281	542768	**44,1**
	Not Involved	7659	534828	542487		
45-54	Involved	178	232	410	494915	**48,19**
	Not Involved	7737	486768	494505		
55-64	Involved	248	280	529	392525	**54,4**
	Not Involved	6277	385719	391996		
65-74	Involved	206	218	423	205794	**53,15**
	Not Involved	3588	201783	205371		
>74	Involved	149	149	298	114758	**42,69**
	Not Involved	2611	111849	114460		

Notice that the Odds Ratios were reduced and targeted group ages likely to be influenced from the Blockchain platform (25-45 years old) had a reduction average of nearly 40%. As expected, the weighted Odds Ratio was reduced from **64,64** to **49,32**.

So far, it can be concluded that this Blockchain platform has a great potential impact on society. This because the age group that statistically presents the most dangerous driver behavior is also the target group more likely to join this technology. Those hypotheses were based on the trend towards the technology modernization and by the interest in using a resource that would reduce the premium charged by insurers.

Table 7.7: New Odds Ratio on a Blockchain Platform Influenced Scenario

Age	Old	New	Reduction
16-20	89,76	76,09	15,23%
21-24	72,68	47,53	34,60%
25-34	**71,14**	**40,97**	**42,41%**
35-44	**72,19**	**44,1**	**38,91%**
45-54	64,71	48,19	25,53%
55-64	62,72	54,4	13,27%
65-74	56,7	53,15	6,26%
>74	42,83	42,69	0,33%

7.4 Statistical Modeling of Pedestrian Crash Severity

7.4.1 Statistical Modeling Description

As noticed, the weighted Odds Ratio (William Haenszel, et al.) applied method requires categorical explanatory variables, in this case the age ranges. In order to better understand the age influence on the driver behavior, it is interesting to input this collected data (the various ages) as a continuous variable. That because, segmenting this data throw breaking points could hide points of interest. Therefore, the Odds Ratio calculation throw the logistic regression model is an alternative. Not only that, but with the logistic regression model it is possible to combine more than one explanatory variable to better understand the factors influencing the driver behavior, similar reasoning addressed on (David Yang, et al.).

The equation that represents this statistical model is:

$$p_i = \frac{e^{a+b_1x_1+b_2x_2+...+b_nx_n}}{1+e^{a+b_1x_1+b_2x_2+...+b_nx_n}} \tag{7.2}$$

From equation 7.2, the x_n parameters are the explanatory variables and the b_n their corresponded coefficients, a is a constant term and p_i is the probability of a given y_i output equals to 1 (a binary event; occurrence or not occurrence).

7.4.2 Pedestrian Crashes Database Description

The database used for the following two logistic regression models developed is publicly available at (NCDOT) and reports details about crashes involving pedestrians in Chapel Hill Region of North Carolina from January 2007 through December 2013. From (NCDOT) "Information for each crash includes: County, City, Crash Date, Crash Day, Crash Group, Crash Location, Crash Time, Crash Severity, Bike/Pedestrian Age Group, Bike/Pedestrian Alcohol Detected, Bike Direction, Bike/Pedestrian Injury, Bike/Pedestrian Position, Bike/Pedestrian Race, Bike/Pedestrian Sex, Ambulance Response, Driver Age Group, Driver Estimated Speed, Speed Limit, Driver Alcohol Detected, Driver Injury, Driver Race, Driver Sex, Driver Vehicle Type, Hit and Run, Development, Light Condition, Locality, Number of Lanes, Road Characteristics/Class/Condition/Configuration, Road Defects/Features, Traffic Control, Crash Type, and/or Weather."

As described, the driver's age was set as a continuously explanatory variable in both models and combined with other influence parameters. So on, were developed hypothetical scenarios where a *Blockchain Influence Factor* is added to evaluate the correlation among all those variables.

7.4.3 Influence Factors on Driver's Alcoholic Sobriety

A driver caught in an alcoholic condition is a strong indicator of a terrible driver behavior. Driving drunk is an irresponsible attitude that causes serious accidents. Thus, this will be the dependent variable analyzed in this model and, therefore, interpreted as a significant driver behavior indicator. The proposed Blockchain platform predicts that sensors could detect the driver's sobriety so that the person could be penalized in some *DBTOKENs*. Depending on the case, in countries where the law does not tolerate any alcohol level, the driver can suffer even more serious consequences.

In addition to the continuous explanatory variable, the driver's age, variable codes "No Injury", "Possible Injury", "Evident Injury" and "Killed or Disabling Injury" are the four dummy variables representing four categorized severity levels when a pedestrian crash occurred. Important to emphasize that those severity levels refer to the crash injury on an overall analysis, not only related to the pedestrian condition. First, in the logistic regression analysis, "No Injury" was selected as the reference variable during the data regression process because is the less likely to be related with a not sober driver. Further, the other variables were tested as reference variables, and those results are compared below.

Estimated coefficients, p-Values, and Odds Ratios for all explanatory variables in the final logistic regression model are presented in Table 7.8.

Table 7.8: Estimated Results for the Binary Logit Model with "Alcohol" (Driver Sobriety) as a Dependent Variable

Variable	Coefficient	p-Value	Odds Ratio	1/Odds Ratio
Age	-0,016	0,181	0,984	1,016
Possible Injury	12,953	0,017	4,2E+05	2,4E-06
Evident Injury	12,693	0,035	3,3E+05	3,1E-06
Killed/Disabling Injury	13,223	0,015	5,5E+05	1,9E-06

From statistical theory, the p-Value represents a variable's significance level for a respective analysis, so the smaller it is, the more significant is the variable for the final model (David Yang, et al.). Those p-Values were calculated in *Excel* throw the Likelihood Ratio statistical test (Mark Harmon). The Odds Ratios explained in section 7.3 were simply calculated as the exponential of the respective coefficient value.

Regarding the coefficient interpretation, analogous to the results obtained in the reference (David Yang, et al.), the estimated coefficient for the variable "Age" is a negative value. This means that, as the driver's age increases, the likelihood of him or her being considered drunk after a pedestrian crash is reduced. As a result, the inverse Odds Ratio value for "Age" (1,02) means that the predicted chances of a motorist driving drunk are decreased by 1,02 times with increasing age.

However, the p-Value for the "Age" variable is a little above the established threshold (0,18>0,10), meaning that this variable does not have a high significant correlation with the output. This p-Value is a statistical parameter that indicates whether the variables have or not a strong correlation with the result, so usually values between 0,05 and 0,01 are accepted. From a didactic study perspective, a reason for that could be the small size of the sample comparable to the wide range of possibilities. In other words, the database provided only approximately 300 pedestrian crash (NCDOT) occurrences, while the driver's age goes from 16 to 70 years old. Probably, a dataset with more case occurrences would led to very small p-Values, as happens in the reference (David Yang, et al.) when the p-Value for the "Age" variable is less than 0,001 and almost 47.000 datapoints were computed. Since a p-Value lower than 0,05 represents a 95% level of confidence, for this prototype a 80-85% level of confidence will be also considered as valuable, so a p-Value up to 0,2 will be accepted for now.

It can be noticed that the variables regarding the crash severity present really small values for the Odds Ratio inverse fraction. This data interpretation follows that the output probability of the driver being drunk for the reference variable, "No Injury", is 3.07E-06 times the probability for the "Evident Injury". Since the p-Value for all those dummy variables are <0,05 they can all be significant for the model. However, since the Odds Ratios correlation seemed to be weak (they have a magnitude powered by a 10^{-6} factor), a new model was developed but with the "Evident Injury" as the reference variable and the results are presented in Table 7.9.

Table 7.9: Estimated Results for the Binary Logit Model with "Alcohol" (Driver Sobriety) as a Dependent Variable – Second running model

Variable	Coefficient	p-value	Odds Ratio	1/Odds Ratio
Age	-0,016	0,181	0,984	1,016
No Injury	-15,867	0,551	1,3E-07	7,8E+06
Possible Injury	0,259	0,035	1,296	0,771
Killed or Disabling Injury	0,529	0,387	1,698	0,588

As expected there is a huge difference among the inverse value of the Odds Ratios and the p-Values, Table 7.9 shows that the output probability of a driver being drunk in a "Evident Injury" crash scenario is in the order of magnitude of one million times the "No Injury" while is only 0,59 times the "Killed/Disabling Injury". To explain those results, by looking at the p-Values it can be noticed that the values for the "No Injury" and "Killed/Disabling Injury" are very out of range for 0,05>p>0,01 and so they are not considered significant for the final model. However, while the "Possible Injury" variable has a p-Value<0,05 (and so is accepted as significant for the model), the inverse value of the Odds Ratios shows a value close to 1 between this variable and the reference variable "Evident Injury".

As a consequence, further in the second model approach, the severity of the injury will be treated as a binary variable as well, a severe or not pedestrian damage, since the dummy variables approach for a division of four levels of severity did not show a good fit. Another fact that limits this modeling approach in comparison with the reference (David Yang, et al.) is the human factor that in a crash, there are at least two people involved. This means that, for a red light violation the decision of committing the violation or not relies only on the driver's choice, while in a pedestrian crash the fault can be either the pedestrian or the driver, or a combination of the two factors. Therefore, it would be interesting to have an even greater number of data-points than in the red signal analysis (so more than 47.000), because the randomness of the both factors combined is greater.

As a result, follows in Table 7.10 two comparisons taking in account the age and the crash severity:

Table 7.10: Age Comparison of Driver's Probability of Being Drunk in a Pedestrian Crash with "Evident Injury" Severity Level

Severity Level	Driver's Age	Probability of being drunk
Evident Injury	**20**	16.62%
Evident Injury	**40**	12.64%

As discussed, Table 7.10 shows that for a 20 to a 40 years old driver, there is a 3,98 percentage points on the probability of being caught drunk in a pedestrian crash accident with an "Evident Injury" level.

In order to evaluate a scenario where the Blockchain Platform diminishes the alcoholic state of the drivers, a new dummy variable called *Application Positive Influence Factor* was coded as "Low", "Medium" and "High" in accordance with the corresponding influences rates. Coherently with the previous discussion, a "High" level was related to people from 25 to 45 years old, the "Low" level was related to drivers from 56 to 70 years old and so the "Medium" level was set to age ranges from 16 to 24 and 46 to 55 years old. The reference variable was defined as the "Low" influence level. For this new scenario, it was considered that if the person was before drunk in the pedestrian crash, but he or she is in the "High" influence group, then now the person would not be driving drunk anymore. The results are presented in Table 7.11

Regarding the influence levels, since only the "High" level was set as sufficient

Table 7.11: Estimated Results for the Logistic Regression Model with "Alcohol" as a Dependent Variable in a Blockchain influenced Scenario

Variable	Coefficient	p-Value	Odds Ratio	1/Odds Ratio
Age	-0,022	0,160	0,9777	1,023
No Injury	-16,298	0,070	8,0E-08	1,2E+07
Possible Injury	-0,219	0,490	0,802	1,250
Killed or Disabling Injury	0,537	0,364	1,711	0,584
Medium	-0,617	0,314	0,539	1,854
High	-15,124	0,0003	2,7E-07	3,7E+06

influencing to change the driver's sobriety level output, there is a notorious inverse value of the Odds Ratios for this variable while comparing it to the reference variable ("Low") and a much smaller rate when comparing the "Low" and "Medium" parameters. This means that a "Low" Blockchain influenced driver, has a probability of being caught drunk in an order of magnitude a million times bigger than a "High" influenced driver. As well, it can be emphasized the very small p-Value for the "High" variable when comparing to the others, what expresses its significance in the final model, and because of that have no meaning in accounting for the "Medium" variable in a final model.

Table 7.12: Driver's Probability of Being Drunk Compared among Blockchain Influenced Scenarios

Severity Level	Driver's Age	Probability of being drunk	Blockchain Influence Factor
Evident Injury	20	25.83%	**LOW**
Evident Injury	20	15.82%	**MEDIUM**
Evident Injury	20	0.00%	**HIGH**

Finally, results illustrating this *Blockchain Influenced Scenario* are presented in

Table 7.12. For the category "Low Blockchain Influenced" scenario the probability of a driver who caused an "Evident Injury" pedestrian crash to be driving drunk is 25,83% while for the "Medium Influenced" scenario is 15,82%. Regarding the "High Influenced" scenario the result falls almost to a null value.

7.4.4 Factors Influencing Pedestrian Accidents

The Pedestrian Crash Dataset (NCDOT) was used to develop a second logistic statistical model, but with different input and output data. In this case, three explanatory variables were considered: again, the "Age" as a continuously parameter, the driver's sobriety (binary information if the individual was drunk or not) and the average speed measured at the time of a pedestrian crash. For the speed variable, 12 average speeds were considered, first as a continuous explanatory variable as the driver's age and then as 12 dummy variables, since the results showed that this was a significant factor for the final model. However, results presented in Table 7.13 are related to the first attempt since the final model with no dummy variables presented a better fit for this dataset size problem solving.

The dependent variable was set as the occurrence or not of a pedestrian serious injury, thus related to the pedestrian condition due to the accident. Therefore, the binary occurrence "Not Severe Injury" was referred to cases where the pedestrian had "No Injury" or "Possible Injury" while the "Severe Injury" occurrence was considered when the pedestrian had a "Evident Injury" or "Killed or Disabling Injury". This approach was defined from the previously correlation analysis among many injuries severity levels, where it was concluded that dividing four severity levels did not have a great statistical significance, probably due to few available datapoints. Here, the crash severity level is related to the pedestrian state and not the accident as a whole.

The logistic statistical modeling results are presented in Table 7.13. Again, the estimated coefficient for variable "Age" is a negative value, meaning that as the driver's age increases, the probability of causing severe damage to a pedestrian in an acci-

Table 7.13: Estimated Results for the Logistic Regression Model with Pedestrian Injury as a Dependent Variable

Variable	Coefficient	p-Value	Odds Ratio	1/Odds Ratio
Age	-0,014	0,064	0,985	1,015
Alcohol	0,664	0,260	1,944	0,514
Speed	0,040	1,86E-05	1,041	0,960

dent, decreases. Here, the p-Value is lower than 0,10 what means a higher level of significance for this variable in the final model.

Regarding the driver's sobriety as an input binary variable, the estimated coefficient is positive, meaning that if the driver is drunk there is a higher probability of a pedestrian accident being severe, as expected. However, from the p-Value significance analysis this variable was not accepted as significant in the final model, since its p-Value is higher than 0,10 and even the pre-set 0,20 limit (meaning a confidence interval lower than 80%). This might explain why in the first logistic regression model approach the majority of data inputs did not show a significance correlation with the output, the probability of the driver being drunk or not. So, by comparing the two models, it can be concluded that the driver's sobriety does not have a high correlation with the pedestrian crash injury level.

Considering the driver's average speed, also a positive estimated coefficient, it represents that there is a higher probability of a pedestrian crash being severed as the higher is the vehicle's speed. It is emphasized that the p-Value for this variable is very small (p-Value<0,001) and so indicates a high impact on the dependent variable for the final model. So far, from those two models it can be concluded that the correlation between the driver's age and the severity of a pedestrian crash is much more related to a speed factor than to the driver's state of sobriety.

From the results presented in Table 7.14, it is possible to discuss the impact among the three explanatory variables on the probability of the pedestrian being seriously injury due to a pedestrian crash. Considering the "Driver A" as the reference, the

Table 7.14: Influence by Age, Alcoholic Sobriety and Average Speed on the Probability of a Pedestrian Seriously Injured due to a Pedestrian Crash

	Driver A	Driver B	Driver C	Driver D
Driver's Age	20	**40**	20	20
Alcohol	1	1	**0**	1
Average Speed (mph)	35	35	35	**50**
Probability of a Pedestrian Seriously Injury	**88,83%**	**85,55%**	**80,35%**	**93,60%**

output probability decreases 3,28 percentage points if a drunk driver's age goes from 20 to 40 years old (comparing Driver "A" and "B"). On the other hand, if the reference driver is not anymore considered drunk, so "Driver C", the output probability decreases 8,48 percentage points. Finally, if the motorist is driving with a 50 mph average speed instead of a 35 mph, so "Driver D" comparison, the probability increases 4,77 percentage points.

Henceforth, this model is reevaluated by considering a scenario where there is a Blockchain platform influencing different age groups. In the first logistic regression model (*Influence Factors on Driver's Sobriety*), the *Blockchain Influence Factor* was considered as a dummy variable and coded as "Low", "Medium" and "High". However, it was concluded that there was a small step on the impact generated from the "Low" to "Medium" and a sharply step when the category changed from "Low" to "High". So, in this model, this variable was also treated with a binary approach. From the results obtained on previous age groups studies, it was defined that the *Blockchain Influence Factor* would be set "High", then binary 1 for drivers aged 25 to 45 and "Not High", then binary 0 for drivers under 25 years or over 45 years old.

As a consequence, the explanatory variables were edited to illustrate the *Blockchain Influence Scenario*. If the alcoholic condition was positive and the driver belonged to the "High" influenced group, then the alcoholic condition was set as negative, due to the previously considered severe *DBTOKENS* penalties related.

As well as, if the measured average speed was above 38 mph and again, the driver belonged to the “High” influenced group, then the average speed was set to the theorical posted speed limit of 38mph. This reference average speed was defined based on the 11 posted speed limits considered in the report (David Yang, et al.) that ranges from 25 mph to 45 mph.

Unlike the first logistic regression model, *Logit Model with "Alcohol" (Driver Sobriety) as a Dependent Variable in a Blockchain influenced Scenario*, the output results (“Severe” or “Not Severe” Pedestrian Injury in this case) was not manipulated. The reason for this is to estimate more realistically how the results (see Table 7.15) behave by changing only the explanatory input variables.

Table 7.15: Estimated Results for the Logistic Regression Model with the Pedestrian’s Level of Injury as a Dependent Variable in a Blockchain influenced Scenario

Variable	Coefficient	p-Value	Odds Ratio	1/Odds Ratio
Age	-0,022	0,009	0,977	1,022
Alcohol	0,650	0,280	1,916	0,5218
Speed	0,041	1,417E-05	1,042	0,959
Blockchain Influence Factor	-0,727	0,015	0,482	2,07

Comparing the Tables7.14 and 7.15, the “Age”, “Alcohol” and “Average Speed” explanatory variables follow the same pattern. However, notice a smaller p-Value for “Age” (p-Value<0,10), what means a higher significance in the final model within the new conditions. This is coherent because the "Blockchain Influence Factor", the new variable, is directly related among age ranges.

Regarding this Blockchain variable, a negative estimated coefficient indicates that the more is the driver influenced by the application, the smaller is the probability of causing a severe injury in a pedestrian crash. Also, examining the p-Value, it is obtained a value below 0,10; meaning that this is high significant explanatory variable in the final model.

To conclude, in Table 7.16 are presented the output results, the correspondents probabilities of a individual being seriously injured due to a pedestrian crash in a

Blockchain influenced scenario. The last line is related to probability results from Table 7.14 in order to provide a comparative analysis. For all those hypothetical scenarios there were significant probability percentage points reductions, what indicates very satisfactory results.

Table 7.16: Scenario Influenced by Age, Alcoholic, Average Speed and Blockchain on the Probability of a Pedestrian Seriously Injured due to a Pedestrian Crash

	Driver A	Driver B	Driver C	Driver D
Driver's Age	20	**40**	20	20
Alcohol	1	1	**0**	1
Average Speed (mph)	35	35	35	**50**
Blockchain Influence Factor	1	1	1	1
Probability of a Pedestrian Seriously Injury	**85,81%**	**79,37%**	**75,94%**	**91,87%**
Reference Probability without the Blockchain Influence	88,83%	85,55%	80,35%	93,60%

7.5 Model Results

So, the first conclusions were based on (David Yang, et al.), that pointed out a strong correlation between the driver's behavior when committing a red light violation and their age, time of the day and semaphore location. From those results, the "Age" variable was highlighted due to the hypothetical high correlation with a person's being likely or not to use the proposed Blockchain application platform. In order to evaluate the highest impacts from the Blockchain application, fatal and injury datasets in the whole USA were related to the driver's age, under the hypothesis that it would follow the red light violation trend (NHTSA). It was then confirmed that the "Age" could be a relevant variable while analyzing the driver behavior in traffic collisions.

Given that, hypothetical scenarios targeting drivers from 25 to 45 years old were designed, the red light violation provided in (David Yang, et al.), but also examining

Injury, Fatal and Property-Only Damage involvement rate data provided by the National Highway Traffic Safety Administration (NHTSA). This target age groups was set because might be drivers able to use modern technologies, such as Blockchain, but also highly motivated by reducing their insurance premium.

As seen, the influence of Blockchain depends not only on the age of the motorist, but also on the degree of severity of the drivers' behavior indicators. This means that the Blockchain platform would set higher *DBTOKENs* penalties for a driver involved in a pedestrian crash or for a driver being caught drunk than for a driver who commits a red light violation. Due to this proportionally incentive system, it is expected that also the Blockchain influence factor on the driver behavior would be proportional to the penalties set.

Moreover, two logistic regression models were developed in order to examine traffic crash data while considering the "Age" as a continuously variable, in order to better understand their correlation. The first model presented the "Age" as explanatory variable but also the crash severity as dummy variables, so four levels of severity, and the output was the probability of the driver being drunk when the accident occurred. Further, another dummy variable representing the degree of influence (by Age) by the Blockchain application in the driver behavior was added.

Although there were positive results on the driver behavior due to Blockchain influence, this dummy variable model did not seem to be the best approach, and then a second logistic regression model was designed. In this second approach, again the "Age" variable was considered, but also the driver's average speed and the individual's alcohol sobriety. The output in this case was the probability of a pedestrian being or not seriously injured in a pedestrian crash occurrence. Again, another variable representing the Blockchain influence was then set, considering that it would only influence the target age group. As a result, the Blockchain application showed positive and high impact on the driver behavior. Therefore, this second logistic regression model approach was an improvement on whether the data was processed and so on the obtained results.

To conclude, not only the initial hypothesis that the Blockchain application platform could influence the driver behavior under seriously traffic accidents were validated, but also it was measured the possible magnitude of influence under the analysis between target age group likely to use this technology and the correlation among the driver's age and the involvement rate in different types of crash accidents.

Chapter 8

Conclusion

8.1 Results

From the main objectives of this Master's Thesis (highlighted in section 1.3), the respective results are:

1. Despite elucidating various Blockchain applications in the Automotive Industry, the work focused on the insurance sector. While still an underdeveloped idea on the market, Ethereum's smart-contracts have proven to be a powerful tool for contractual issues in terms of non-subjectivity and transparency. The motivation is based on the current insurance business model, with many financial losses and reliability lack due to bureaucracy, fraud and dissatisfaction for both clients and companies;

2. About the platform design, the proposed solution to combine vehicle's telematics with the Blockchain platform is through the Internet of Things (IoT). In this way, the driver behavior measurements serve as input for the smart-contracts to automatically define a corresponding premium's price for each driver with certain frequency. Also, this measured behavior would be available to the driver and the whole community in terms of *DBTOKENs*, the plataform's reputation

tokens. In this way, an incentive system is created so that people can follow their performance in traffic through the amount of *DBTOKENs* received or debited;

3. To prove the positive potential impact of this platform, statistical logistic regression models were developed to compare the current driver's traffic accident involvement rate and a hypothetical scenario where the Blockchain influence factor is correlated with the target age group (25-45 years old). It was noted a sharply drop of risk injury probabilities, mainly because this age group is comparatively very likely to be involved in traffic violations and accidents, but also is the most potentially like to use the Blockchain platform.

8.2 Recommendations for Further Work

As discussed in section 1.5, the major limitation of this project is the bureaucratic feature of implementation. Therefore, it would be interesting that the next steps focus on a specific geographic region, so a country or part of it. That is because, the legislative and bureaucratic requirements would be studied in order to understand how best to implement this Blockchain platform in the car insurance market. It would be interesting to conduct studies regarding the payment means, the time frequency with which the contracts would be generated and possible partnerships with insurance companies and car manufacturers.

Appendix A

Fatality and Injury Rates

This Appendix A section provides the database used to perform the graphic in Figure 7.3 in section 7.1 to emphasize the importance of the variable "Driver's Age".

These data are publicly provided by the National Highway Traffic Safety Administration's Annual Safety Tables Report (NHTSA) and represents the **Motor Vehicle Occupant and Motorcyclist Fatality and Injury Rates per Population by Age Group, 1975-2016**. It was generated on 05/06/2018.

Note: Population estimates for historical years are periodically revised by the U.S. Census Bureau.

Sources: FARS 1975-2015 Final, 2016 ARF; U.S. Bureau of the Census.

Table A.1: Fatality Rate per 100,000 Population

Year	Age Group (Years)										
	<5	5-9	10-15	16-20	21-24	25-34	35-44	45-54	55-64	65-74	>74	Total
1975	4,5	2,71	5,71	38,77	34,9	21,57	15,67	13,42	13,29	14,72	16,98	16,67
1976	4,5	2,56	6,14	40,95	35,01	21,27	15,27	13,71	13,58	14,92	17,27	17,05
1977	4,68	2,83	6,44	42,86	38,73	22,27	15,61	13,9	13,55	14,03	16,13	17,81
1978	4,61	2,66	6,6	44,45	40,75	24,26	16,72	14,07	13,44	14,79	16,36	18,7
1979	4,35	2,84	6,13	44,36	40,06	24,96	17,11	14,03	13,24	13,59	15,51	18,67
1980	4,24	2,67	6	42,94	39,86	24,82	16,85	14,51	12,83	12,96	15,27	18,45
1981	3,75	2,43	5,24	38,56	37,41	24,22	16,63	13,81	12,68	13,16	14,94	17,62
1982	3,67	2,22	4,85	34,51	32,75	20,45	14,3	11,84	11,24	11,85	14,89	15,39
1983	3,55	2,33	4,6	33,18	30,97	19,86	13,87	11,79	10,92	11,92	15,48	14,9
1984	3,13	2,33	5,21	34,94	32,89	20,26	13,91	11,86	11,16	12,98	16,18	15,39
1985	3,18	2,36	5,52	33,72	32,75	19,5	13,87	11,88	11,33	12,63	16,73	15,15
1986	3,42	2,3	6,07	38,16	33,72	21,04	13,82	11,5	11,38	13,46	17,71	15,92
1987	3,78	2,6	6	36,65	32,83	21,05	14,15	12,1	11,93	13,58	18,22	15,92
1988	3,82	2,64	5,74	37,95	33,63	20,5	14,2	12,33	12,15	14,12	19,26	16,02
1989	3,93	2,92	5,48	34,71	30,85	20,1	13,89	12,46	12,18	14,24	19,41	15,43
1990	3,3	2,5	5,25	34,14	30,62	19,81	13,34	12,2	11,91	13,36	18,48	14,89
1991	3,13	2,39	4,86	31,76	28,83	17,79	12,29	11,12	10,75	13,22	19,14	13,78
1992	2,99	2,41	4,75	28,37	25,96	16,54	11,71	10,62	10,53	13,27	18,81	12,89
1993	3,14	2,35	4,67	28,99	26,7	16,47	11,86	10,52	10,86	12,73	20,78	13,02
1994	3,46	2,35	5,07	30,46	26,27	16,07	11,79	11,15	10,71	13,99	20,71	13,18
1995	3,17	2,46	5,15	29,58	27,3	17,03	12,49	11,01	11,42	13,67	20,87	13,43
1996	3,4	2,34	5,07	29,43	27,31	16,78	12,6	11,14	11,58	14,2	20,84	13,46
1997	3,16	2,42	4,96	28,38	25,53	16,49	12,23	11,57	11,96	14,46	22,09	13,34
1998	3,03	2,6	4,6	27,61	25,06	15,81	12,6	11,44	11,53	14,31	21,28	13,09
1999	2,94	2,54	4,49	28,1	25,56	16,13	12,62	11,48	11,52	14,17	20,7	13,16
2000	2,82	2,38	4,27	27,76	25,29	15,55	12,81	11,51	11,38	12,88	19,51	12,88
2001	2,68	2,27	3,77	27,76	24,94	15,67	12,93	11,35	11,01	12,76	19,35	12,79
2002	2,44	2,13	4,07	28,84	25,88	15,75	13,03	11,85	11,1	12,61	18,81	12,99
2003	2,48	2,14	4,13	27,26	24,87	15,54	13,07	12,02	11,24	12,45	19,27	12,87
2004	2,57	2,28	4,25	26,69	24,94	15,82	12,48	12,07	11,05	12,3	18,16	12,74
2005	2,35	2,24	3,49	25,26	25,71	16,33	12,92	11,99	11,6	12,46	17,29	12,74
2006	2,32	1,85	3,31	24,59	26,07	16,37	12,68	11,8	10,95	11,31	15,73	12,39
2007	1,98	1,78	3,17	22,86	25,02	15,4	12,2	11,52	10,58	10,93	15,41	11,85
2008	1,5	1,44	2,42	18,71	21,56	14,28	11,03	10,54	9,82	10,02	14,16	10,56
2009	1,62	1,4	2,17	16,41	17,62	12,45	9,9	9,89	8,78	9,18	13,42	9,45
2010	1,48	1,26	1,95	13,92	17,6	11,84	9,45	9,15	8,88	8,95	14,01	9,02
2011	1,38	1,22	1,82	14	16,67	11,5	9,05	8,97	8,36	9,11	12,62	8,71
2012	1,54	1,17	1,7	13,26	16,94	12,18	9,54	9,27	8,86	9,11	12,16	8,92
2013	1,44	1,19	1,75	12,37	16,09	11,65	9,08	8,86	8,62	8,8	12,45	8,59
2014	1,24	1,23	1,7	12,46	15,9	11,53	8,69	8,99	8,39	8,22	12,15	8,44
2015	1,42	1,29	1,78	13,2	16,74	12,42	9,41	9,44	8,94	9,09	12,61	9,01
2016	1,53	1,41	1,87	13,35	17,54	13,18	10,02	9,52	9,34	9,3	13,23	9,4

Table A.2: Injury Rate per 100,000 Population

Year	Age Group (Years)											
	<5	5-9	10-15	16-20	21-24	25-34	35-44	45-54	55-64	65-74	>74	Total
1975	417	444	734	3.283	2.666	1.800	1.308	1.030	876	710	656	1.319
1976	370	469	727	3.210	2.467	1.672	1.280	985	801	713	618	1.251
1977	329	430	674	3.110	2.494	1.672	1.227	989	844	750	514	1.220
1978	384	470	709	2.921	2.317	1.574	1.144	977	801	727	521	1.162
1979	323	438	685	2.988	2.253	1.573	1.101	971	783	722	586	1.140
1980	367	471	657	2.885	2.307	1.606	1.195	956	821	707	592	1.155
1981	411	468	706	2.958	2.369	1.667	1.225	987	857	756	598	1.192
1982	418	483	742	3.193	2.456	1.722	1.291	1.132	926	755	624	1.257
1983	418	533	731	3.132	2.432	1.766	1.295	1.085	904	788	654	1.256
1984	400	461	684	2.981	2.401	1.689	1.257	1.012	815	761	641	1.196
1985	403	440	677	2.780	2.123	1.586	1.158	1.029	873	696	587	1.133
1986	383	477	662	2.828	2.169	1.596	1.135	1.028	801	759	610	1.136
1987	350	405	547	2.690	2.096	1.450	1.159	948	830	723	665	1.083
1988	311	372	510	2.451	2.032	1.392	1.094	931	754	666	578	1.018
1989	304	380	513	2.371	1.905	1.318	1.033	873	761	614	549	974
1990	302	375	468	2.255	1.853	1.336	1.022	873	728	604	523	953
1991	286	352	476	2.115	1.710	1.214	1.009	876	724	598	494	912
1992	265	322	472	1.962	1.720	1.225	951	830	680	538	467	873
1993	270	286	403	1.828	1.583	1.155	922	762	662	553	490	825
1994	266	288	354	1.713	1.523	1.135	841	751	625	550	433	786
1995	242	265	353	1.533	1.389	1.039	798	717	598	489	402	729
1996	220	260	322	1.342	1.378	965	735	695	566	503	397	685
1997	191	251	314	1.313	1.332	935	804	706	569	460	416	682
1998	229	242	299	1.251	1.255	957	785	689	583	456	384	671
1999	197	266	276	1.307	1.351	1.018	826	740	618	512	422	709
2000	228	264	283	1.248	1.342	974	777	716	624	503	437	692
2001	228	240	300	1.188	1.268	1.008	819	758	620	492	403	695
2002	235	280	305	1.337	1.382	1.024	846	741	642	531	404	722
2003	2,48	2,14	4,13	27,26	24,87	15,54	13,07	12,02	11,24	12,45	19,27	12,87
2004	2,57	2,28	4,25	26,69	24,94	15,82	12,48	12,07	11,05	12,3	18,16	12,74
2005	2,35	2,24	3,49	25,26	25,71	16,33	12,92	11,99	11,6	12,46	17,29	12,74
2006	2,32	1,85	3,31	24,59	26,07	16,37	12,68	11,8	10,95	11,31	15,73	12,39
2007	1,98	1,78	3,17	22,86	25,02	15,4	12,2	11,52	10,58	10,93	15,41	11,85
2008	1,5	1,44	2,42	18,71	21,56	14,28	11,03	10,54	9,82	10,02	14,16	10,56
2009	1,62	1,4	2,17	16,41	17,62	12,45	9,9	9,89	8,78	9,18	13,42	9,45
2010	1,48	1,26	1,95	13,92	17,6	11,84	9,45	9,15	8,88	8,95	14,01	9,02
2011	1,38	1,22	1,82	14	16,67	11,5	9,05	8,97	8,36	9,11	12,62	8,71
2012	1,54	1,17	1,7	13,26	16,94	12,18	9,54	9,27	8,86	9,11	12,16	8,92
2013	1,44	1,19	1,75	12,37	16,09	11,65	9,08	8,86	8,62	8,8	12,45	8,59
2014	1,24	1,23	1,7	12,46	15,9	11,53	8,69	8,99	8,39	8,22	12,15	8,44
2015	1,42	1,29	1,78	13,2	16,74	12,42	9,41	9,44	8,94	9,09	12,61	9,01
2016	1,53	1,41	1,87	13,35	17,54	13,18	10,02	9,52	9,34	9,3	13,23	9,4

Appendix B

Red Light Violation vs. Blockchain

Here are presented the results for the red light violation's (David Yang, et al. (2006)) hypothetical influenced scenarios by the Blockchain platform.
The B.1 is respective to the *Medium Influence Scenario* and so B.2 to the *Low Influence Scenario*.

Table B.1: Medium Influence Scenario

Age Group	No. of RLVs	% of RLVs	No. of LDs	% of LDs	% of RLVs/ % of LDs	Total MVMT	% of MVMT	% of RLVs/ % of MVMT
<or = 19	**1.334**	**4,83%**	883.858	4,09%	**1,18**	**77.624**	**4,09%**	**1,18**
20 to 29	**6.513**	**23,57%**	3.925.985	18,16%	**1,30**	**366.473**	**19,33%**	**1,22**
30 to 39	**5.669**	**20,52%**	4.997.068	23,11%	**0,89**	**467.145**	**24,64%**	**0,83**
40 to 49	**5.593**	**20,24%**	4.797.117	22,18%	**0,91**	**447.426**	**23,60%**	**0,86**
50 to 59	**4.305**	**15,58%**	3.401.805	15,73%	**0,99**	**269.654**	**14,22%**	**1,10**
60 to 69	**2.249**	**8,14%**	1.883.240	8,71%	**0,93**	**166.699**	**8,79%**	**0,93**
>or = 70	**1.966**	**7,11%**	1.734.720	8,02%	**0,89**	**101.161**	**5,33%**	**1,33**
Sub-Total	**27.629**	***	***	***	***	***	***	***
Missing Data	**7.952**	***	***	***	***	***	***	***
Total	**35.581**	**100,00%**	21.623.793	100,00%	***	**1.896.183**	**100,00%**	***

Table B.2: Low Influence Scenario

Age Group	No. of RLVs	% of RLVs	No. of LDs	% of LDs	% of RLVs/ % of LDs	Total MVMT	% of MVMT	% of RLVs/ % of MVMT
<or = 19	**1.501**	**4,50%**	883.858	4,09%	**1,10**	**80.397**	**4,03%**	**1,12**
20 to 29	**8.141**	**24,42%**	3.925.985	18,16%	**1,35**	**389.377**	**19,49%**	**1,25**
30 to 39	**7.558**	**22,67%**	4.997.068	23,11%	**0,98**	**503.080**	**25,19%**	**0,90**
40 to 49	**6.992**	**20,97%**	4.797.117	22,18%	**0,95**	**475.390**	**23,80%**	**0,88**
50 to 59	**4.843**	**14,53%**	3.401.805	15,73%	**0,92**	**279.285**	**13,98%**	**1,04**
60 to 69	**2.330**	**6,99%**	1.883.240	8,71%	**0,80**	**168.594**	**8,44%**	**0,83**
>or = 70	**1.972**	**5,92%**	1.734.720	8,02%	**0,74**	**101.273**	**5,07%**	**1,17**
Sub-Total	**33.337**	***	***	***	***	***	***	***
Missing Data	**7.952**	***	***	***	***	***	***	***
Total	**41.289**	**100,00%**	21.623.793	100,00%	***	**1.997.395**	**100,00%**	***

Appendix C

Driver Involvement Rates in Car Accidents

The presented database are the **Driver Involvement Rates per 100,000 Licensed Drivers by Age, Sex, and Crash Severity in 2015** and it is publicly available in (NHTSA). It was accessed on 05/05/2018.

Sources: NASS GES 2015; Licensed Drivers-Federal Highway Administration

Notes: Drivers include motorcycle riders. Some States include restricted driver licenses and graduated driver licenses in their licensed driver counts.

Table C.1: Drivers in Fatal Crashes

Age (Years)	Sex					
	Male		Female		**Total**	
	Drivers	Involvement Rate	Drivers	Involvement Rate	**Drivers**	**Involvement Rate**
<16	112	*	Rate	*	**Rate**	*
16-20	2.944	49,28	1.313	22,73	**4.258**	**36,24**
21-24	3.723	51,22	1.289	18,06	**5.015**	**34,81**
25-34	7.445	39,01	2.543	13,17	**9.993**	**26,03**
35-44	5.808	32,4	1.959	10,72	**7.768**	**21,46**
45-54	6.067	31	1.847	9,28	**7.914**	**20,05**
55-64	5.019	27,16	1.499	7,79	**6.525**	**17,3**
65-74	2.795	22,92	998	7,78	**3.794**	**15,16**
>74	1.878	26,36	884	11,12	**2.762**	**18,33**
Unknown	59	*	8	*	**978**	*
Total	35.850	33,3	12.381	11,21	**49.162**	**22,54**

Table C.2: Drivers in Injury Crashes

Age (Years)	Sex					
	Male		Female		**Total**	
	Drivers	Involvement Rate	Drivers	Involvement Rate	**Drivers**	**Involvement Rate**
<16	19.000	*	17.000	*	**36.000**	*
16-20	198.000	3.310	177.000	3.065	**375.000**	**3.189**
21-24	190.000	2.618	164.000	2.292	**354.000**	**2.457**
25-34	376.000	1.969	308.000	1.597	**684.000**	**1.782**
35-44	290.000	1.615	245.000	1.343	**535.000**	**1.478**
45-54	275.000	1.405	212.000	1.067	**487.000**	**1.234**
55-64	218.000	1.180	168.000	872	**386.000**	**1.023**
65-74	116.000	952	85.000	666	**202.000**	**806**
>74	65.000	913	47.000	587	**112.000**	**741**
Total	1.747.000	1.623	1.424.000	1.289	**3.171.000**	**1.454**

Table C.3: Drivers in Property-Damage-Only Crashes

Age (Years)	Sex					
	Male		Female		**Total**	
	Drivers	Involvement Rate	Drivers	Involvement Rate	**Drivers**	**Involvement Rate**
<16	57.000	*	41.000	*	**98.000**	*
16-20	555.000	9.297	447.000	7.735	**1.002.000**	**8.530**
21-24	504.000	6.931	398.000	5.577	**902.000**	**6.260**
25-34	988.000	5.175	753.000	3.903	**1.741.000**	**4.535**
35-44	776.000	4.330	578.000	3.163	**1.354.000**	**3.741**
45-54	709.000	3.625	489.000	2.458	**1.199.000**	**3.037**
55-64	573.000	3.103	400.000	2.081	**974.000**	**2.582**
65-74	295.000	2.419	205.000	1.597	**500.000**	**1.998**
>74	150.000	2.109	113.000	1.420	**263.000**	**1.746**
Total	4.608.000	4.280	3.425.000	3.101	**8.032.000**	**3.683**

Table C.4: Drivers in All Crashes

Age (Years)	Sex					
	Male		Female		**Total**	
	Drivers	Involvement Rate	Drivers	Involvement Rate	**Drivers**	**Involvement Rate**
<16	76.000	*	58.000	*	**134.000**	*
16-20	756.000	12.657	625.000	10.823	**1.381.000**	**11.755**
21-24	698.000	9.600	563.000	7.888	**1.261.000**	**8.752**
25-34	1.371.000	7.183	1.064.000	5.513	**2.435.000**	**6.344**
35-44	1.072.000	5.978	825.000	4.517	**1.897.000**	**5.240**
45-54	990.000	5.061	704.000	3.534	**1.694.000**	**4.291**
55-64	796.000	4.310	570.000	2.961	**1.366.000**	**3.622**
65-74	414.000	3.394	291.000	2.271	**705.000**	**2.818**
>74	217.000	3.049	160.000	2.018	**378.000**	**2.505**
Total	6.390.000	5.936	4.861.000	4.401	**11.252.000**	**5.159**

Appendix D

General Data Protection Regulation

The following information is publicy available on (European Commission) regarding the 2018 reform of EU data protection rules. It specifies what changes after May 2018, when the General Data Protection Regulation rules will be applied. It was accessed on 06/11/2018.

European Commission

A new era for data protection in the EU

What changes after May 2018

The Facebook/Cambridge Analytica revelations show the EU has made the right choice to propose and carry out an ambitious data protection reform through the General Data Protection Regulation (GDPR).

The General Data Protection Regulation rules will apply as of 25 May 2018. They will bring several improvements to deal with data protection violations in the future:

CLEAR LANGUAGE

TODAY	TOMORROW
Often businesses explain their privacy policies in lenghty and complicated terms	Privacy policies will have to be written in a **clear, straightforward language**

CONSENT FROM USER

TODAY	TOMORROW
Businesses sometimes assume that the user's silence means consent to data processing, or they hide a request for consent in long, legalistic, terms and conditions — that nobody reads	The user will need to give an **affirmative consent** before his/her data can be used by a business. Silence is no consent

MORE TRANSPARENCY

TODAY	TOMORROW
The user might not be informed when his/her data is transferred outside the EU	Businesses will need to **clearly inform** the user **about** such **transfers**
Sometimes businesses collect and process personal data for different purposes than for the reason initially announced without informing the user about it	Businesses will be able to collect and process data only for a **well-defined purpose**. They will have to inform the user about new purposes for processing
Businesses use algorithms to make decisions about the user based on his/her personal data (e.g. when applying for a loan); the user is often unaware about this	Businesses will have to **inform** the user **whether the decision is automated** and give him/her a possibility to contest it

STRONGER RIGHTS

TODAY	TOMORROW
Often businesses do not inform users when there is a data breach, for instance when the data is stolen	Businesses will have to **inform** users without delay in case of harmful data breach
Often the user cannot take his/her data from a business and move it to another competing service	The user will be able to **move** his/her **data**, for instance to another social media platform
It can be difficult for the user to get a copy of the data businesses keep about him/her	The user will have the right to **access** and get a copy of his/her data, a business has on him/her
It may be difficult for a user to have his/her data deleted	Users will have a clearly defined **“right to be forgotten”** (right to erasure), with clear safeguards

STRONGER ENFORCEMENT

TODAY	TOMORROW
Data protection authorities have limited means and powers to cooperate	The **European Data Protection Board** grouping all 28 data protection authorities, will have the powers to provide **guidance** and **interpretation** and adopt **binding decisions** in case several EU countries are concerned by the same case
Authorities have no or limited fines at their disposal in case a business violates the rules	The 28 data protection authorities will have harmonised powers and will be able to **impose fines** to businesses up to 20 million EUR or 4% of a company’s worldwide turnover

Visit the European Commission’s online guidance on data protection reform — available in all EU languages:
europa.eu/dataprotection

Bibliography

[Aidan Coleman 2017] AIDAN COLEMAN: How To Make Blockchain And IOT A Reality In Industry 4.0. (2017). – URL https://www.iotone.com/guide/how-to-make-blockchain-and-iot-a-reality-in-industry-4.0/g995

[Aigang] AIGANG: . – URL https://aigang.network/

[Ambrosus] AMBROSUS: . – URL https://ambrosus.com/#overview

[Andreas Antonopoulos 2017] ANDREAS ANTONOPOULOS: *Mastering Bitcoin: Programming The Open Blockchain*. 2nd. O'Reiley, 2017

[Anitta Patience, et al. 2016] ANITTA PATIENCE, ET AL.: Analytical Performance Evaluation of OpenStack IaaS Cloud Using M/M/1 and M/M/c Queues. (2016)

[Arcade City] ARCADE CITY: . – URL https://arcade.city/

[AT Kearney 2010] AT KEARNEY: Telematics: The Game Changer. (2010). – URL https://www.atkearney.com/documents/10192/548707/Telematics.pdf/19079b53-8042-43ea-b870-ef42b1f033a6

[Bailey Reutzel 2017] BAILEY REUTZEL: How Blockchain Tech Could Move Self-Driving Cars Into the Fast Lane. (2017). – URL https://www.coindesk.com/blockchain-move-self-driving-cars-fast-lane/

[Baseline Telematics] BASELINE TELEMATICS: Pay as You Drive. . – URL http://www.baselinetelematics.com/pt/solutions/pay-as-you-drive/

[Bernard Marr 2016] BERNARD MARR : What Everyone Must Know About Industry 4.0. In: *Forbes* (2016). – URL https://www.forbes.com/sites/bernardmarr/2016/06/20/what-everyone-must-know-about-industry-4-0/#3046da31795f

[BIOTS 2018] BIOTS: (2018). – URL http://biots.org/

[Blablacar] BLABLACAR: . – URL https://www.blablacar.com.br/

[BlueTorino] BLUETORINO: . – URL https://www.bluetorino.eu/

[Boston Consulting Group] BOSTON CONSULTING GROUP: Self-Driving Vehicles, Car Sharing, and the Urban Mobility Revolution. . – URL https://www.bcg.com/industries/automotive/self-driving-vehicles-car-sharing.aspx

[CareWallet] CAREWALLET: . – URL https://car-ewallet.zf.com/

[CarTaxi] CARTAXI: . – URL hhttps://cartaxi.io/

[CarVertical] CARVERTICAL: . – URL https://www.carvertical.com/

[Chris Ballinger, et al. 2016] CHRIS BALLINGER, ET AL.: Blockchain Mobility Consortium. (2016). – URL https://www.dlt.mobi/

[Chris Hammerschmidt 2017] CHRIS HAMMERSCHMIDT: Consensus in Blockchain Systems. In Short. (2017). – URL https://medium.com/@chrshmmmr/consensus-in-blockchain-systems-in-short-691fc7d1fefe

[Christoph Mussenbrock, et al.] CHRISTOPH MUSSENBROCK, ET AL.: Etherisc. . – URL https://etherisc.com/hero

[Christopher Clack, et al. 2016] CHRISTOPHER CLACK, ET AL.: Smart Contract Templates: foundations, design landscape and research directions. (2016)

[Coalition Against Insurance Fraud 2016] COALITION AGAINST INSURANCE FRAUD: How big is $80 billion? (2016). – URL http://www.insurancefraud.org/80-billion.htm

[CoinBR 2016] COINBR: Guia básico sobre ETHEREUM. (2016)

[Corporate News 2017] CORPORATE NEWS: Toyota Research Institute Explores Blockchain Technology for Development of New Mobility Ecosystem. (2017). – URL http://corporatenews.pressroom.toyota.com/releases/toyota+research+institute+explores+blockchain+technology.htm

[Cryptofinancas 2017] CRYPTOFINANCAS: O que são Tokens e para que servem? O que é uma ICO? Como as Altcoins são lançadas no mercado? O que são criptomoedas e para que servem? (2017). – URL https://steemit.com/bitcoin/@cryptofinancas/o-que-sao-tokens-e-para-que-servem-o-que-e-uma-ico-como-as-\altcoins-sao-lancadas-no-mercado-o-que-sao-criptomoedas-e\-para-que

[Darenta] DARENTA: . – URL https://darenta.ru/en/

[Dash] DASH: . – URL https://www.dash.org/

[David Edwards, et al. 2016] DAVID EDWARDS, ET AL.: ChainThat Blockchain Innovation Platform. (2016). – URL https://www.youtube.com/channel/UCanQY4BfDIgcFzjQF7_Cuyg/videos

[David Harding 2015] DAVID HARDING: Blockchain pruning problems and solutions. In: *https://dtrt.org/posts/blockchain-pruning-problems-and-solutions/* (2015)

[David Muller] DAVID MULLER: Hyundai Offers Potential Insurance Break for

Drivers Who Share Data. . – URL https://www.caranddriver.com/news/hyundai-offers-potential-insurance-break-for-drivers-who-share-data

[David Yang, et al. 2006] DAVID YANG, ET AL.: Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras. In: *Department of Transportation National Highway Traffic Safety Administration* (2006)

[Deloitte(a) 2018] DELOITTE(A): Accelerating Technology disruption in the automotive market. (2018)

[Deloitte(b) 2018] DELOITTE(B): When two chains combine - Supply chain meets Blockchain. (2018)

[Deloitte(c) 2017] DELOITTE(C): Deloitte Smart ID Platform. (2017). – URL http://www.deloitte.co.uk/smartID/

[Don Tapscott 2016] DON TAPSCOTT: How blockchains could change the world. In: *McKinsey Interview* (2016). – URL https://www.mckinsey.com/industries/high-tech/our-insights/how-blockchains-could-change-the-world

[Enjoy] ENJOY: . – URL https://enjoy.eni.com/it

[Ethereum] ETHEREUM: . – URL https://www.ethereum.org/

[Ethereum 2014] ETHEREUM: Ethereum/dapp-bin: A place for all the ÐApps to live. (2014). – URL https://github.com/ethereum/dapp-bin

[Etherisc] ETHERISC: Flight Dapp Demo. . – URL https://fdd-demo.etherisc.com/

[Etherisc 2016] ETHERISC: Etherisc White Paper. (2016)

[Etherisc 2017] ETHERISC: Building a Sample Car Insurance App on Blockchain in 30 Minutes. (2017). – URL https://blog.etherisc.com/building-a-sample-car-insurance-app-on-blockchain-in-30-minutes\-92d818318b86

[European Commission 2018] EUROPEAN COMMISSION: New era for data protection in the EU: what changes after May 2018. In: *2018 reform of EU data protection rules* (2018). – URL https://ec.europa.eu/commission/priorities/justice-and-fundamental-rights/data-protection/2018-reform-eu-data-protection-rules_en

[Eusiry 2014] EUSIRY: Sara Assicurazioni: competitive vehicle insurance pricing using satellite navigation. (2014). – URL https://www.eurisy.org/good-practice-sara-assicurazioni-competitive-vehicle-insurance\-pricing-using-satellite-navigation_66

[EY 2016] EY: Introducing Pay As You Drive (PHYD) Insurance. (2016)

[Filecoin] FILECOIN: . – URL https://filecoin.io/

[FuturICT 2.0 2017] FUTURICT 2.0: (2017). – URL https://futurict2.eu/

[Gartner 2017] GARTNER: Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016. (2017). – URL https://www.gartner.com/newsroom/id/3598917

[Hyperledger 2017] HYPERLEDGER: Deloitte. (2017). – URL https://www.hyperledger.org/resources/vendor-directory

[IBM 2018] IBM: Integrate Watson IoT Platform with blockchain. (2018). – URL https://www.ibm.com/internet-of-things/spotlight/blockchain

[IMS(a)] IMS(A): Company | About Us. In: *Intelligent Mechatronic Systems*. – URL https://www.intellimec.com/about-ims

[IMS(b)] IMS(B): Comparing Mobile Apps Hybrid Bluetooth and OBD2. In: *Intelligent Mechatronic Systems*

[IMS(c)] IMS(C): The Future Trends of Usage Based Insurance and Telematics. In: *Intelligent Mechatronic Systems*. – URL https://www.intellimec.com/insights/usage-based-insurance-trends

[IMS(d)] IMS(D): Usage Based Insurance and Vehicle Telematics Study. In: *Intelligent Mechatronic Systems*

[Insurance Information Institute 2014] INSURANCE INFORMATION INSTITUTE: Background on: Pay-as-you drive auto insurance (telematics). (2014). – URL https://www.iii.org/article/background-on-pay-as-you-drive-auto-insurance-telematics#top

[InsurePal] INSUREPAL: . – URL https://insurepal.io/

[IPFS] IPFS: . – URL https://ipfs.io/

[Jack Shaw 2017] JACK SHAW: The Blockchain Transformation of Automotive Manufacturing, Jack Shaw, American Blockchain Council. (2017). – URL https://www.youtube.com/watch?v=r-loHmr-Xys

[Joe McKendrick 2016] JOE MCKENDRICK: Blockchain and Smart Contracts: A Pilot in the Car-Leasing Business. (2016). – URL https://www.rtinsights.com/blockchain-pilot-smart-contracts-docusign-visa/

[Jon Tindall 2012] JON TINDALL: Developing Insurance Telematics. In: *Finity Insurance Telematics* (2012). – URL https://www.finity.com.au/

[Jonathan Rohr, et al. 2017] JONATHAN ROHR, ET AL.: Blockchain-Based Token Sales, Initial Coin Offerings, and the Democratization of Public Capital Markets. In: *University of Tennessee College of Law* (2017)

[Josiah Wilmoth] JOSIAH WILMOTH: ICO 101: Utility Tokens vs. Security Tokens. . – URL https://strategiccoin.com/ico-101-utility-tokens-vs-security-tokens/

[Kasko2Go] KASKO2GO: . – URL https://kasko2go.com/

[Khwaja Shaik 2018] KHWAJA SHAIK: Why blockchain and IoT are best friends. (2018). – URL https://www.ibm.com/blogs/blockchain/2018/01/why-blockchain-and-iot-are-best-friends

[Kylie Jane Wakefield 2015] KYLIE JANE WAKEFIELD: Driving behavior data can determine personalized insurance policy rates and terms. In: *IBM Big Data & Analytics Hubs* (2015). – URL http://www.ibmbigdatahub.com/blog/driving-behavior-data-can-determine-personalized-insurance-policy\-rates-and-terms

[Lazooz] LAZOOZ: . – URL http://lazooz.org/

[Leon Di 2017] LEON DI: Why Do I Need a Public and Private Key on the Blockchain? (2017). – URL https://blog.wetrust.io/why-do-i-need-a-public-and-private-key-on-the-blockchain-c2ea74\a69e76

[Lou Frenzel 2013] LOU FRENZEL: Telematics Connect Your Car To The World. (2013). – URL http://www.electronicdesign.com/communications/telematics-connect-your-car-world

[Lukas Kairys 2017] LUKAS KAIRYS: What is Blockchain and Smart Contracts? Brief introduction. (2017). – URL https://medium.com/startup-grind/gentle-intro-to-blockchain-and-smart-contracts-part-1-3328afca62ab

[Marco Iansiti, et al. 2017] MARCO IANSITI, ET AL.: The Truth About Blockchain. In: *Harvard Business Review, Article Technology* (2017)

[Mark Harmon 2014] MARK HARMON: Likelihood Ratio Is Better Than Wald Statistic To Determine if the Variable Coefficients Are Significant For Excel 2010 and Excel 2013. (2014). – URL http://blog.excelmasterseries.com/2014/06/likelihood-ratio-is-better-than-wald.html

[Mary McHugh 2009] MARY MCHUGH: The odds ratio: calculation, usage, and interpretation. In: *Biochemia Medica* (2009)

[Masterthecrypto] MASTERTHECRYPTO: Coins, Tokens and Altcoins: What's the Difference? . – URL https://masterthecrypto.com/differences-between-cryptocurrency-coins-and-tokens/

[Messe Leipzig] MESSE LEIPZIG: Technologies of industry 4.0. In: *HST Systemtechnik GmbH and Co. KG.* – URL https://www.hst.de/e/topics/topic/news/detail/News/important-terms-for-the-digital-transformation-of-the-water\-industry.html

[NAIC 2018] NAIC: Usage-Based Insurance and Telematic. (2018). – URL http://www.naic.org/cipr_topics/topic_usage_based_insurance.htm

[NCDOT 2017] NCDOT: Pedestrian Crashes. (2017). – URL https://catalog.data.gov/dataset/pedestrian-crashes

[News BTC 2016] NEWS BTC: Uservice Is a Global Decentralized Blockchain Platform for the Auto Industry. (2016). – URL https://www.newsbtc.com/press-releases/uservice-global-decentralized-blockchain-platform-auto-industry/

[NHTSA 2016] NHTSA: Traffic Safety Facts Annual Report Tables: Motor Vehicle Occupant and Motorcyclist Fatality and Injury Rates per Population by Age Group, 1975-2016. (2016). – URL https://cdan.nhtsa.gov/tsftables/tsfar.htm

[Nicholas Confessore 2018] NICHOLAS CONFESSORE: Cambridge Analytica and Facebook: The Scandal and the Fallout So Far. (2018). – URL https://www.nytimes.com/2018/04/04/us/politics/cambridge-analytica-scandal-fallout.html

[Oxford Dictionaries] OXFORD DICTIONARIES: Definition of telematics in English. In: *Oxford Dictionaries*. – URL https://en.oxforddictionaries.com/definition/telematics

[Salil Aggarwal, et al. 2018] SALIL AGGARWAL, ET AL.: From buzz to buzz: Automotive Players on the Highway to car data monetization. In: *McKinsey Center for Future Mobility* (2018)

[Sandro Sperandei 2013] SANDRO SPERANDEI: Lessons in biostatistics - Understanding logistic regression analysis. In: *Biochemia Medica* (2013). – URL http://www.biochemia-medica.com/taxonomy/term/1206

[Sean Dennis, et al.] SEAN DENNIS, ET AL.: Loyyal. . – URL https://loyyal.com/

[ShareandCharge] SHAREANDCHARGE: . – URL https://shareandcharge.com/

[Shetty Rakesh 2017] SHETTY RAKESH: IoT Lowers Costs, Improves Risk Assessment For Auto Insurance Industry. (2017). – URL http://www.digitalistmag.com/iot/2017/07/19/iot-lowers-costs-improves-risk-assessment-for-auto-insurance\-industry-05221322

[State of Dapps] STATE OF DAPPS: . – URL https://www.stateofthedapps.com/

[Steven Buchko 2017] STEVEN BUCHKO: How Long do Bitcoin Transactions Take? (2017). – URL https://coincentral.com/how-long-do-bitcoin-transfers-take/

[Stewart Rogers 2018] STEWART ROGERS: Kasko2Go uses military-grade tech to drive its blockchain-based car insurance. (2018). – URL https://venturebeat.com/2018/03/02/kasko2go-uses-military-grade-tech-to-drive-its-blockchain-based\-car-insurance/

[STORJ] STORJ: . – URL https://storj.io/

[Stuart Haber, et al. 1991] STUART HABER, ET AL.: How to time-stamp a digital document. In: *Journal of Cryptology* (1991)

[Towers Watson 2013] TOWERS WATSON: Usage-Based Insurance: Consumer Survey Understanding What Customers Want. In: *Insights* (2013). – URL http://www.towerswatson.com/DownloadMedia.aspx?media={7B1AF5A1-3E67-4458-9FC6-9FAD4615A49A}

[Trevor Mogg 2018] TREVOR MOGG: Tesla's biggest recall to date will fix 123,000 early Model S cars. (2018). – URL https://www.digitaltrends.com/cars/tesla-recall-123000-model-s-cars/

[Uber] UBER: . – URL https://www.uber.com/it/

[Unibright 2017] UNIBRIGHT: Blockchain evolution: from 1.0 to 4.0. (2017). – URL https://medium.com/@UnibrightIO/blockchain-evolution-from-1-0-to-4-0-3fbdbccfc666

[Useservice] USESERVICE: . – URL https://usrv.io/pt/

[Validity Lab 2017] VALIDITY LAB: EthCarInsurance. (2017). – URL https://github.com/validitylabs/ethCarInsurance

[Wikipedia 2016] WIKIPEDIA: The DAO (organization). (2016). – URL https://en.wikipedia.org/wiki/The_DAO_(organization)

[Wikipedia 2018] WIKIPEDIA: Usage-based insurance. (2018). – URL https://en.wikipedia.org/wiki/Usage-based_insurance

[William Haenszel, et al. 1959] WILLIAM HAENSZEL, ET AL.: Statistical aspects of the analysis of data from retrospective studies of disease. In: *J. Natl Cancer Inst. [PubMed]* (1959)

[Zdechovský 2017] ZDECHOVSKÝ, Tomáš: Odometer fraud resonates across the whole European Union. (2017). – URL https://www.euractiv.com/section/road-safety/opinion/odometer-fraud-resonates-across-the-whole-european-union/