POLITECNICO DI TORINO

Department of Management and Production Engineering

Master of Science in Engineering and Management

Master Dissertation Topic

Benefit and Cost Analysis of Blockchain Technology in the Supply Chain and Monitoring in the Automotive Industry

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Abstract

Blockchain technology is an easily accessible distributed data management system in which blocks linked in a chain that keep tamper-proof transaction records. Unlike other databases, it includes different technological systems such as peer to peer network, distributed ledger, cryptography, consensus mechanism and smart contract. While blockchain brings visibility, security, trust environment and transparency to the supply chain of companies to ensure sustainability, on the other hand, blockchain innovations come together with emergent technologies to provide scalable data management, decentralized networking, automation, predictive performance, real-time traceability that significantly affect productivity and profitability.

While this study addresses about the shortcomings of the existing supply chain and improvements coming from blockchain technology to the supply chain, it also focuses on the structure of blockchain technology, how it works, where it is used and future predictions of it. The importance of the collaboration among artificial intelligence, internet of things and blockchain technologies for a fully automated and flawless supply chain are indicated. Additionally, the study discusses the use cases of blockchain technology in the automotive industry to enlighten the companies by giving information about relationship between the automotive supply chain and blockchain technology, and it mentions that how it is used by the companies in the industry to understand market situations. The main purpose of this dissertation is to determine the general financial parameters of the investment to be made by the automotive companies that want to adapt blockchain technology to their supply chain and to make a benefit-cost calculation. Firms in the different sectors can customize the given parameters according to the use case of blockchain technology and utilize some of them as the basis for their calculation. In addition, the study gives advice to companies for project management of the investment and shows how the blockchain will affect the automotive industry strategically.

Keywords: *Blockchain, Artificial Intelligence, Internet of Things, Supply Chain, Automotive Industry, Financial Analysis, Strategy, Project Management*

Preface

Dissertation is presented at Politecnico di Torino to conclude the Engineering and Management Master of Science course. The course was held between 2018 and 2021 academic years and the final presentation was carried out in April 2021. This study was completely executed by Cagatay Kargacier (s258972) and supported by Professor Guido Perboli from Department of Management and Production Engineering (DIGEP) and Professor Stefano Musso from Department of Automation and Computer Science (DAUIN) whose proposal was to develop a research study and analysis about blockchain technology for the automotive supply chain. We together targeted that in the light of the benefit and cost calculations and economic analysis shown at the end of the thesis, how to evaluate the financial analysis of the investment to be made to establish a blockchain-based automotive supply chain.

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1. Introduction

Although the importance of the concept of supply chain varies from sector to sector or from business to business, it has the power to significantly affect companies' flexible resource usage, production and storage costs, time to market, profitability and customer satisfaction. Because, basically, the supply chain includes the transportation activities from the procurement of raw material or part to be used in a production process to reaching of end consumer taking final product, by utilizing of resource flow such as people, materials, information and money. Especially in the automotive supply chain, there are many business processes that need to be transparent, many different stakeholders who want to establish an atmosphere of trust, and a significant amount of parts and document flow that will affect efficiency. Supply chains have turned into a multi-dimensional and complex structure in the automotive industry, whose technology infrastructure is gradually developed and the distribution network is increasingly global.

Efficient logistics activities, real-time communication between stakeholders in the supply chain and smoothly money and information flow are golden keys for effective management of supply chain, reducing costs and providing better service. However, achieving superior performance is not always as simple as it seems. That's why, businesses are trying to provide a more controllable and smarter flow of data and parts by adapting disruptive technologies such as Internet of Things and Artificial Intelligence to their supply chains. The countless amount of data produced and operated by these technologies becomes a difficult burden for companies in terms of safekeeping, storage and handling. However, obstacles in data management and transparency are solved by providing a safer and faster system with the decentralized structure of blockchain technology and smart contract system. Blockchain technology with industry 4.0 technologies also forms the basis of the technological infrastructure of companies that want to transform all procurement processes into automation in the future. Firms have begun to explore blockchain technology to achieve their major goals bringing efficiency and traceability in their supply chains and to provide a more sustainable and auditable system.

2. Research Objective and Research Questions

The main rationale of the dissertation is to examine the supply chain use cases of blockchain technology, to observe up-to-date analysis, to discuss its effects on the automotive industry and the automotive supply chain, and finally to prepare a financial assessment of the integration of blockchain technology into automotive the supply chain.

STRUCTURE OF THE RESEARCH

Chapter 1: "Introduction"

Chapter 2: "Research Objective and Research Questions"

Chapter 3: "Supply Chain Management"

An overview of the supply chain, solutions brought by industry 4.0 applications to supply chain processes, important problems and causes of problems in the existing supply chain, suggestions on how to solve the problems.

Chapter 4: "Blockchain"

An overview of blockchain (definition, history, features), Blockchain structure types and comparison between them (public, private, consortium, hybrid), General network types (centralized, decentralized, distributed), Examination of blockchain working system and terms (block, hash , node), Introduction of the main blockchain platforms and their features (Bitcoin, Ethereum, Hyperledger, Corda, Quorum, Ripple), A summary of blockchain use cases in different sectors, The effects of blockchain technology on the supply chain and its uses in the supply chain and a review of the benefits and challenges of blockchain, Exploring and interpreting the future expectations of the blockchain technology, Explaining the blockchain as a service logic and the contributions of IBM to blockchain technology and examining the Tradelens blockchain supply chain solution.

Chapter 5: "Interrelation of Industry 4.0 and Blockchain"

Introduction of Industry 4.0, mutual benefits and sample analyzes of blockchain technology and Industry 4.0, the introduction and lacks of Internet of Things technology, detailed examination of the benefits of blockchain technology to the Internet of things technology,

the definition of artificial intelligence and its mutual relationship with blockchain technology and analysis of the benefits they offer.

Chapter 6: "Blockchain in Automotive Industry"

General evaluation of blockchain technology in the automotive sector, Detailed examination of the use cases of blockchain technology in the automotive sector (Mobility Services, Insurance, Data Security, Digital Passport, Recalls, Transfer of Ownership, Digital Wallet, Supply Chain Management, Digital Twin), Blockchain studies of giant automotive companies so far (MOBI, Renault Group, Mercedes Benz, Toyota, Hyundai, BMW Group, Ford, Tesla, General Motors, Daimler, Lamborghini, Volkswagen, Porsche), Examination of the existing automotive supply chain and duty descriptions of stakeholders, Blockchain-based automotive supply chain design and interpretation of it , Summarizing all the benefits of blockchain technology brings to the automotive supply chain.

Chapter 7: "Economic Analysis of Creation of Blockchain-Based Automotive Supply Chain"

Trying to understand the supply flow data in the automotive sector numerically and summarizing some sample data, Creating blockchain technology under 4 main headings in terms of usability in the automotive supply chain, Examining the economic parameters and calculations from the Forrester Case Study, A development of new financial calculation strategy by taking into account different studies and data, Creating an example case for an automotive firm integrating blockchain-driven supply chain, Ways to find a budget for blockchain investment, Performing project management calculations for example blockchain investment, Strategic assessment for the blockchain project in the automotive industry.

Chapter 8: "Conclusion"

RESEARCH QUESTIONS

Despite the increasing interest and research in Industry 4.0 technologies, most of the businesses have not fully achieved their strategies to use emergent technologies together. However, companies have to endure some important technological investments in order to achieve full automation in the future and in present must build their infrastructures in line with technologies. In particular, blockchain technology plays a key role by ensuring sustainability and security in the technological association to be established. Therefore, this dissertation primarily seeks to understand the use cases of blockchain technology and its relationship with other technologies. Particularly, the gains of blockchain technology, which is increasingly popular in the automotive industry, on the supply chain have been tried to be explained.

This dissertation will be guided by the following research questions;

- What is the supply chain and what are its shortcomings?
- What is blockchain technology, how does it work, where is it used and what is its future position?
- What is the technological relationship between blockchain technology, artificial intelligence and Internet of things, and how do they affect each other?
- How does blockchain technology affect the automotive industry, how does it shape the automotive supply chain and what are the current use cases of blockchain by giant automotive companies?
- What is the supply flow in the automotive industry and how does blockchain technology affect it?
- What are the benefits and costs of adapting blockchain technology to the automotive supply chain, how can the investment be calculated financially?
- How to find a budget to do blockchain investment?
- How to do project management of blockchain investment?
- What is the strategic return of the blockchain project in the automotive industry?

3. Supply Chain Management

3.1 Overview

Supply Chain is a complex logistic system where raw materials are transformed into products or services and delivered to end users. The supply chain is a system that includes suppliers, logistics service providers, manufacturers, distributors and retailers, and provides material, information and financial flow between them. (1)

Activities carried out in the supply chain; Raw Material and Component Supply, Assembly and Production, Storage and Stock Control, Management of Orders, Distribution, Customer Delivery, Information Systems etc.

Supply Chain Management refers to the coordinated flow of goods, services and information from the point of origin to the final destination and includes the planning and management of all operations, containing sourcing, purchasing, processing and logistics management. Most importantly, it consists of coordination and cooperation activities between channel partners such as suppliers, intermediaries, third-party service providers and customers. (2)

Activities carried out in the supply chain management; Supplier Relationship Management, Demand Management, Manufacturing Flow Management, Product Development and Commercialization, The Order Fulfillment, Customer Relationship Management, Customer Service Management, Returns Management etc. (3)

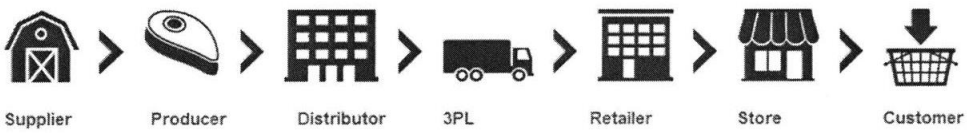


Figure 1 : Stakeholders in the Supply Chain (4)

We try to keep up an unprecedented era of global trade, where technology is constantly evolving and customer expectations are rising. Today's best supply chain strategies require a demand-driven operating model that successfully brings together people, processes and technology to deliver goods and services at an extraordinary pace. (5) One of the biggest

challenges faced by businesses today is the need to respond quickly to rapidly increasing demand levels. Supply chain agility and flexibility, which have the ability of supply chain companies to adapt quickly to fluctuations in the business environment and increase the competitiveness of companies, can be more easily achieved by digitizing the supply chain. Businesses that can effectively run their supply chains to implement to today's ever-changing and developing technology-oriented business environment will survive and be successful.

3.2 Digitalization of Supply Chain with Industry 4.0

It is important to transfer all possible processes to the digital platform, from the internal processes to the process of demand management and order documents sent to the suppliers. The use of digital transformation and smart systems will make the supply chain faster, more transparent and more automated at every stage. In this way, businesses are enabled to gain competitive advantage by using their resources more efficiently.

Industry 4.0 has been defined as “a name for the current trend of automation and data exchange in manufacturing technologies, including cyber-physical systems, the Internet of things, cloud computing and cognitive computing and creating the smart factory”. (6)

Integration of Industry 4.0 continues to affect industries around the world, the supply chain sector included. Emergent trends brings never-seen-before innovative technologies that can completely modify relationship between parties on the operations of a supply chain network or logistic process. (7)

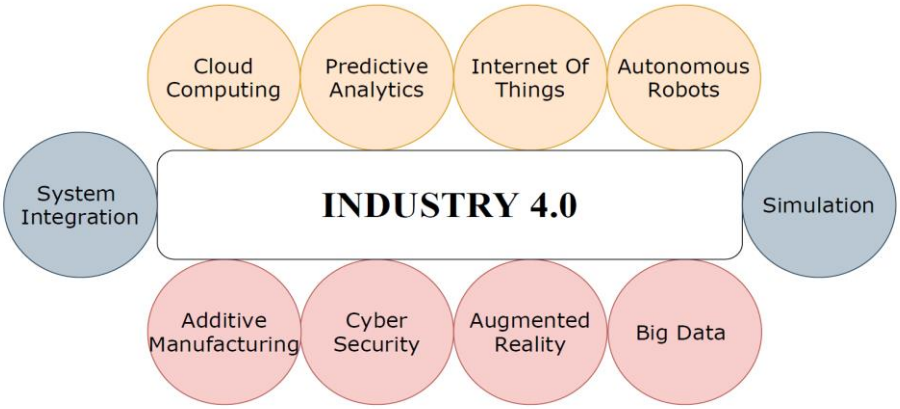


Figure 2 : Technology Elements in Industry 4.0

Basically, Industry 4.0, which aims to improve production and engineering processes, increase the quality of products and services, optimize the relationship between customers and organizations, brings new business opportunities and provide economic benefits, has started to affect many areas. The adoption of the Industry 4.0 paradigm and the implementation of cyber-physical systems will increase the overall productivity, flexibility and agility of possible improvements by digitizing the activities in the supply chains. (8)

3.3 Shortages in Existing Supply Chain

Traditional strategies and methods of supply chain management whose aim is to increase revenues and reduce costs according to the information coming from customers, suppliers, products and services have become inadequate in our globalizing and rapidly changing world. This situation has brought some problems in supply chain management.

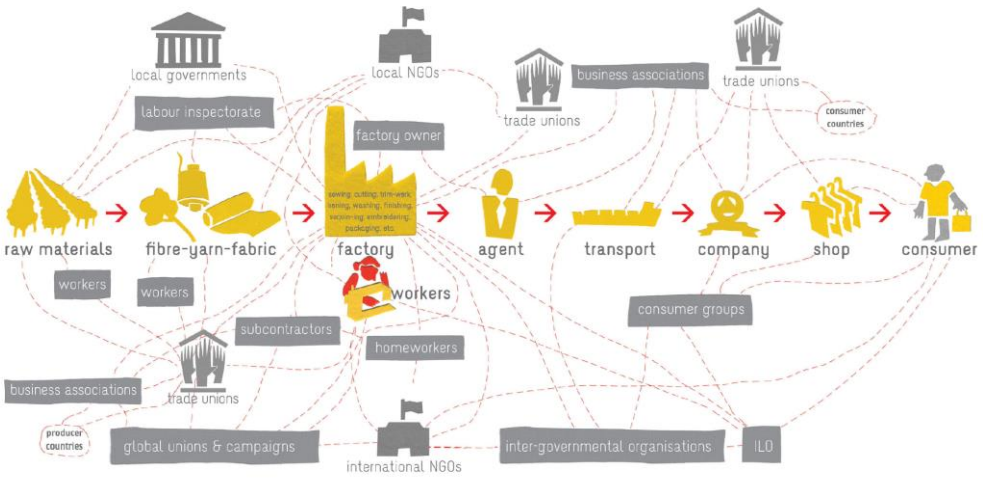


Figure 3 : Actors in the Supply Chain Network (9)

First of all, with globalization and technology, supply and logistics operations have become very complex. One of the important reasons is that supply chain includes different type of parties such as suppliers, legal institutions, producers, insurers, custom authorities, 3PLs, buyers, etc. That's why, there is always intensive document transaction among parties. These documents are numerous and diverse in types (payments, invoices, customs documents, etc.), sometimes more than one state border, different customs and the different legal structures. These complex structure make today's supply chain multi-dimensional, multi-agency and multi-document. Before facing a significant financial loss, in order to

prevent negative result or at least prioritize possible risk, managers have to consider to create a mitigation action plans.

Tracing every transaction and document is time consuming and costly. However if this process is skipped, there will be always a risk that important documents will be lost or face the fraud. Furthermore, it will be more difficult to control the documentation process as many parties will participate in the chain when conducting international trade.

One of the most common problems in traditional supply chains is the lack of transparency. Transparency will become even more risky, especially if the communication between the parties is not established properly. The trust problem and its negative effects on the trade flow have always hurt the players in the chain and lost time. In particular, transparency has become a more crucial concept in the food industry, which includes factors affecting human health. Every step of the processes taking place in the food supply chain must be monitored with real-time data. However, the traditional supply chain system does not allow to take advantage of this opportunity. In addition, it is extremely difficult to investigate whether there are any illegal or unethical practices in the system.

Firms have to take advantage of different strategies to ensure continuity, flexibility, operational efficiency and profitability. Strategic models such as lean manufacturing and real-time inventory flow, optimizing product life cycle and time to market have made the supply chain more optimized but more complex. (10) Firms have to react accurately and quickly to changing demands and requests in order to always achieve customer satisfaction. However, as it is not possible to establish a sustainable system in supply chains with poor traceability, loss of sales is likely to occur. Especially the large number of stakeholders at different levels are an important risk factor for delays.

4. Blockchain

4.1 Overview

Blockchain can be briefly defined as a distributed database that provides encrypted and permanent transaction. The system is managed by servers that are connected a peer-to-peer network (P2P). (11) Blockchain technology, built with a chained model, that can be tracked but not broken, allows transactions without being connected to a center. Thus, transactions can be carried out directly between the buyer and the seller securely.

History

The history of blockchain technology is based on the recent past. Even though some researches have been done until today, they have not yet reached their main goals.

The foundation of blockchain technology was laid in the early 1990s with the research of cryptography experts Stuart Haber and Scott Stornetta. Although their work was insufficient at some points, they managed to approach the blockchain definition somewhat. These two experts were inspired by the concept of 'hash tree' created by Ralph Merkle in the 1970s. (12)

In October 2008, Bitcoin, the first cryptocurrency, was introduced by an anonymous person named Satoshi Nakamoto with the white paper “Bitcoin: Peer-to-Peer Electronic Cash System”. In Nakamoto's article, the concept of blockchain was born due to the methods and various schemes applied. Blockchain logic has developed rapidly and has achieved to turn into a basic technological concept that is accepted globally. In this study, it is stated that the Bitcoin infrastructure is completely based on blockchain technology that basically a new order that will affect the existing system is mentioned. According to the logic of the study, a secure recording system that cannot be destroyed unless using a centralized structure will be established in the future. (13)

Main Features

Immutability and Distributed Ledger

There is no central authority or a single person to manage the network. All players has copy of the digital ledger to prove transparent structure. Anyone can be a node or a hub, anyone can participate in record keeping. If someone wants to corrupt the network, he has to modify all of data stored on every node in the network. Since millions of people has copy of data, it will be impossible to corrupt it. (14) Users in the network can validate or reject a data based on consensus rules. As there are many nodes to operate the transaction, the system run faster.

Secure System

The hash codes in the blocks are determined after sophisticated mathematical operations, therefore, blockchain has a very complex structure and it is impossible to change. Once the information is verified and added to the blockchain, it is stored forever. Because records are kept in multiple locations, information is not lost if a single network is damaged or cyber attacked. Also, data modification made by a single user is considered invalid in case of conflict with records on another network. (14) The system ensure high level of security depending on the high degree of mathematical encryption.

Transparency

Each member authorized to access can transparently follow and view the life cycle of the data, transaction and all historical footprints. The private information of the parties is encrypted, taking into account personal privacy. (15)

Peer to Peer Network

Each participant on the network has its own synchronized copy. Thus, the participants can view and confirm the transactions taking place on the network. This situation eliminates the central authority on the network and connects the participants directly, thus transactions are done between 2 parties without intermediary. (16)

Cryptography

Cryptography refers to the encryption of data. Random dataset that has a rule structure can only be recycled back to its original and meaningful form by those who have the key used when encrypting. (17)

Smart Contracts

Nick Szabo introduced smart contracts in 1994 as a terms of contract is executed by a computerized transaction protocol. (18) Smart contracts cause a predetermined snippet of code to act with specific data. There is no need for intermediaries during this process. It encrypts the whole process in a transparent way, as well as preventing unwanted external interference. (19)

Distributed Ledger Technology

DLT is a technology that allows us to distribute data, and blockchain is the first functional variant of DLT. DLTs are specific database types where data, computers or participants are recorded, shared and synchronized in a distributed network. Distributed ledgers allow transactions to have public witnesses, making any cyber-attack even more difficult. (20) Distributed ledgers use nodes to record transactions and then copy this information across the network. Blockchain brings these data together in blocks and chains them to each other.

Consensus

Anyone can send transactions to the blockchain, so all transactions need to be constantly checked and audited by nodes. Taking the place of central authority, consensus algorithms are applied to let a group of people decide that all transactions are verified and authentic. (21) The consensus mechanism is the protocols that ensure the nodes are sure of which transaction is valid and which one will be added to the blockchain. The most popular consensus mechanisms are Proof of Work and Proof of Stake. (22)

4.2 Blockchain Structure Types

Property	Public blockchain	Consortium blockchain	Private blockchain
Consensus determination	All miners	Selected set of nodes	One organization
Read permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Centralized	No	Partial	Yes
Consensus process	Permissionless	Permissioned	Permissioned

Table 1 : Types of Blockchain System (23)

Public Blockchain

Every transaction can be created, validated and observed by all users on the network as it is a fully decentralized, permissionless, and open-source system. All nodes are given the same transmission power. Although all of the transactions are visible, users can use an anonymous profile and hide their real identities if they wish. Most significant public blockchain types are Bitcoin and Ethereum. Decision making systems work through a consensus algorithm such as Proof of Work (PoW) or Proof of Stake (PoS). (23)

Private Blockchain

Transactions are controlled by an individual or a single organization. The owner of the network decides who can view or validate the data and who has the right to edit. Private blockchain networks are better applied to internal systems in a private company that don't need to open the external access, such as database management and auditing. (24) Well known private blockchain network are Bankchain, Monax and Hyperledger.

Consortium Blockchain

It operates under the leadership of a group instead of a single entity. There are multiple central custodians for reading, writing and controlling the blockchain. Consensus can be reached by voting or by a special algorithm. In this type of network, the authorities can make the transactions open to everyone, or they can give access to designated participants. (25) These types of blockchain networks can be used to track transactions by the accounting team or financial institution.

Hybrid Blockchain

This system benefits from both public and private blockchain structure. While the public blockchain provides transparency and better management to the system, the private blockchain provides a more secure and closed structure to the system. (26) This system supply to enterprise significant flexibility to choose what data should be transparent and what data should be private.

4.3 General Network Types

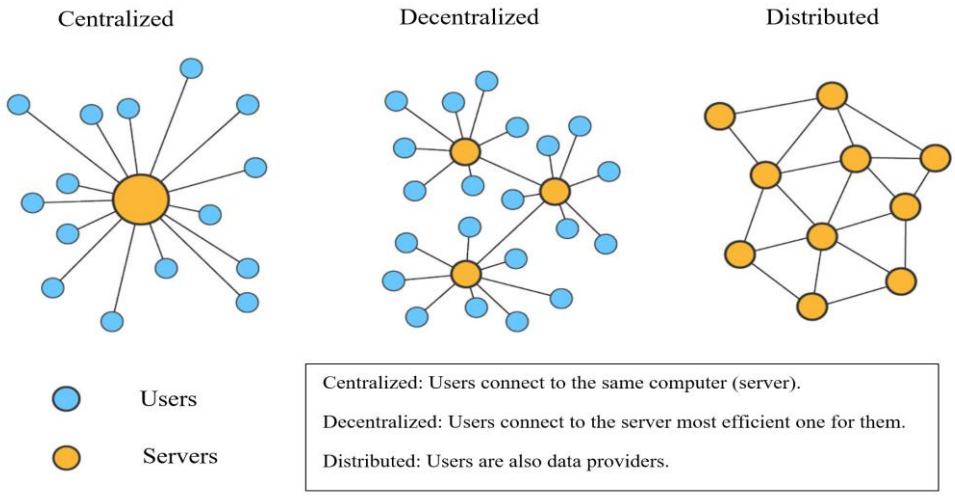


Figure 4 : Network Types in the Blockchain (27)

Centralized Network

Users are connected to a central network "server" that provide source code to run on a computer. Central system is quick and easy to set up. It contains all necessary user's information and contents. Most of the internet applications that we use every day are centralized. The communication of a bank with its customers represents exactly a central structure. (28)

Decentralized Network

Consensus does not take place in a single center. Multiple central owners provide to execute the system properly by storing a copy of the resources users can access. (Information is spread in multiple nodes). (29)

Distributed Network

The system consists of an architectural structure with many different servers. This server cluster works together to perform common tasks. Even if the relations between the assigned tasks and servers change over time, there is always a cooperation. Bittorrent is an example of distributed system. Google's working principle also coincides with this architecture. Outgoing calls are processed by many different computers. (30)

4.4 How Blockchain Works

As everyone knows that blockchain networks offer an open, transparent, decentralized solution for valuable documents, money and important document's data without the need for intermediary systems. So what are the technical structures important for the operation of this system and how they interact?

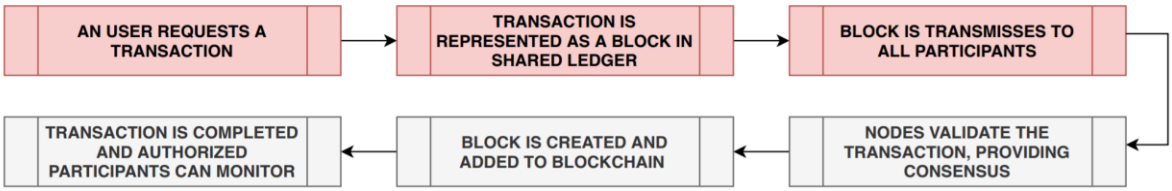


Figure 5 : General Process of the Blockchain System

Miners gather the processed data, archive and block them in accordance with encryption standards. The data for all transactions are eventually converted into a hash. However, miners have to add the output hash of the previous block into the block to ensure that all blocks are linked. (31) Each miner has a copy of the blockchain on his or her computer, and everyone trusts whatever blockchain has the most computing jobs. The model of using computers to create blocks is called Proof of Work (PoW). In addition, there are models called Proof of Stake (PoS) that do not require much computing power and can be scaled to more users. (32) The blocks and encryption information are checked by the computer (server) named nodes who support the network. In case of sufficient approval, the block is added to the chain. The miner who successfully completes the transaction wins a reward according to the consensus structure applied in the system.

Block

Structures in which all transaction data are stored are briefly defined as blocks. These block structures are ordered in chain logic depending on time. However, since there is no block behind the first block, it is called a genesis block. Every block contains; unique hash, hash in previous block, a timestamp and transaction data. (33) The data stored in a block varies according to the type of blockchain. For example, the blocks of cryptocurrencies store transaction data such as the sender, receiver and the amount of money.

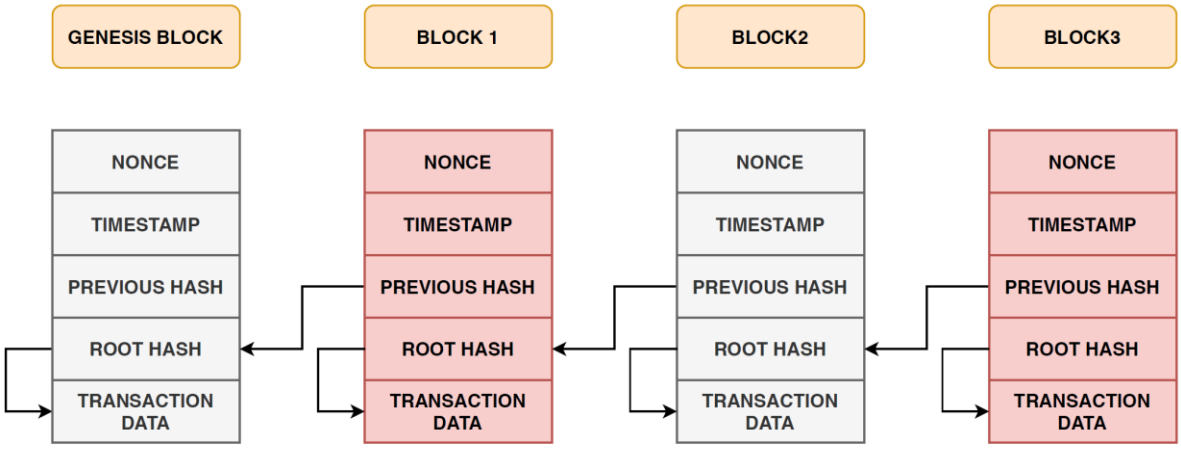


Figure 6 : Structure of the Blocks

Hash – Hashing

It is the process of encrypting any text to make it unreadable or unpredictable. The data entered is converted into a fixed-length output by mathematical operation. Hashing is also a method of creating cryptographic data using algorithms. In this respect, cryptographic hashes are like digital signatures. Both traditional and cryptographic hash functions are deterministic. So as long as the input is not changed, the same hash is always output. A hash algorithm called SHA-256 is used in the Bitcoin network. (It provides 64-character output in hexadecimal.) (34)

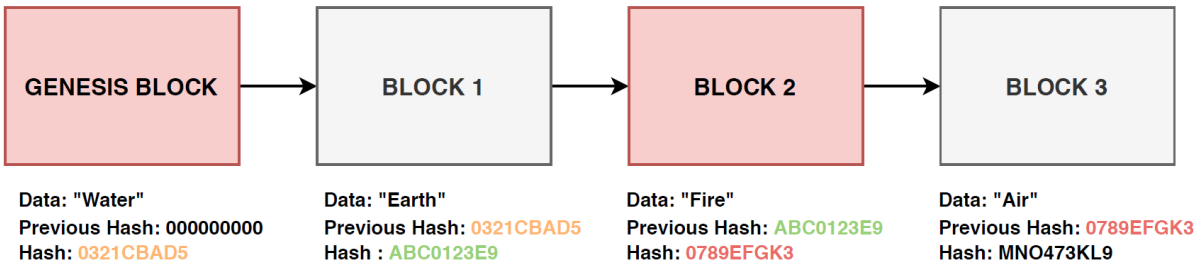


Figure 7 : Structure of the Hashing

Node

When the miner tries to add a new block to the blockchain, it distributes the block to all nodes on the network. (35) Nodes can add or reject the block, depending on the block's legitimacy and valid transaction. (36) Nodes have duties to store and spread blockchain data and transaction history. Any computer or physical network device connected to Bitcoin is considered a node since it communicates with each other.

4.5 Main Blockchain Platforms

After analyzing the technical structure of the blockchain system and how it works, it is necessary to understand how it will be integrated. What should someone do first, if wants to take advantage of the blockchain system? Is it necessary to create your own blockchain platform from scratch? Since creating such a system would require a lot of workload, it makes more sense to take advantage of open source blockchain platforms that have already been built.

Bitcoin

Bitcoin is the most well-known blockchain platform and started operating as an open network in early 2009. Thanks to Bitcoin's underlying technology, the two parties connect directly to each other without the need for a secure broker. In short, the logic is called as P2P (end-to-end) money transfer and cryptocurrency of the Bitcoin platform is called Bitcoin (BTC). Every users involved in the bitcoin platform have unique the digital wallet (Bitcoin address). These wallets usually contain a public key (to allow others to send Bitcoin). Apart from that, there is another key that makes your account personal and acts as a password. This is your digital signature and keeps you anonymous. Physically there is no

Bitcoin, only balances associated with a cryptographically secure public ledger. The Bitcoin blockchain code is open source, can be downloaded and modified to generate new types of sub-coins or to serve different purposes. The Bitcoin platform is mainly focused on running transactions by using the bitcoin cryptocurrency. (37) All transactions in the Bitcoin system are kept on a public, secure (immutable) and common blockchain structure on the network. There is no center in this structure and action is taken in accordance with the consensus structure whose rules have been determined from the beginning to approve the transaction.

Technically: Since the Bitcoin platform uses the proof of work consensus mechanism, validating a block and adding it into chain requires large amounts of electrical energy and high computing power. Bitcoin has been written with C++ language. (38) In BTC mining, ASICs were used due to the need for high hardware and powerful computers. The average generation time of blocks in Bitcoin is 10 minutes. The BTC supply is limited to 21 million. In the Bitcoin system, each block is limited to 1MB (8MB in Bitcoin Cash).

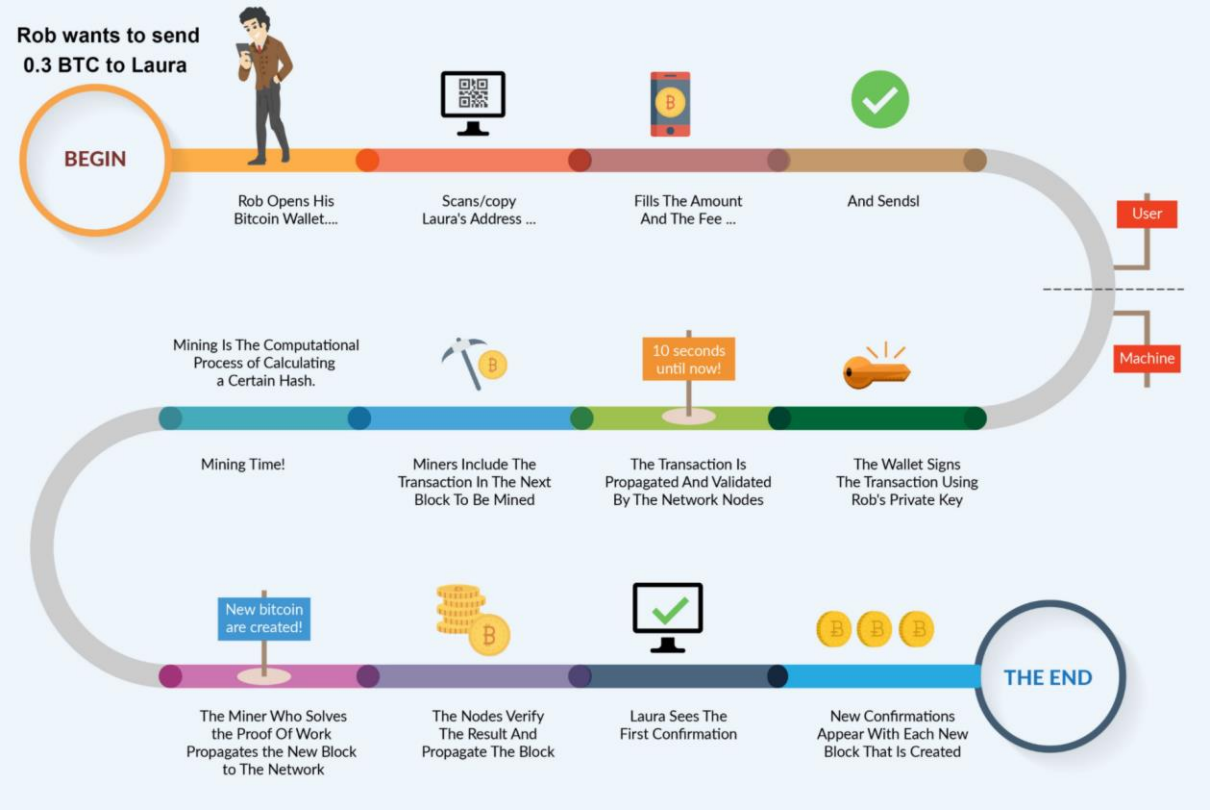


Figure 8 : Process of the Bitcoin Transfer (39)

Ethereum

Ethereum, launched in July 2015 and distributed among thousands of computers around the world, is a well-established and open-ended decentralized software platform. Ethereum allows developers to build and run distributed applications. Theoretically, everything we observe can be prepared as a program within Ethereum. The Ethereum platform has been in a continuous development process by creating and sharing release plans (Frontier, Homestead, Metropolis, and Serenity).

Ethereum, which has its own proprietary programming language (Solidity) that allows people to write scripts, calls this system smart contracts. Ethereum also includes the cryptocurrency called Ether. Ether is mainly used for two purposes: It is traded as a digital currency on exchanges in the same way as other cryptocurrencies, and is used to run applications on the Ethereum network. (40) Miners spend their own computational resources, the processing power of their system, to verify that every Ether transaction and smart contract results are valid.

Technically: Every transaction or storage usage in the Ethereum blockchain is measured with a value called "gas". More complex operations like making a smart contract require more gas. Ethereum mining is done with GPU (graphics card). For this reason, it is possible to mine with home computers. In Ethereum, a new block is created every 15 seconds. There is no supply limit for Ethereum for now. (41)

Hyperledger

Founded by the Linux Foundation in 2015, Hyperledger is an open source collaboration initiative to develop industrial and enterprise blockchain projects. (42) Hyperledger is not a firm or a currency.

Purposes; (43)

- Developing blockchain frameworks where companies will manage their management level operations.
- Providing impartial, open and fully community-oriented infrastructures for operations supported by both commercial and technical administrations.
- Building technical communities to develop projects.

Today there are more than 100 members of the Hyperledger platform. A wide range of industry leaders such as banking, finance, manufacturing, supply chain, technology have become members. SAP, Intel, IBM, Samsung, Huawei, Nokia, BNP Paribas, JP Morgan, BBVA, Airbus, Daimler, American Express etc. In addition to these, many startups from different sectors are among these members. (Consensys, Factom etc.) (43)

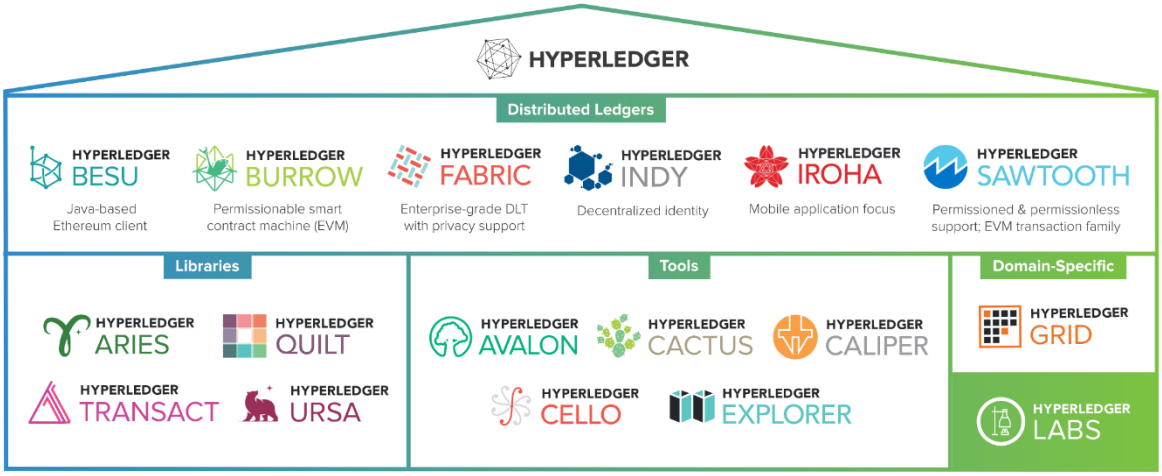


Figure 9 : Different Hyperledger Technologies (43)

Hyperledger's "umbrella strategy" promotes and supports a variety of business blockchain technologies, frameworks, libraries, interfaces and applications. Currently, Hyperledger hosts the following projects in the figure 9.

Corda

Corda was created by a consortium known as R3, which includes more than 80 financial institutions and regulators. It is a distributed ledger platform, not exactly a blockchain solution, designed specifically for the financial sector. (37) It is an open source platform that can be used to build applications for financial institutions. It is a permissioned private network designed to save, manage and synchronize contracts and other common data between partners. On the Corda platform, data can only be viewed by the parties involved in the relevant contract and legally needing access to the contract-related information. The consensus structure is transaction-level and supports a plug-and-play approach. It uses the Java Virtual Machine (JVM) to write and run the contracts in its structure. (44)

Quorum

Quorum is an enterprise blockchain platform specifically designed for financial use cases. The main goal of the Quorum project is to develop an enterprise Ethereum client that enables businesses to adopt and benefit from blockchain technology. (45) Because Quorum is an open source project, the platform's codebase is open for anyone to audit, which increases trust in the platform. It provides data confidentiality by separating general and special cases and providing private peer-to-peer encrypted message exchange. Since its development in 2015, Quorum has been protected by J.P. Morgan and supported by world giants such as S&P. (46)

Ripple

Jed McCaleb and Chris Larson started building Ripple in 2012, the system was named OpenCoin. Then, it was re-launched in 2013 under the name of Ripple. (47) Ripple is basically a real-time international money transfer / payment platform. The Ripple platform, which is used outside of crypto currency, is an open source protocol designed to perform transactions quickly and cheaply. Ripple uses its own special consensus protocol (Interledger Protocol). (48) Ripple is the name of the company that is the umbrella organization of XRP and RippleNet. Although Ripple has its own cryptocurrency (XRP), it has a system independent of currencies. Users can create their own platforms on RippleNet and make transactions as they wish. RippleNet can be defined as a network developed by Ripple for the purpose of sending and receiving money internationally. Among the beneficiaries of RippleNet technology are banks and corporate payment companies that provide financial services.

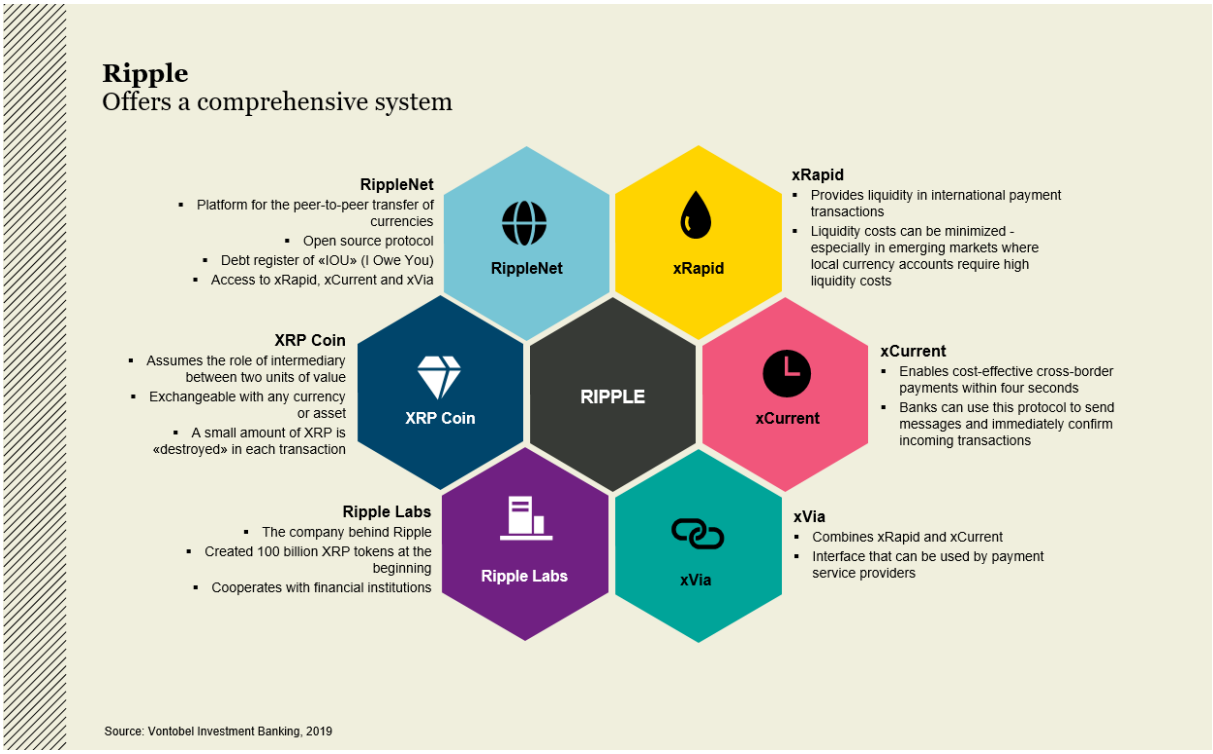


Figure 10 : Different Ripple Technologies (49)

4.6 Blockchain Use Cases

The most important use case in blockchain technology has been the concept of crypto money and Bitcoin. Today, it is known that there are more than a thousand cryptocurrencies other than Bitcoin. The total market value of cryptocurrencies is around 583 billion dollars, and Bitcoin with a market value approaching 366 billion dollars constitutes a very important part of this value. (50)

Blockchain technology is a technique developed to keep records securely. Many of its critical features have the potential to shape the data recording industry of the future digital age. Apart from cryptocurrencies, it is predicted that blockchain technology can be used in many business areas, especially where there is a trust problem and intermediaries. There are many various blockchain use cases that can be exploited in different industries.

The key blockchain use cases are summarized in the figure 11 below.

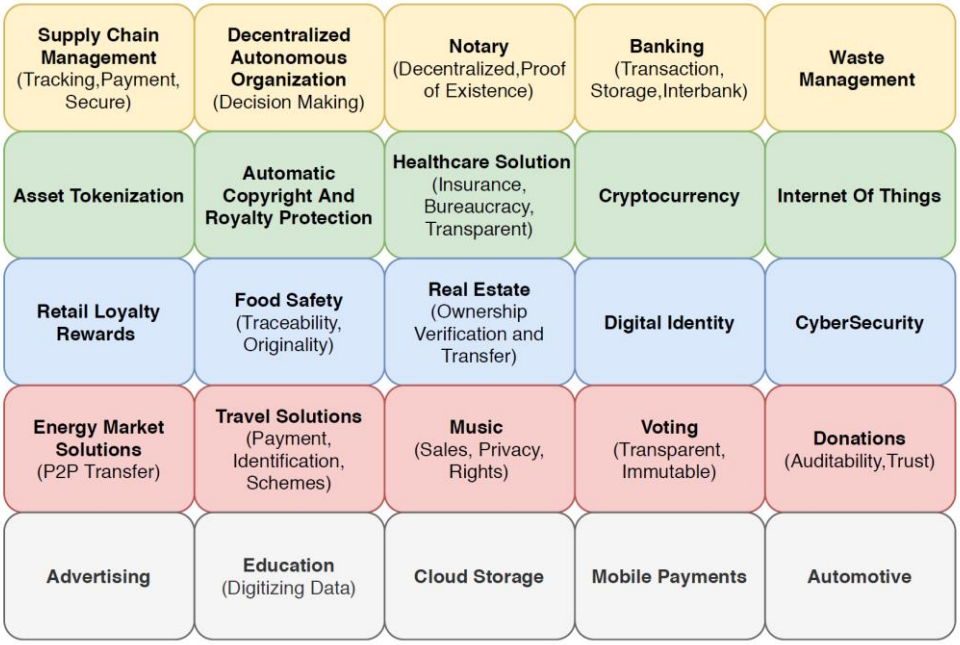


Figure 11 : Blockchain Use Cases

According to HFS Research Center in Figure 12: The figure shows most interested use cases in enterprise blockchain adoption according to specific sample that includes 640 blockchain engagements across 12 service providers (Accenture, Cognizant, DXC, EY, IBM, Infosys, KPMG, LTI, Mphasis, NTT DATA, TCS, and Wipro). It can be clearly seen that supply chain has emerged as the hottest use case for blockchain followed by document management, industry-specific use cases, trade management, payments, identity, and customer experience. (51)

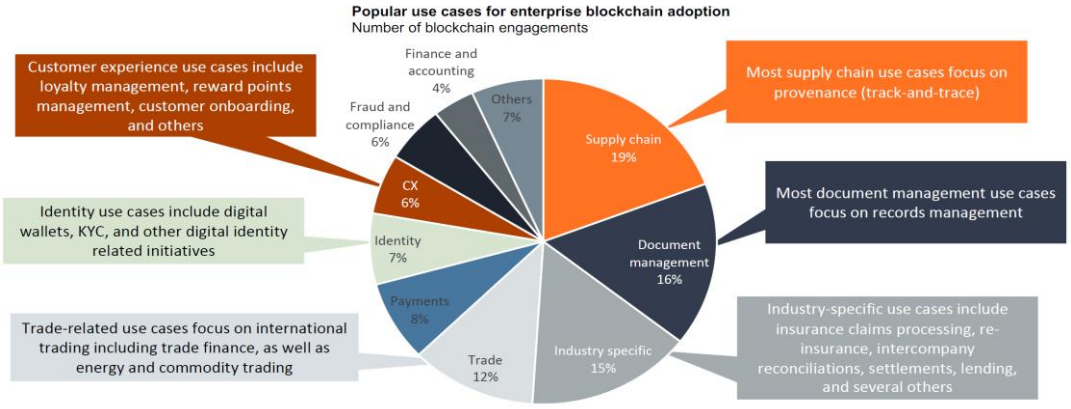


Figure 12 : Popular Blockchain Use Cases (HFS Research Center 2020) (51)

4.7 How Blockchain is used in Supply Chain

Supply chain management which enables the growth of the company, increase in profit rate and decrease in costs if done with the right methods has critical importance for all companies. Supply chain management which has many parties and critical operations is an area that can benefit the most from blockchain technology. Thanks to blockchain technology, transactions can be documented in a permanent way and non-locally, and tracked securely and transparently.

In the traditional supply chain, there are still many factors that harm companies and their communication. Especially in the increasingly globalized trade world, with the increase in consumption, there will be more disruptions and frauds in the supply chain. In more clear terms, as long as the old system continues, players in the chain will continue to suffer in terms of time and money.

Supply chain processes have become more and more complex because of these cases; Supply of raw materials from different places, the existence of a wide variety of production processes, the presence of a wide variety of stakeholders from different countries in the distribution channels, the fact that the products pass through different geographies in the delivery process, different custom practices of each state, various payment methods, lost documents, and the distrust in institutions or processes. Blockchain technology promises solutions to many such problems in the supply chain management (52).

However, the blockchain system brings many innovations along with it. If these innovations are implemented, relations between companies begin to be based on a more solid foundation. This improvement reflects positively on the supply chain in terms of time and cost. Since companies minimize the risk factor, the transactions are faster, more transparent and more traceable. In addition to these benefits, all transactions are recorded in such a way that as a less corruptible and better-automated, although the old-fashioned document load is reduced.

When you consider a supply chain, trust is the most important factor for every actor in the whole process, from customers to suppliers, to act together.

An example: A steering wheel manufacturer sends 300 steering wheels to the factory warehouse, insures it and delivers it to the logistics company. The logistics company carries it and issues invoices. The receiving company delivers it to OEM for assembly on the vehicle after testing and inspection. For this process, data is entered from 6-7 different points and approved. Blockchain traces all of this, and the accounting of the automotive company that will make the payment does not hesitate whether the transaction is concluded or not. Here, smart contracts come into play. The system does this query itself. The system determines the payment period using the business contract between companies. The payment is made within the specified period of the contract. Sometimes by delay, it prevents the company from using credit and uses the financial power of the business partner.

4.7.1 Use Cases in Supply Chain

Blockchain technology has different use cases in the supply chain field depending on sector. Since food safety is more prominent in the food industry, the blockchain system focuses on transparency and real-time tracking in the life cycle of the product from the raw material to the customer. On the other hand, supplier relationships are very crucial as there are thousands of parts product flows in the automotive industry. Due to intensive procurement procedures and international trade flow, in the auto industry, product tracking, smart contracts and automated documentation processes are utilized.

The general summary of these use cases can be analyzed from the table below. This table is created after the Capgemini Research Institute's meeting with the experts of 447 companies coming from different sector in 2018. (53)

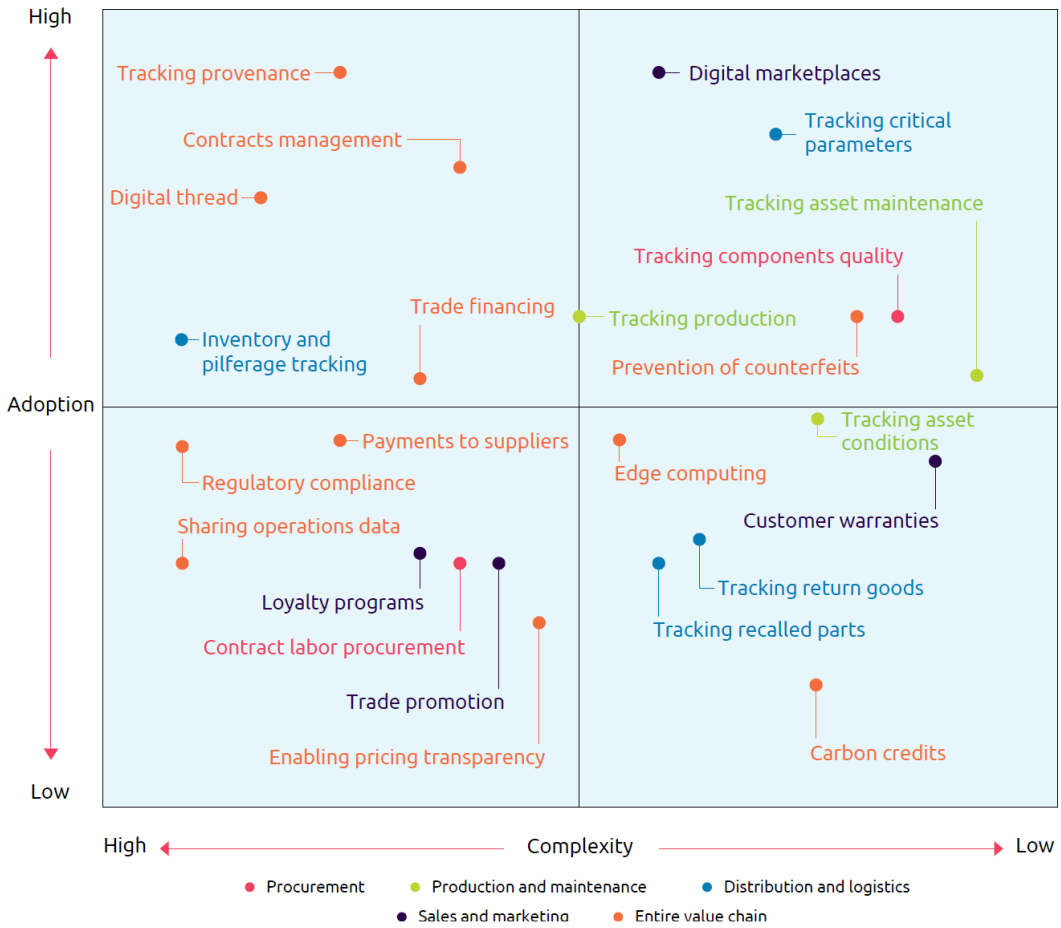


Figure 13 : Blockchain Use Cases in the Supply Chain (Capgemini, 2018) (53)

Benefits of Blockchain in Supply Chain

It can be briefly list the general advantages of the blockchain system, which is needed by the traditional supply chain, as follows.

- Traceability brings operational efficiency by digitalization of entire supply chain network. Tracking will be easier since all of information about product can be accessed by embedded sensors and RFID tags.
- Integration of automated and self-running contract structure for repetitive shipping and billing. (54)
- Enhanced security of transaction refers to establishing trust between parties that provide smooth process.
- Easily detection of fraud and data errors with immutable and distributed ledger.
- Eliminating or reducing the need for intermediaries (bank, notary etc.).
- Less paperwork by digital platform.

- Transparency with authorization system in open-access data.
- With smart contract, customized and individual contracts can be defined for each function.

With a blockchain infrastructure, where the goods are monitored transparently from the first production point to the end buyer, an effective supply chain management can be achieved where everyone accesses the same data, is instantly informed, and takes fast action. Tracking the products from production to the end user, proving their authenticity and origin, accelerating the flow of goods are provided. Blockchain can help digitize and streamline offshore shipping processes, saving time and money.

Hurdles of Blockchain in Supply Chain

Although there are many innovations and improvements that blockchain technology will bring to the supply chain, it has different obstacles worth considering. According to the DHL and Accenture 2018 joint blockchain report (55), there will be difficulties in adopting the technology at first, due to the different levels of digital readiness of companies and different interpretations of the mutual benefits of cooperation.

There are some tough barriers for businesses looking to take advantage of blockchain technology, as follows.

Loyalty of Old Routines: Businesses most likely do not want to abandon their long-standing business habits, because keeping up with new technology requires both financial burden and technology knowledge and training. According to Ken Evans, CEO of Konexial; “Most companies still operate rigid, structured ERP systems that do not support blockchain technology.” (56)

Lack of Resources: Trying to change the company's infrastructure and business processes is an important initiative that can disrupt internal and external operations and use financial and time-based resources from other projects. (57)

High Investment Cost: Even if blockchain technology provides significant savings in transaction costs, the high investment costs required in the beginning can be a deterrent. Lack of human resources, the length of the learning process and unforeseen software risks increase the total cost of ownership.

Complex System: In blockchain technology, it is not yet possible to talk about a fully standard structure or system. Since there are many different platforms and use cases, there is no common governing body and procedure to guide technology steps. These shortcomings can lead to conflicts between businesses with different conditions in the supply chain.

Non Global Standart: The lack of globally accepted standards regarding the application areas of blockchain technology is seen as an important obstacle to the application of the technology. The fact that the regulatory framework has not yet been determined and operational uncertainties and financial risks that may arise in practice reduce companies' appetite for investment in this area. (58)

Technical Problems: Architecture and software infrastructure in blockchain technology is very complex. Facing difficult technical problems in the established systems or the emergence of problems that have not been encountered before can cause great damage to the system. For example, it has been monitored that some blockchain technologies have poor scale performance or work slowly. Similarly, it has been claimed that some applications require excessive electricity consumption and enormous computing power, which overshadows the expected benefit. (59) As blockchain technology is still at the stage of learning, unpredictable software errors invite cyber attackers, and serious economic losses can be experienced, especially if these flaws in open blockchain platforms are detected.

Scalability: Because the number of transactions made with blockchain technology increases, it causes the system to slow down. The low storage capacity of the blocks in the chain and slow transaction confirmation per second can prevent sustainability. Blockchain platforms show lower transaction performance compared to currently used solutions. For example, while the blockchain platform of Bitcoin can perform an average of 7 transactions per second, modern credit card platforms can process approximately 8000 transactions per second. The processing power consumed by the miners to add new blocks in the Bitcoin network has exceeded the amount of electricity consumed by some small countries around the world. (60)

Missing Parties: Almost all members of the network are expected to be included in the system in order to support a wide-ranging supply chain network from raw material to customer delivery with blockchain technology. Only in this way, it can be fully transparent

and real-time tracking. However, some parties in the supply chain network may not be ready to join the blockchain system. This will make the established system inefficient. According to Bhagat Nainani, Group Vice President of IoT and Blockchain Applications Development, Oracle; “The biggest challenge with blockchain is on-boarding suppliers and convincing them of the benefits of transparent operations.” (56)

4.8 Future Expectations of Blockchain Technology

The supply chain ecosystem has undergone a major transformation with Industry 4.0. On the one hand, all processes are entrusted to smart devices with the internet of things, on the other hand, all processes are transformed into intelligent and automatic systems that can manage themselves with artificial intelligence technology. Ecosystem wants more efficiency, speed, security and transparency, and the ability to work together. For this reason, the developing new technological ecosystem will need a large network and infrastructure. Supply chain management, where all processes are managed from a single center, is unfortunately not enough for new technological developments. At this point, blockchain technology comes into play, in which all partners in the network manage the system, not from a single center. The world's largest logistics companies have already started working to build their processes on blockchain technology. Despite all the potential and real benefits mentioned, blockchain technology is still in its infancy.

Businesses need to question the compatibility of their technology investments with the systems to be used in the future. If they invest in technologies that they cannot use in the future, they will have to bear serious costs to rebuilt infrastructure again. In other words, if businesses want to benefit from blockchain technology in the future, they must first prepare their own technological infrastructure in line with the industry 4.0 ecosystem. Blockchain is simply an autonomous, distributed, trust-based database management. The harmonization of these technologies with business models and strategies is the only key to success.

According to Gartner, %80 of blockchain projects expected to be implemented in the supply chain area by 2022 will remain in the pilot phase or POC stage. (61) The most important reason for this is that the blockchain model used in the supply chain is inappropriate. In other words, technological model used in banking and finance will be insufficient as blockchain infrastructure in the supply chain area. Different blockchain models need to be

developed for the supply chain. Recently, the efforts of businesses, organizations and academic circles to accelerate the information exchange and reach more people by creating an ecosystem in order to close the information gap come into prominence.

The using of emergent trends in Industry 4.0 such as big data, artificial intelligence, robotic, autonomous vehicle, 3D printing, virtual reality and internet of things started to change supply chain ecosystem. The greatest benefit will come into play when businesses combine blockchain technology with these technologies for greater power and synergy. (54)

Kelly Marchese, Principal, Supply Chain & Network Operations at Deloitte Consulting says "Future organizations will leverage technologies such as blockchain to exchange value, connect siloes operations, collaborate with partners in a secure manner, and accelerate the evolution into digital supply chains." (56)

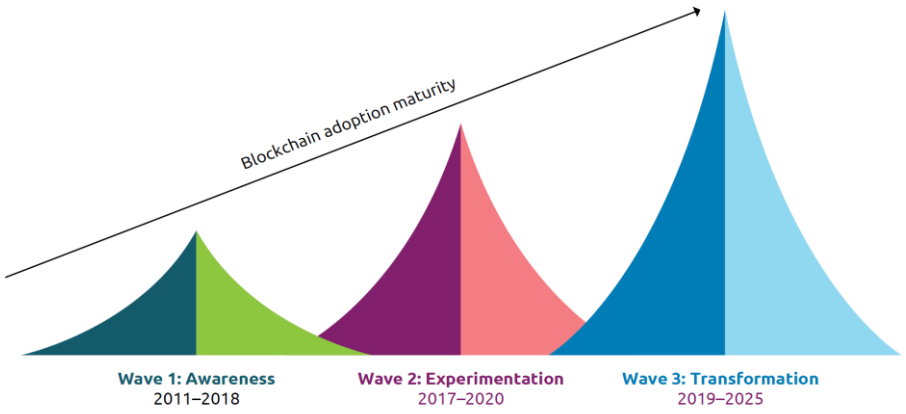


Figure 14 : Blockchain Integration Phases (Capgemini, 2018) (62)

According to Capgemini and Swinburne University of Technology, integration of blockchain technology will proceed in 3 main steps.

- *Wave1:* In the first wave, organizations learn technology and absorb information.
- *Wave2:* Organizations are exploring proofs of concept and working on establishing consortia. Industries other than financial services have also started investing in blockchain.
- *Wave3:* Businesses will assume enterprise transformation, establishing policies for privacy and data management.

According to research and consultant firm Gartner's report, while investment in blockchain technology will approach $176 billion by 2025, it will be worth $3.1 trillion by 2030. (63) By 2023 blockchain will support the global movement and tracking of $2 trillion of goods and services annually. (64)

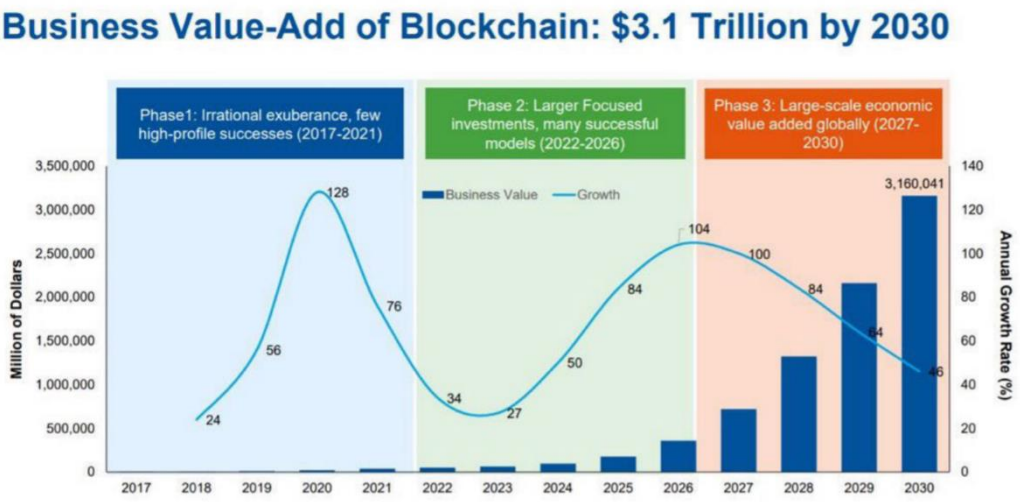


Figure 15 : Blockchain Future Phases (65)

According to research firm Gartner, within the next 5 years, blockchain technology will affect the businesses of most IT leaders and force them to change. By 2025, blockchain technology will reach maturity and companies will be able to benefit from blockchain solutions based on certain standards. After 2025, blockchain technology will be continuously improved, so that easier adaptation processes will take place, less costly and more efficient use cases will occur. (66) Technologies such as IoT, AI, and ML will get closer to blockchain and integration processes will be easier. With the improvements made, the values that can be tokenized will be expanded and they will be able to perform transactions at more micro level and support them in smart contracts. Micro-transactions between autonomous computerized objects will enable illiquid assets (such as intellectual property, data, physical object etc.) and assets that previously could not be converted into money to be used for monetary activities. The transparent system will increase the privacy of personal data, thereby making self-managed identity solutions and financial transactions more calculable and convertible to tokens. Depending on smart contracts, economic decision-making processes will be carried out autonomously by machines. (64)

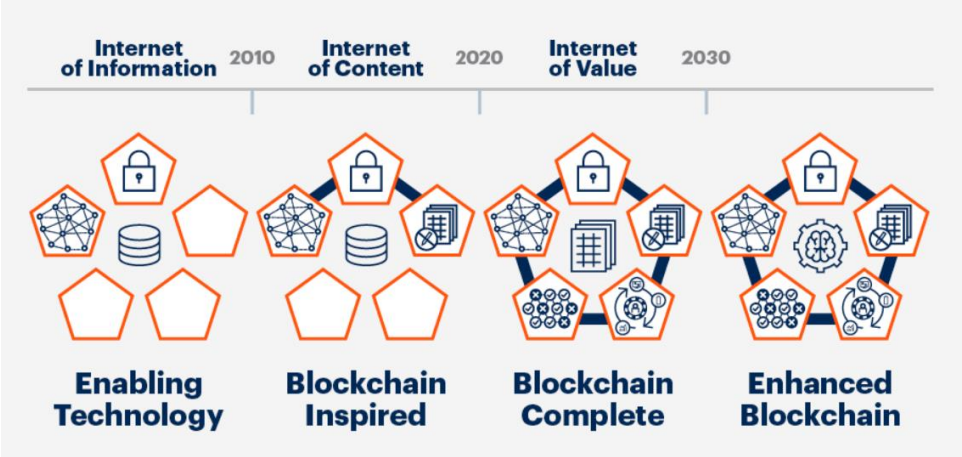


Figure 16 : Evolution of Blockchain Technology (66)

4.9 Blockchain as a Service

BaaS is the provision and management of cloud-based networks by 3rd party firm to businesses that want to set up blockchain applications. Its purpose is to provide a 3rd party blockchain integrated solution on behalf of other businesses thanks to cloud-based networks. (67) Moreover, BaaS firms support by offering ready-made application packages, management functions and smart contracts to businesses that are weak in the IT field or do not have time to build the blockchain system in their own company. (68) . BaaS providers analyze the technical details of blockchain technology and perform the necessary activities to make the system more agile and usable. Then it makes the technology accessible and offers to companies that want to purchase services based on blockchain system. Thus, a suitable environment is prepared for companies who want to explore blockchain's opportunities. This cloud system has been launched as an extra business area for companies in the technology sector or companies with strong IT and has recently developed greatly and the demand for service providers is increasing steadily.

These are most well-known BaaS providers and platforms;

IBM, Amazon AWS, Microsoft Azure, Google, Oracle, SAP, Dragonchain, BlockStream, Deloitte, Kaleido, Baıdu, Accenture, Huawei, Alibaba, Chainstack, Factom, LeewayHertz, Hewlett-Packard, Bext 360, Cognizant, Tata Consultancy Services, DXC Technology,Wipro, EY, Infosys, HCL Technologies, TCS, Capgemini, Fujitsu, GFT,

KPMG, LTI, Mphasis, PwC, Atos, Provenance SyncFab, ShipChain, OriginTrail, OpenPort, SkuChain , Blockverify, CargoX, Morpheus Network etc.

Alibaba Cloud BaaS is an enterprise-level PaaS (Platform as a Service) based on blockchain technologies, and is powered by Ant Financial Blockchain Team. The service provides to businesses build a solid and secure blockchain system, and manage the deployment, operation, maintenance, and development of blockchain smoothly. (69)

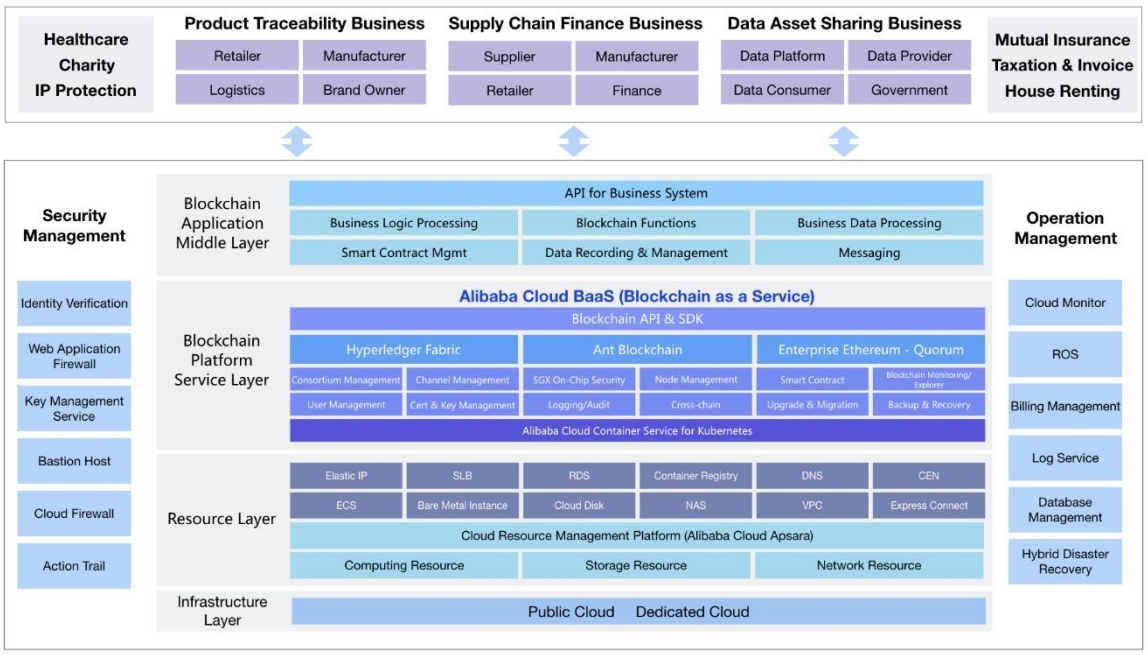


Table 2 : The architecture of AliBaba Cloud BaaS (69)

4.9.1 IBM Case Study

IBM is one of the experienced leaders in blockchain technology. IBM services is ready to use and fully professional solution on the sector. Consulting to IBM for blockchain technologies, it will be more reasonable for firms in terms of building blockchain, run the interface and manage the operation instead of doing it yourself. (70) IBM blockchain platform offers an operated blockchain-as-a-service (BaaS) providing that empowers you to perform blockchain components in environments of your option. Clients can build, operate, and grow their blockchain networks with an offering that can be used from development through production. (71) As a BaaS provider, IBM works on many different sectors with various use cases. While providing solutions to companies with many product packages, it also creates common platforms with other blockchain providers. IBM uses Hyperledger

Fabric that is flexible blockchain framework. Hyperledger Fabric supplies a framework for growing blockchain solutions with a modular architecture, pluggable applications, and container technology. (72) Thanks to interaction between IBM and Hyperledger, IBM blockchain platform is an accessible, multi-cloudy and successful. It offers consultancy and product packages to many companies, especially in the field of blockchain-based supply chain. IBM focus on many use cases in different sectors such as supply chain, trade finance, financial services, insurance, retail, media and entertainment, identity protection, provenance for food etc.

Some solutions offered by IBM as a service to businesses or some of the known platforms developed with IBM's collaborators are as follows.

Blockchain investments (representative list)	
Investment theme	**Details**
Blockchain accelerators/ solutions	• IBM Blockchain Platform: An end-to-end enterprise-grade platform for building blockchain networks with deployment flexibility (on-premise, SaaS, and multi-cloud); based on open-source collaboration in the Hyperledger community / Hyperledger Fabric v1.4 framework by the Linux Foundation • IBM Food Trust (Provenance Engine): Food provenance using track & trace on the blockchain to ensure products are safe for consumers • IBM Blockchain Trusted Identity: A decentralized approach to identity management built on top of open standards in combination with Decentralized Identity Foundation (DIF), W3C, and other standard groups • IBM WorldWire: Blockchain banking solution to help financial institutions address the processes of universal cross-border payments. It is designed to reduce the settlement time and lower the cost of completing global payments for businesses and consumers • IBM Consortium launch methodology: Drives consensus between network participants and focuses on building a right-sized governance and commercial framework to assist in accelerating the consortium journey and promoting adoption of the network • IBM Enterprise Design Thinking framework and IBM Garage: Allows consortium members to collaboratively decide on an outcome-based roadmap for the network and create a business value design that can guide the proper business strategy • IBM Blockchain Security Testing: X-Force® Red Blockchain testing helps organizations build and use blockchain technology with the connected infrastructure securely. The service includes manually reviewing chain code, security controls, and processes such as access controls, identifying a probable adversarial path to compromise, and moving laterally within a blockchain ledger network
Other blockchain alliances	• Maersk: Maersk and IBM collaborate on TradeLens, built on the IBM Blockchain Platform, to improve global trade and digitize supply chains • Food Safety: Collaboration across an ecosystem of producers, suppliers, manufacturers, and retailers to create safe and sustainable food system • We.Trade: Twelve major European banks selected IBM to bring blockchain-based trade finance to small and medium enterprises – the digital trade chain network • Health utility network: Aetna, Anthem, Health Care Service Corporation (HCSC), PNC Bank, and IBM are in a new collaboration to design and create a network using blockchain technology to improve transparency and interoperability in the healthcare industry • Deloitte and KPMG: Partnered to leverage blockchain technology and industry experience • Trust Your Supplier: Digital identity platform to improve supplier qualification, validation, onboarding, and life cycle management • Learning Credentialing Network (LCN): Managing the identity, education credentials, and organizational access to the same for education
Talent investments	• Around 2,000+ blockchain practitioners globally • More than 100,000 certification badges issued • Formal certification and virtual training, in-person bootcamps, advanced consulting, and technical training • IBM Blockchain academic initiative to provide students and educators with training resources and skill development and establish blockchain student communities • IBM is working with more than 1,000 universities to help meet the increasing demand for a skilled technical workforce trained in blockchain • Commitment and investment in P-TECH, IBM Veterans Employment Initiative, and IBM New Collar Certificate Program
Other investments	• Columbia and IBM announced 10 growth-stage start-ups as participants in the NETWORK acceleration program • Acquired RedHat to allow for hybrid cloud and unprecedented innovation in the next-generation of blockchain and DLT development, implementation, and application

Table 3 : IBM Blockchain Solutions (73)

TradeLens

TradeLens, launched by IBM and Maersk in April 2018, is a global supply chain solution focused on container shipping and logistics to ensure a more effective, transparent and reliable global trade. (74) The platform works by providing a standards-based open API that allows supply chain data to be tracked unchanged and shared via a permission-based blockchain. TradeLens uses IBM blockchain technology for digital supply chains. The

system provides strong association between multiple businesses players thanks to transparent transaction without compromising details, privacy. TradeLens's more than 150 members include international port and terminal operators, overseas carriers and a wide variety of carriers, customs officials, 3PLs, freight forwarders, logistics companies, legal bodies, insurers, software developers, shipping companies, supplier, cargo owners etc. TradeLens uses data coming from IoT sensors to track many variables (temperature and humidity control, dimension and weight of container etc.). Smart contract structure in TradeLens pave the way for many parties inside international trade to cooperate in the digital atmosphere. (74)

Every party in the Tradelens supply chain network can follow the real-time flow of information transparently. But here is important the authorization of information. Each member can access information within his / her authority. The information authorization system and smart contract infrastructure provide a high level of trust among members.

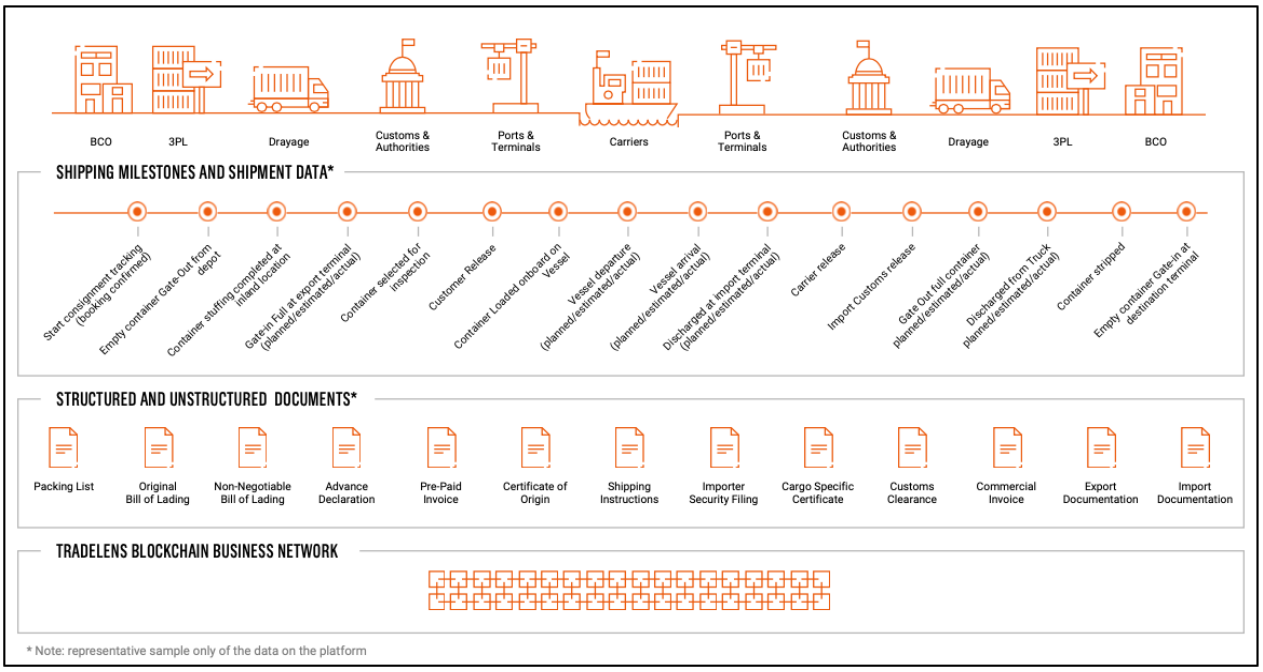


Figure 17 : Tradelens Data Sharing Concept (75)

5. Interrelation of Industry 4.0 and Blockchain

5.1 Overview

The first industrial revolution was defined as the mechanization of production, the second industrial revolution as the serialization of production, while the third industrial revolution was defined as the automation of production. The rapid development and integration of computer hardware, software, networks and digital technologies, which are the determinants of the 3rd industrial revolution, transformed societies and economies. These processes brought in a nutshell the transition from muscle strength to mechanical strength, and finally we're talking about the fourth industrial revolution and smart and connected machines and systems. Industry 4.0 basically aims to bring information technologies and industry together. With industry 4.0, within the scope of modular smart factories, it is aimed to monitor physical transactions with cyber-physical systems, create a virtual copy of the physical world and make decentralized decisions. (76) Internet of things and cyber-physical systems will be able to communicate with each other and with people in real time and work in cooperation. Industry 4.0 brings emergent technologies to many sectors such as internet of things, artificial intelligence, robotic and automation, augmented reality, big data, cyber security and cloud etc.

New technological trends brought by Industry 4.0 lead to the digitalization of production or logistics processes and to become more efficient. However, there are obstacles that to be considered such as trust between parties and data protection in front of the implementation of digitalization in production processes or in the procurement and logistics process. (77)

The supply chain, which has started to integrate with Industry 4.0, needs to adapt some basic rules for sustainability and applicability;

- ***End to End Visibility:*** Trace all flows to be more efficient by reducing losses and problems.
- ***Flexibility:*** Manage fluctuated demand changing to reach customer satisfaction and profitability and to be competitive.
- ***Trust:*** Data flow (sending, storage and validation) transparently between stakeholders to provide non-stop transaction confidently.

- ***Security:*** Immutable and decentralized data flow, document flow, money flow.

One of the most important cornerstones of Industry 4.0 will be blockchain technology. Because blockchain technology has features that can make industry 4.0 more productive, more reliable and more traceable. Sectors benefiting from Industry 4.0 technologies will be able to secure and store their data and provide automated, transparent processes thanks to blockchain technology. (62) The decentralized ledger technology underlying the blockchain system ensures the immutability of data and allows the secure storage and real time transparent by monitoring of data flows throughout the process. With blockchain technology increasing trust between parties, one of the biggest obstacles to full automation in the supply, production and logistics line can be eliminated.

Thanks to the data storage area provided by the blockchain, everything that happens in the production, supply and marketing line is recorded and identified with special ID. Since every transaction in the processes can be identified, processes can be self-managed and automated. Solving the problems that occur in the system will be faster and less costly.

With natural encryptions, information that the company does not want to disclose, such as financial data, production records and digital designs, can be hidden and securely transmitted to other parties in the desired amount. (78)

The value of investments in IoT technology is estimated to be $1.3 trillion by 2020, while artificial intelligence technology is expected to remain at $59.8 billion by 2025. On the other hand, the market value of blockchain technology is estimated to be $3 trillion by 2024. (79)

An example case (80) ; Focusing on the accumulated heat stresses of its employees, Fujitsu has developed a system that monitors physiological value data such as temperature, humidity and pulse with IoT technology. It uses AI technology to better evaluate this accumulated data and forecast according to environmental conditions. Thus, it aims to provide a healthier and more convenient working environment. If the technology of blockchain is integrated into this system, the data is protected and stored by ensuring complete confidentiality against cyber-attacks.

In a nutshell, with IoT data is collected by multiple sensor systems and technological tools, then analyzed and taught to the system to make faster and more accurate decisions with

artificial intelligence, then saved and shared on the blockchain as a permanent and immutable record. (81)

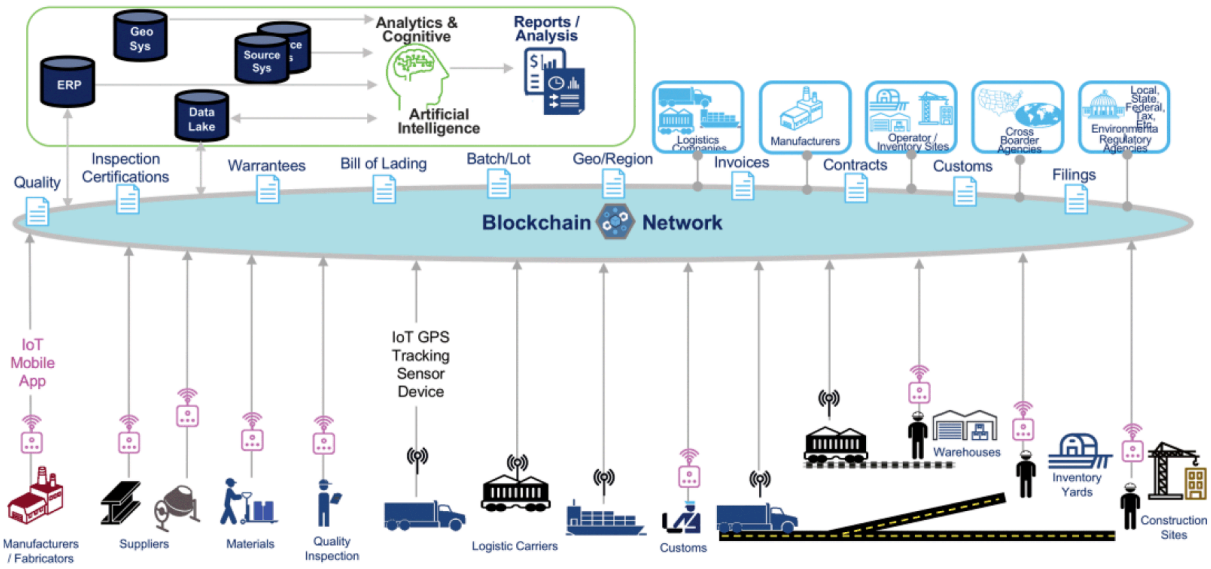


Figure 18 : Using of Blockchain, IoT and Artificial Intelligence in a Supply Chain (82)

One of the most important industries that would benefit from the combination of artificial intelligence, IoT and blockchain technology is the supply chain. The system, which includes these technologies, is an important candidate for a full automation process. (83) The strongest common point of these systems is the good management of data and information. With IoT technology, data is instantaneously entered during the production, supply, purchasing phase while artificial intelligence technology processes data and information and creates efficient models. For example, future sales forecasts, anticipating potential problems, route optimization. Blockchain technology enables data, information, history and methods transparently monitored and to be recorded in a way that cannot be manipulated.

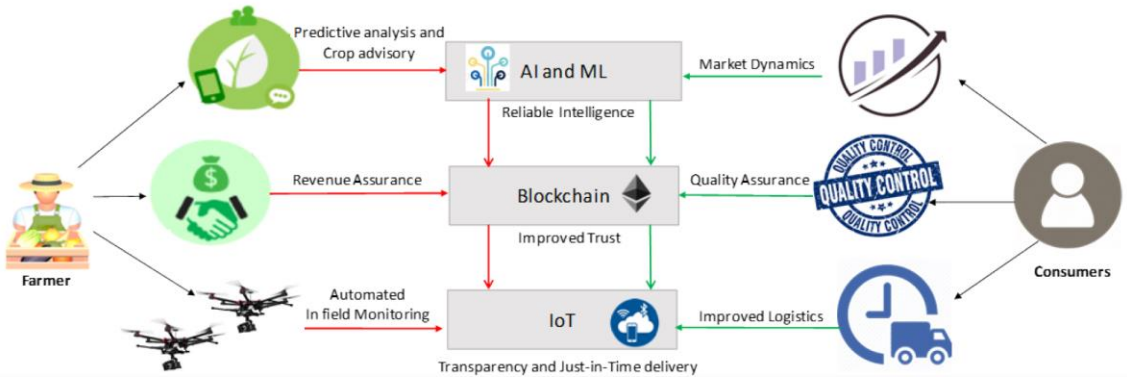


Figure 19 : Intelligent Flexible Farming (84)

5.2 Internet of Things and Blockchain

5.2.1 Definition of Internet of Things

The first application of the IoT concept in history has been developed until today after a group of academics from Cambridge University shared the images of the coffee machine over the internet thanks to a camera system in 1999.

At the simplest level, it means that any physical object that inclusive sensor and software can be connected to the internet directly or indirectly to communicate with other devices. (85) Devices connect to each other and share information and data, creating a smart network. IoT devices, smart devices, can record process and present huge amounts of data. The vast majority of such computing processes are carried out in developing technology, especially with the help of wireless networks or wireless sensor networks. Since smart devices can collect and analyze many data, they are suitable for automation systems and developing predictive reactions. These objects can be anything you can think of; mobile phones, coffee machines, cameras, cars, industrial equipment, home appliances etc. Internet of things is used in dozens of areas, including smart cities, smart cars, smart homes, industry 4.0, operation monitoring, predictive maintenance and manufacturing etc.

5.2.2 Drawbacks of Internet of Things

With IoT technology, information and data from person to person, person to object or object to object are transferred quickly. IoT that has the ability to perception collect data directly or indirectly from the physical world and spread it to the cyber world. (86) This leads to perilous types of security and privacy problems, making it one of the biggest obstacles to the spread of IoT. Especially if IoTs with vulnerabilities are not updated, they become a serious target for hackers. (87)

Security and Privacy

Lack of security frameworks and breadth of security issues are major hurdles to improving IoT security. Today, there is no common approach or standard for cybersecurity in IoT, so IoT manufacturers try to implement their own security protocols and often cannot provide effective and strong security encryption against to cyber-attacks. According to IoT security

consultant Rohan Kotian, “Most IoT terminals are not encrypted when processing data or communicating with other devices. As the sensitivity of the sound and data passing through the environment increases, the potential for interruption and intervention increases." (88)

The capture of IoT devices creates many different risks depending on the intended use. For example, spying can be done with indoor cameras, the use of life-saving health equipment can be prevented, and the data of an industrial production can be changed. (89) After attackers take control of the device, they can manipulate data, commit crimes that will affect physical or mental health against individuals, seriously damage services or operations, or infiltrate the user's internet network and identity information and commit cyber-crimes.

A strong security infrastructure should be created for IoT devices that have not achieved any security standards. (90) Because discovered or not yet discovered potential vulnerabilities are a serious threat to people and their organizations. That's why, blockchain infrastructure can be presented as a supporting technology to overcome the shortcomings of IoT.

5.2.3 Relevance of Internet of Things and Blockchain

Increasing complex structures in the supply chain network have forced companies to digitalize. Stakeholders try to find a way to reach trust based flow in the supply chain network by diminishing dependence between parties. (91) During the transition to an effective digitalization, companies should try to benefit from IoT and blockchain technologies together. In particular, real-time data tracking, data immutability, high speed performance and increased trust between parties depend on the proper application of these two technologies. IoT integrated blockchain technology can support firms in terms of visibility and traceability which play a significant role in sustainable SCM.

Some of the consultant firms and platforms that combine blockchain and IoT technology together to offer products for companies in terms of traceability, security and transparency in SCM;

IBM Watson IoT Platform , ORACLE, Amazon AWS, Mıcrosoft Azure, Google, Deloitte, AliBaba, Accenture, WaltonChain , Ambrosus , Riddle & Code , Brieftrace, Everledger, modum.io , LeewayHertz, Clarion, HashCash, EY Consulting, BCG Consulting etc.

Traceability

The life cycle of the entire supply chain network is monitored in real time by placing sensors, digital labels, RFID and chips, which can be found in IoT technology, and this data is transmitted and stored securely with blockchain technology. (91) For example, physical conditions such as temperature, humidity, light and location of a medical drug are safely recorded at every stage of the supply chain. In addition, the necessary authorization and originality documents in the pharmaceutical industry are sent, approved and stored in a digital environment. In this way, fraud is prevented and product losses are protected.

Consumers always want to know quality of product, where and how it comes from. Transparent information about product must be passed to the customer in order to achieve customer satisfaction and provide customer confidence. (92)

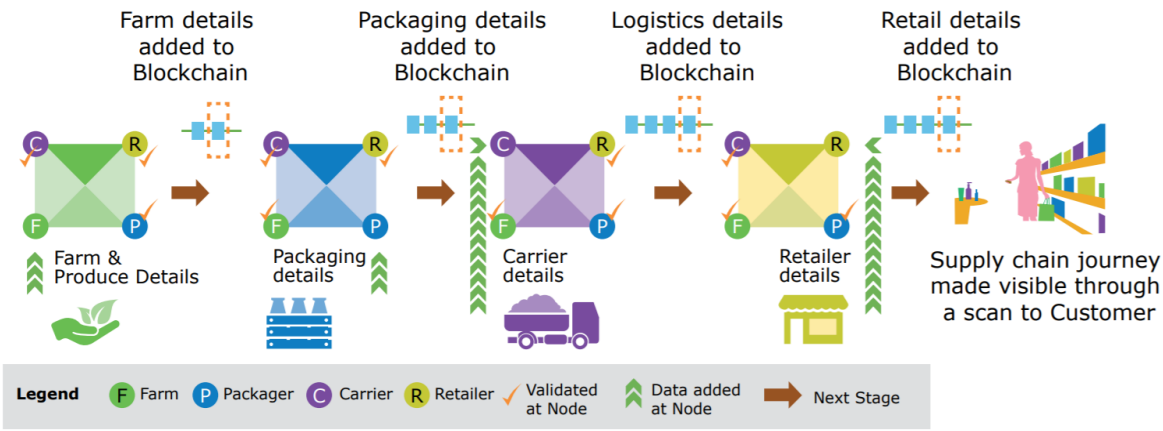


Figure 20 : Iot and Blockchain System Supported Food Supply Chain (92)

It is easily say that one of the most important strategic targets in all sectors are customer satisfaction and brand loyalty. In order to achieve these goals companies needs leveraging product traceability in a digitalized supply chain network. Especially companies in the food industry have to trace the origin of their products and the journey in the supply chain network correctly for these two goals and customer health. Thus, by tracking product origin (provenance), product information can be conveyed to the consumer correctly and customer confidence can be established. According to the WHO, one-out-of-ten people fall ill and around 420,000 die due to contaminated food. (93) Ensuring food safety is a costly and time consuming process to control in complex supply chains. (94) A producer firm in food industry trace the quality of their foods are not getting tampered in the supply chain and

prevent the fraud attempt. Retailer and customer will be know the product is not spoiled since they have already received real time data transparently by using IoT enabled blockchain system.

Since there are many different stages in the journey of the products in the logistics process, especially in a global supply chain network, a real-time location, quantity and status tracking can be done in a transparent and unchanging manner with the cooperation of IoT and blockchain in order to prevent product fraud, product spoilage and product steal. Tracking where the product is located in real time with IoT prevents fraud and strengthens the relationship between parties. The location data received during the exchange of products between parties is transferred to blockchain technology to protect the data and the pre-determined procedures that are real time product possession and financial transfer etc. in smart contracts are automatically processed.

Digital Environment

One of the most important problems in the traditional supply chain network is document exchange. In particular, legal documents and financial transaction documents that need to be transferred and controlled should be transmitted between parties in a correct and secure manner. Real-time viewing of these documents on smart devices and their secure, unalterable inter-party transfer can be achieved by effectively managing IoT and blockchain technology. In this way, the transactions made are quickly approved in the digital environment without the need for wasting paper and fraud attempts are prevented. (95) Inter-party trust is established and significant costs that may arise are avoided.

Predictive Performance and Automation

Thanks to IoT supported processes in the supply chain network, many performance data are recorded. This performance data is an important step to automate processes in the most optimized way. Parties can store these data in blockchain-based cloud systems and share them with each other in real time to improve processes. Collected data are evaluated for better performance and earnings. For example, if there is a communication breakdown when there is a stock-related malfunction usually at the same points, this situation can be digitalized and automated with smart contracts.

No Intermediaries

Thanks to blockchain, transactions are carried out quickly and securely between parties without the need for intermediaries. (96) In particular, in a supply chain network, insurers and financial institutions can be important intermediaries in terms of time. Money transfer between parties is carried out faster and cheaper with IoT-based devices without the need for banks and its commission. Another different case; when there is a money and goods exchange between buyer and vendor, the buyer who will pay by taking a loan from the bank does not take the money into his own account, thanks to smart contracts, the money transfer goes directly from the bank to the vendor when goods goes to buyer simultaneously.

5.3 Artificial Intelligence and Blockchain

5.3.1 Definition of Artificial Intelligence

Artificial intelligence is a machine that allows a computer or a robot connected to a computer system to act in a similar way to human intelligence and has the ability to continuously improve itself. (97) This invention, which dates back to the Turing Machines in the 1940s, was created by analyzing human thinking methods and is also developed by analyzing this ability. The feature that distinguishes this software, which has a wide area in computer science, from ordinary software is its ability to imitate human intelligence. In the future, it is aimed to reach a hardware which runs completely like the human brain.

In order to achieve the goals, artificial intelligence should succeed in the issues such as learning and understanding from experience, making meaning from complex messages, responding to a new situation quickly, using reasoning ability in solving problems, dealing with unfamiliar situations.

Artificial intelligence is widely used today in sports competitions, health, automotive, video games, finance and economics. Researchers are trying to develop AI systems that can make faster decisions that can better manage problems at critical points in human life or processes at unstable points. (84) There are many examples of artificial intelligence that make people's lives easier by offering practical solutions. The most used types of artificial intelligence today; (98)

- *Voice recognition:* Only real user can give voice commands to the device used.
- *Image recognition:* Understanding of objects by driverless vehicles.
- *Language processing:* Ability to language translate or correct typo.
- *Judgment:* Being able to make the right decisions within the rules and information transferred to the system.
- *Problem solving or Regression analysis:* Creating logical results and minimizing the risk of error by analyzing big data in production.
- *Suggestion:* Providing personalized suggestions or virtual assistance to the customer.

5.3.2 Relevance of Artificial Intelligence and Blockchain

The combination of artificial intelligence technology and blockchain technology positively affects digital transformation and provides competitive advantage by achieving more effective operational process, higher employee and customer satisfaction. Blockchain ensures cost and time effective system and data consistency while AI makes self-learning and productive system. (99)

Basically, while blockchain deals with decentralized storage, authentication, traceability and execution, AI is concerned with understanding, evaluating, and decision-making processes of specific patterns and datasets. AI and blockchain share several features that will ensure a smooth interaction in the near future.

There is no doubt that they will have significant impacts on the future when the two technologies are integrated with each other. The alliance of AI and blockchain provides transparent, faster, immutable, secure and decentralized system for the fairly much considerable data and information that AI-driven systems must collect, store, and operate. (100) However, in order to establish this integration correctly, companies are still at the beginning of the learning phase. Mostly, companies are trying to learn and apply the two technologies separately still. (101) As technologies are learned independently by companies and develop further, it is inevitable that they will undertake important projects together in the near future.

Some of the consultant firms and platforms that combine blockchain and AI technology; Fetch.ai, Core Scientific , SingularityNET, DeepBrain Chain, Synapse AI, MATRIX,

NUMERAI, BurstiQ, AI CRYPTO, Endor, AIX Trade, Neuralnet, BotChain, Indorse.io, Namahe.io, Senno.io etc.

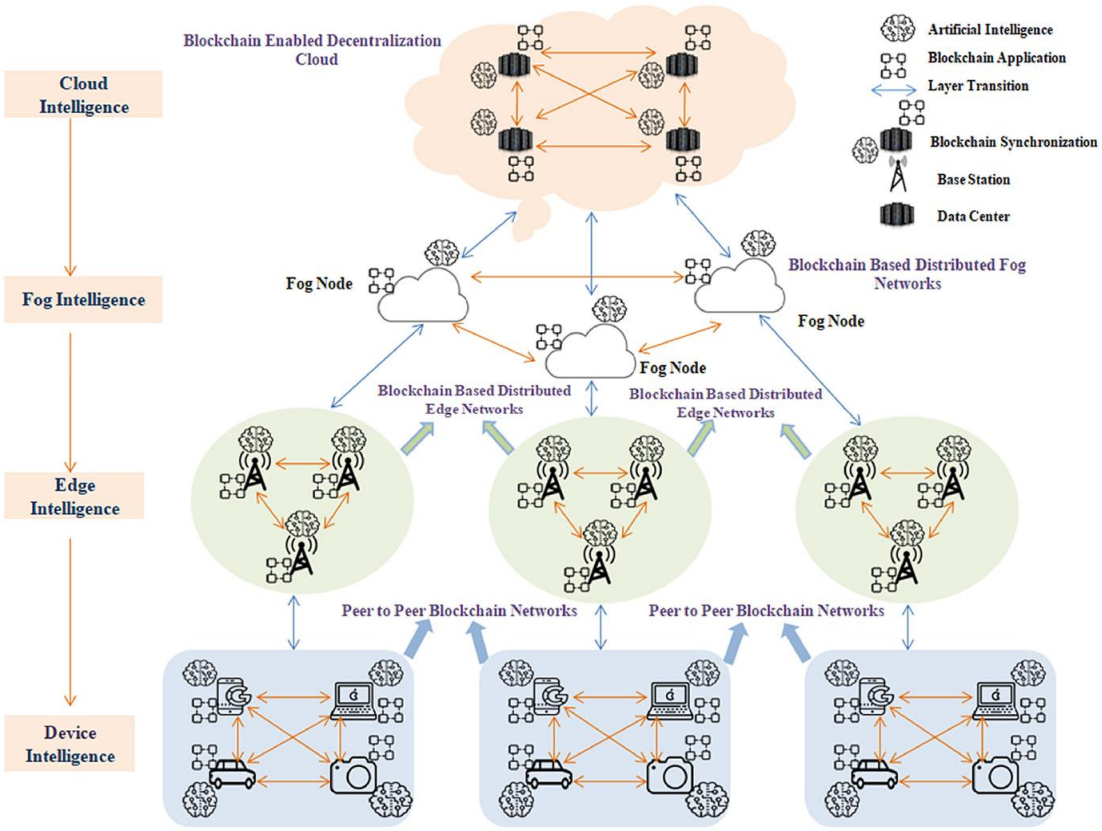


Figure 21 : Combination Architecture of AI and Blockchain Technology (102)

The figure 21 is a combination architecture of AI and blockchain technology designed to solve the centralization problems of IoT applications, perform data analysis on a larger and faster scale, and close security gaps.

- *Device intelligence:* Blockchain and AI-powered IoT devices generate large amounts of data.
- *Edge intelligence:* Artificial intelligence supported base stations analyze traffic data from detection devices.
- *Fog intelligence:* The data in the Edge Intelligence section is processed into cloud intelligence with AI and blockchain-powered fog nodes.
- *Cloud intelligence:* It consists of data centers. It is the secure storage of artificial intelligence-supported data from IoT application areas such as smart cities, smart factories, smart healthcare services, and smart transportation in a decentralized cloud

provided by blockchain technology. At the same time, each data center stores data output that solves the accuracy, latency, and privacy issues of IoT devices.

Blockchain-Driven Artificial Intelligence

Data Management

The security threat must be prevented to advance any widely accepted technology. The autonomous nature of machines requires a high level of security to reduce the likelihood of disaster. (103) A decentralized database for multiple clients in a specific network and high mathematical encryption in the blockchain provides a reliable infrastructure in the machines connecting AI. Today, one of the most important pillars of technology is the importance of high level information gathering and data analysis. For this reason, data management has always been an important determinant of success. The success or failure of businesses largely depends on how the effective information around them is processed and managed.

For the advancement of AI technology, there is a need for various data from numerous sources and the correct transfer of these data. With the concept of peer-to-peer connection, blockchain makes data accessible to everyone on the network with its open and distributed ledger.

With tons of data stored in a decentralized system, there are several advantages compared to a traditional central storage hub. In the event of a crisis or natural disaster, data is not stored in one place, therefore it is protected. Cyber-attacks are eliminated and making the data set more resistant to corruption.

Artificial intelligence thrives on data oceans, and blockchain can expand this access and ensure the reliability of information, but can distribute it before privacy concerns initiatives are launched. Working with regulators and governments should be a must to demonstrate the value that AI enabled blockchain can bring to individuals and society.

Trust in Recording Transaction

The decision-making mechanism of artificial intelligence produces outputs based on algorithms and provides information flow to the authorities to adapt the outputs to the system. The decentralized logbook of blockchain technology can prevent the process from

being manipulated or destroyed by any human. (104) In this way, the confidence in the artificial intelligence system, the proposed output and the application of the output is increased, so that the information is transparently transferred.

Immutable Network

Multiple machines connected to a common data pool analyze data and can make important decisions for different tasks or begin a joint decision-making process for more comprehensive planning processes. (105) In this context, by providing immutable network, data processes and decision-making outputs must be coordinated correctly and managed in a fast manner.

Decentralized Decision Making

By using a decentralized and distributed decision-making mechanism, decisions taken from different machines serving a common purpose can be implemented according to the majority rule. (106) Each machine can record and confirm its own decision with a transparent system.

According to the some studies, the decentralized infrastructure of blockchain adds meaning to artificial intelligence applications and system from different angles.

- *Decentralized optimization strategies:* More relevant data, more suitable servers and correct processing processes are selected to reach the most optimum artificial intelligence solution. (107) Thanks to the decentralized structure, new data sources can be accessed and the most relevant data can be extracted to reach more optimized system. Strategies in different optimization targets can be run simultaneously in a decentralized structure.
- *Decentralized planning strategies:* Artificial intelligence applications combine with other different systems and use planning strategies to solve more complex problems. Planning strategies provide logical algorithms to make the system more productive and flexible and help artificial intelligence applications. (108) Decentralized blockchain technology makes planning strategies more permanent and traceable.
- *Decentralized perception strategies:* It helps to collect data from different views by reaching different perception centers and ensures that these data are stored and

transferred in a more secure and transparent way. The methods and processes of perception strategies that reach more accurate data are invariably recorded in the system. (84)

- *Decentralized learning strategies:* Different learning methods are used for the development of the automation processes provided by artificial intelligence. With decentralized learning methods, fully coordinated autonomous learning can be achieved and the process of resources data saved. (84)
- *Decentralized search strategies:* Since artificial intelligence applications require a large data repositories, data search strategies must be developed. Optimal search strategies can be achieved with reliable recording of more efficient search histories that benefit the system. (84)

Artificial Intelligence-Driven Blockchain

Some barriers and constraints in blockchain technology can be improved with AI technology. It can turn into a smarter system that learns on its own.

Sustainability

AI technology is currently used for optimization of large-scale systems such as power system planning. (109) In the blockchain, the mining process is still inefficient and requires high mathematical computing power and energy. It is easier to find a way that reach more efficient and less expensive mining process by implemented AI technology. Artificial intelligence technology can improve itself by examining numerous data and reach more optimized results. The feature can reduce the energy consumption for the mining process and improve the system for more logical algorithms.

Efficiency

AI can do distribution of tasks and time between miners effectively with dynamic learning to accelerate resources estimation and improve system performance. The energy and time efficiency of data movement and data storage processes can be increased by self-learning logic. AI systems gives an opportunity to reach advanced blockchain system. Parameters of situation, dataset, problem, process and pattern can be used and elected by optimized steps

thanks to deep learning technique. It can identify inappropriate situations and extraordinary data and processes and bring the system to a more secure and efficient point.

Scalability

One of the most important obstacles to the more effective use of blockchain technology is scalability. Scalability can be defined as operations per second in the most general sense. And it's about how the increased amount of work is managed efficiently. Scalability can be examined under 4 main headings as fast data throughput, latency period, bootstrap time and cost per transaction. (110) Scalability in the blockchain technology means to manage number of users, transaction, nodes. (Cost per transaction, confirmation time, validation time etc.). AI can help to system in terms of collaborative learning in decentralized dataset and find new data shredding techniques. Decentralized machine learning can be beneficial for the scalability of a blockchain. AI has ability to find a more efficient way in the use of resources that diminish the expenses involved in the blockchain network. (111)

Security

Transaction records on the blockchain are made more secure using cryptography. Each member of the network has its own private key as a digital signature and is used for their transactions. (112) The digital signature will no longer be active when attempting to change transaction records. Since blockchain is a decentralized peer-to-peer platform, it is very difficult to intervene in the system, but with high computing power, 51% majority can be reached and manipulated. AI ensure more secure system in the some layers that have already weak structure by creating stronger encryption and more resistant smart contracts with high mathematical calculations.

Privacy

One of the strengths of blockchain technology is privacy. But there are many fraud (phishing scams) methods in the internet world. For example; in e-mail-based phishing attacks, there is a possibility that personal information and wallet information can be accessed through fake link sharing. According to Chainalysis report, the blockchain investors lost $225 million in 2017 due to phishing scams. (113) In order to prevent these situations, there should be run system algorithms that are more secure and give importance to privacy.

Artificial intelligence technology can run algorithms to protect privacy by making the system smarter. Furthermore, it can help you to write more secure smart contracts by analyzing the privacy points of the system during the transactions after many data-based learning.

Smart Contracts

Artificial intelligence can transform smart contracts into a smarter and more analytical structure. An artificial intelligence system can analyze the entire lifecycle or history of previously concluded contracts, and thus behaviors of parties, conditions, transactions can be improved. (114) It can identify shortcomings or redundancies in the contract more quickly, then modify contracts to make future contracts more efficient. The security and privacy infrastructure of smart contracts used in blockchain technology is one of the most important issues. The DAO that connects smart contracts was hacked in 2016 and $50 million was stolen from the network. (115) Artificial intelligence technology can prevent from the manipulation or exploitation of smart contracts with a human-free, automated intelligent infrastructure.

6. Blockchain in Automotive Industry

6.1 Overview

In the past years, many startups have explored blockchain applications in depth and looked for ways to adapt them to the automotive industry. While some initiatives gradually approached the goal, others either gave up already or disappeared by consuming the resources of their investors. Although the automotive industry seems like an appropriate environment for blockchain technology, a longer period of trial and error is needed for the industry to move in this direction, mature and achieve its goals. In the future, it is expected with curiosity which use cases the automotive industry will focus on and what level it will reach.

Users with blockchain technology can track transactions and data flow with a secure and transparent traceability, without the need for intermediary financial institutions, and at the same time, each process is invariably recorded and digitally copied to users thanks to a decentralized infrastructure. The established system can significantly reduce costs and time delays by providing the efficiency in the both demand and supply sides that companies want to achieve. (116) As every sector makes researches and investments to benefit from this technology and catch trends, manufacturers and suppliers in the automotive sector also have been affected by blockchain technology and have taken action. Blockchain technology is already a new and emerging technology. Companies in the automotive industry are at the stage of learning technology, modeling and experiencing of use cases. On the other hand, some companies have already successfully adapted blockchain technology in different usage scenarios and continue to develop it.

The automotive industry is seen as one of the sectors that paves the way for new technologies with the moves made on autonomous systems and artificial intelligence. Technology moves made support each other and complement the missing parts. Artificial Intelligence, IoT and blockchain technology complement each other in the field of supply chain and play an important role in the production of autonomous-connected-electrified vehicles and future investments. (117) Blockchain is at the center of research, not surprisingly, with the potential to take these moves one step further. Automakers, on the

other hand, are quietly investing in blockchain infrastructure while trying to find new ways to meet their technological needs. (118)

6.2 Blockchain Use Cases in Automotive Industry

The automotive industry has always followed new technological trends closely for different reasons such as reducing operational costs, increasing productivity, achieving full automation, ensuring customer satisfaction and brand awareness. One of the important trends that started to be learned and applied is blockchain technology that provides many different perspectives to the automotive industry. So, what are the use cases of blockchain technology in the automotive industry?

Mobility Services

Businesses are in the search that to meet the needs of the mobility sector affected by global technological trends and to find quick responses. Firms in the mobility sector are investing in digitalization and big data analytics initiatives to strengthen operational efficiency as long as demand patterns change due to geographical differences. Blockchain technology makes the mobility sector more transparent and secure by providing non-manipulable data and transaction records by providing a smart contract infrastructure in use cases such as car sharing, car rental or leasing.

Car Sharing: The car sharing market is increasingly attracting the attention of users and continues to spread. Blockchain technology may be one of the ways to avoid complexities caused by excessive demand and system' volume. With the smart contract structure of blockchain technology, a less costly, secure and transparent data transfer structure can be created in peer-to-peer or manufacturer-based vehicle sharing. (119) Transactions such as trip history, money transfers between spouses are carried out securely in the system and an automatic flow is provided. For example, if the car manufacturer provides car sharing services with third-party service providers, money transfers are transferred between parties as a percentage of car ownership automatically. Trust problems in peer-to-peer car rentals and privacy problems of personal data flows on existing car sharing platforms can be solved with blockchain-based investments. Especially in peer-to-peer vehicle sharing, fraud can be prevented with predetermined smart contracts. (120)

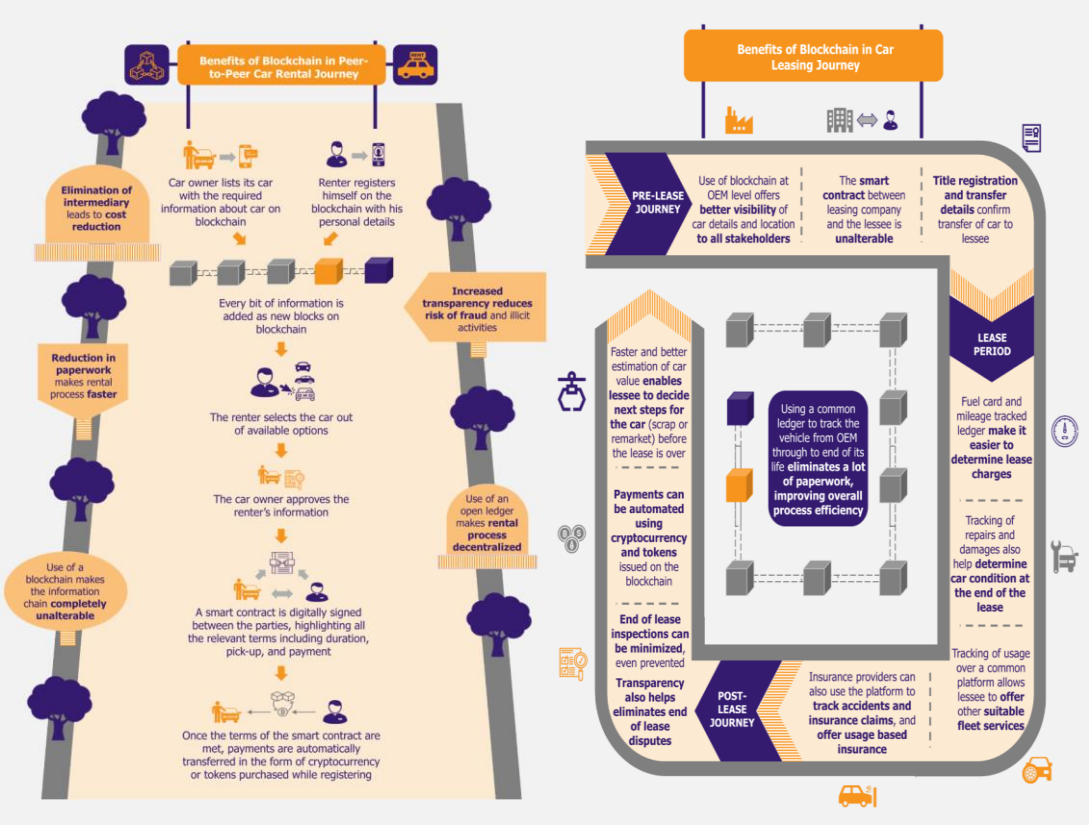


Figure 22 : Process of the Blockchain based Car Rental and Car Leasing (120)

Insurance

One of the most important sectors in which insurance practices are actively used is the automotive sector. According to the research, there were nearly 7 million car accidents in the United States in 2016. (121) This shows how much demand and data flows in the insurance industry. Blockchain technology's traceable and unchangeable database infrastructure can overcome the data density and complexity of insurance transactions in the automobile industry. For example, in the smart cars, the kilometers reached by customers are confirmed and recorded in real time with blockchain technology. Cross-party fraudulent transactions are blocked by the decentralized ledger technology. In particular, insurance companies can issue more efficient policies by reaching their customers' past insurance records and driving history. (122) Furthermore, it can monitor whether it violates the rules already covered by insurance with the blockchain network structure and the data flow provided by IoT technology. Thanks to smart contracts, rules determined between parties are prepared and manipulation is prevented. For some general cases, an automated policy

can be prepared with the infrastructure of blockchain technology, saving time and documentation costs.

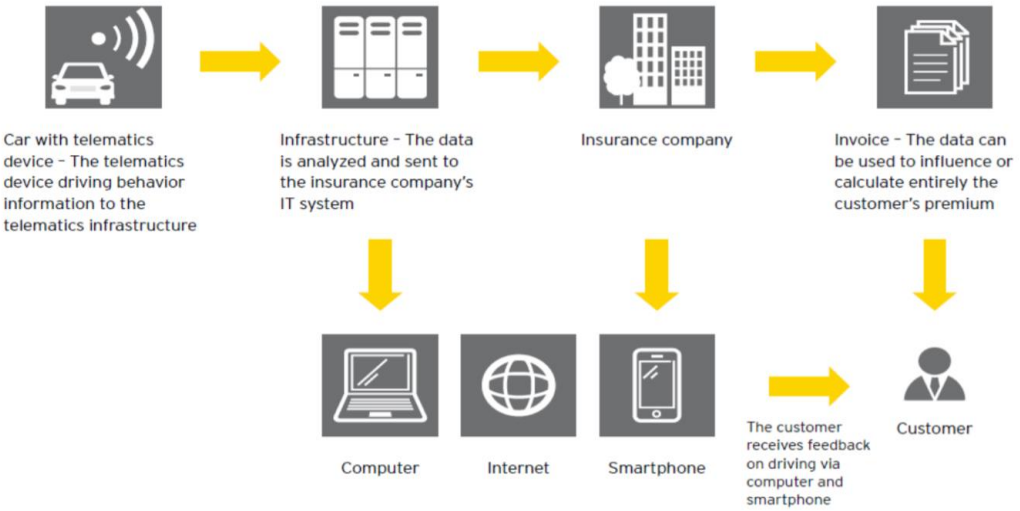


Figure 23 : Process of the Telematic System (123)

According to Oxford Lexico, "Telematics is the technology branch that deals with long-distance transmission of computerized information." (124) According to EY Consulting, "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." (123) The integration between the mobile communications and vehicle monitoring systems can serve as the platform for Usage-Based-Insurance (UBI), Pay-As-You-Drive (PAYD) and Pay-How-You-Drive (PHYD). (125) Accordingly, data such as speed and miles provided by the car in real time are transferred to the insurance company, helping to create profiles of their drivers, and thus insurance companies can modify their policies.

Data Security

The vehicles used today produce, store and share a lot of data depending on their purpose. The storage of these data with a high level of confidentiality and its sharing with the necessary parties are a sensitive issue for both the producer, the customer and the governments. With blockchain technology, data and transactions collected from thousands of sensors in the vehicle can be easily accessed under the authority level of manufacturers, governments and customers, can be stored in a decentralized database and displayed transparently. This prevents the risk of such data being stolen, lost, misrepresented or

destroyed due to a hacker attack, technical problem, natural disaster or similar reasons. Continuous transfer of data collected in smart vehicles or new model vehicles via internet connection or SIM card reveals many weak points in vehicles. Data theft will be prevented, as data received from vehicles with blockchain technology will be stored in more secure environments. (126) Since the data transfer system is distributed to different centers, the probability and potential damage of a cyber or physical attack will be reduced. For example, an autonomous vehicle is prevented from being hacked and controlled remotely by a stranger.

Digital Passport

Digital passport technology, on which many blockchain consulting firms, education and research institutes and startups try to make examinations and developments, and many manufacturers support research, offers companies and customers innovations and opportunities in different fields. The VIN that comes to mind when we say vehicle identification was first used in 1954 and continued to be used without any standard until 1981. Since 1981, the standard 17-character format has been used. (127) Automobile IDs, which contain all the data of the vehicle and the countless processes that it produces in its life cycle, can be stored in a decentralized database in an environment that is accessible to everyone under their authority.

Blockchain-based digital car passports are real-time tamper-proof recording of maintenance activities and other transactions across the entire life cycle of vehicles. For example, all past users and information of the car, car damage and repair records (where, when, how, who?). Thanks to the cryptographic hash process, each vehicle is given a specific digital passport number and it is not possible to tamper this number. In this way, all transactions such as purchases, sales, repairs or insurance can be carried out without any mysteries depending on a realistic passport records. Thus, the fair market value of the vehicles can be calculated and fraud can be prevented. (128)

Recalls

According to CARFAX, 57 million vehicles operating on American roadways have open recalls. (129) In 2009, it was announced that Toyota recalled four million vehicles due to faulty gas pedals and the recall cost was estimated at $ 2 billion. (130) The company has

stated that it has purchased pedals from many suppliers and does not have the mechanisms to track suppliers responsible for faulty pedals. In this respect, there is no way to know which cars have defective pedals. (131)

Automakers can use the numerous data generated in the vehicle to increase customer satisfaction and productivity. In particular, it can analyze the life cycle of car parts in real time, make damage analyzes and improve interior and exterior part designs for future manufacturing. If damaged or prone to breakdown part is found in the vehicle, it can easily recall the vehicle. By capturing customer satisfaction, it increases the dependence on its brand.

A blockchain-based solution can significantly reduce recall costs and transparently monitor the recall process. For example, all the processes and repair documents of the recalled vehicles are reported to the government in the clearest form. Car manufacturers can use authentic digital maintenance records to check the originality of parts and their historical footprints while providing insurance for maintenance service to their customers. Since the VINs of the vehicles are stored in blockchain technology, reaching customers in any recall situation will be much faster and less costly for manufacturers of automobiles and other OEMs. (116)

Transfer of Ownership

In the second hand car market, buyers turn to 3rd party companies to achieve unchanged information and have to believe in the reviews. With the digital passport technology, the buyer can easily reach the unmodified past life cycle of the vehicle, while the vendors can quickly put the fair values of their vehicles on the market. (132) When the ownership of vehicle change, many documents are transferred during the turnover phase. In particular, it is necessary to collect and process documents from different fields such as proof of ownership, proof of sale, financial documents, legal documents and service documents. The blockchain platform provides significant control and accuracy of these flows and prevents any risk of fraud. In addition, with the smart contract structure, all transactions are carried out according to predetermined rules and by providing trust to the parties. If one of the parties has a missing document or money due to the bank, it is detected immediately and the transaction is blocked.

Digital Wallet

Different digital payment and invoicing systems are one of the common trend issues of blockchain and automotive industry, as internet connection will be provided to all vehicles produced in the next 10 years. Thanks to the internet infrastructure in the vehicle, each vehicle's own digital wallet can be created with blockchain technology. One of the major income sources of some states in America is tolls, and according to a study, the money collected from tolls in 2013 was approximately $13 billion. (133) This intensive level of payment and document flow can be performed faster and more reliably with digital wallet. Vehicles will be able to automatically pay toll or parking fees. Even cryptocurrencies transfers can be made between vehicles. Insurance companies or manufacturing companies can reward drivers and transfer micro-level cryptocurrencies to use in different areas such as events, gas station or park if they comply with the rules. (134) An important payment infrastructure is provided for autonomous vehicles that will become widespread in the future and will minimize the relationship with the user.

Supply Chain Management

Blockchain technology can function in every aspect of the automotive industry's supply chain. In short, from raw materials to production, from design to quality control, from development processes to distribution networks, from financial intermediaries to legal authorities, from the marketing process to recall, etc. In each of these processes, tamper-proof data and transactions are recorded continuously in a decentralized database, transferred digitally to each authorized stakeholder and monitored transparently. (135) In order to achieve a fully automated system in payment methods between stakeholders, smart contracts that provide an environment of trust are prepared and costly intermediaries are eliminated.

Blockchain technology let for better observation and association among stakeholders of chain, by boosting efficiency and by the ability to determine the source of a defective shipment of parts or a fixable bottleneck in the supply line. (134) The use of blockchain by manufacturers to improve supply chain management will, in theory, provide constant surveillance of supply, production, and transportation. This will increase the productivity level and reliability of the producers. A large number of parts are supplied and produced in the automotive industry. In particular, different information such as the production time of

each piece, where it was produced, can be easily stored on the blockchain base. Every step in the life cycle of the part, from the part manufacturer to the end customer, is recorded and, in the event of an error, the origin of the error can be quickly identified. Especially since all stakeholders in the supply chain can transparently view the originality of the piece and the stages it has passed, trust is established between the parties.

Having track traceability offers different opportunities to manufacturers. While many information such as maintenance routines, quality control processes, assembly processes and locations of the parts processed and assembled during the production process are recorded and monitored in real time, the documentation of these processes are recorded digitally.

Thanks to blockchain technology, tracking of each parts, products and keeping the connection with suppliers active provides companies convenience and speed in the field of stock visibility or logistics storage. Thus, companies can view their production quantities and needs more clearly. This enables firms to manage the demand and supply relationship correctly and to be successful in production forecasts. Blockchain technology enables companies to manage their production, inventory and logistics systems efficiently, and so, companies can respond quickly to market changes and maintain brand loyalty.

Digital Twin

Another important use case of blockchain is digital twin technology. Digital twin technology is the representation and management of a physical object or process in a digital environment throughout its life cycle. For example, all data in the lifecycle of a part in the vehicle from manufacturer to different customers is copied to its digital twin. Blockchain infrastructure ensures efficient and secure management of data sharing and storage processes. Important information such as service and maintenance processes or ownership histories are copied and stored on the digital twin using blockchain technology. Digital twins are not only used for data sharing and display, but also for analytical solutions and predictive modeling. (136) The combination of blockchain, digital twin, IoT and artificial intelligence technologies is an important investment for smart cities and autonomous vehicles.

It is thought that the odometer of one-third vehicles manufactured in Germany, is illegal interference. For this reason, it is estimated that there is a fraudulent increase of $3700 per

car and around $7.5 billion across Germany. Bosch and TUV Rheinland record the mileage data of vehicles with blockchain technology and transfer them to their digital twin to prevent manipulation of the odometer. (55)

According to Deloitte, 4 items shown below must be implemented together to benefit from digital twin technology; (136)

- IT components transmitting a status or data
- Connectivity in form of bandwidth
- Characterized data architecture running basic analytics
- User interfaces to visualize relevant data

6.3 Blockchain Case Studies in Automotive Industry

Well-known automotive companies have been working on blockchain since 2017. Most of these initiatives are in the pilot phase and open to development. Automobile companies are trying to implement the above-mentioned use cases according to their own strategy.

Some of the giant companies in the automobile industry that maintain blockchain initiatives;

DAIMLER, BMW, MERCEDES BENZ, RENAULT, LAMBORGHINI, PORSCHE, HYUNDAI, TESLA, TOYOTA, VOLKSWAGEN, JAGUAR, MITSUBISHI, FORD, HONDA, AUDI, FCA GROUP, GENERAL MOTORS, VOLVO, BYD AUTO etc.

MOBI

Founded in 2018, MOBI is a consortium consisting of many members with different infrastructures aiming to make the transportation sector more efficient, safer, more transparent and greener by using blockchain and similar technologies. (137) It aims to facilitate the diffusion of blockchain technology and promote standards in adoption of blockchain through research groups, working groups and educational programs. Working groups may involves automakers, blockchain infrastructure platforms, local authorities, non-profit organizations, smart cities, finance providers, consulting firms, research institutes and other organizations. (138)

MOBI partners: Accenture; Aioi Nissay Dowa Insurance Services; ARXUM; Amazon Web Services, Beyond Protocol Inc; BigchainDB; Blockchain at Berkeley; BMW; Bosch; Chronicled; ConsenSys Systems; Context Labs; Cognizant; Continental; Crypto Valley Association; Dashride; Deon Digital AG; Digital Twin Labs; DOVU; Fetch.ai; FOAM; Ford; General Motors; Hyperledger; Honda, Hitachi, Hyundai, IBM, IEEE; IOTA Foundation; Luxoft; MotionWerk; New Cities; NuCypher; Oaken Innovations; Ontario Tech; Ocean Protocol; Outlier Ventures; Quant Stamp; Polito; Riddle & Code; R3; Ripple; Renault; Ride Austin; SBA; Spherity; Shareing; Shift, Spherical Analytics; SyncFab Trusted IoT Alliance; VeChain; Vestella; World Economic Forum; Xain; ZF Car Wallet etc. (139)

MOBI consortium, by preserving privacy it is aimed to set standards on issues such as payment infrastructures, securely data exchange in the automotive sector. Within the scope of the project, it is planned to create a blockchain solution for almost every issue that concerns the automotive industry, from vehicle sharing to autonomous vehicles, by producing APIs.

Members participating in MOBI can access all information and opportunities related to blockchain-based smart mobility. All members have a chance to participate on a working group that offer look at inside of the innovative changes and its impacts afforded by blockchain and distributed ledger. (140) Members will have the opportunity to access the VID (Vehicle Identification) standard offered by the MOBI, and at the same time they will benefit from sponsorship opportunities and innovation platforms.

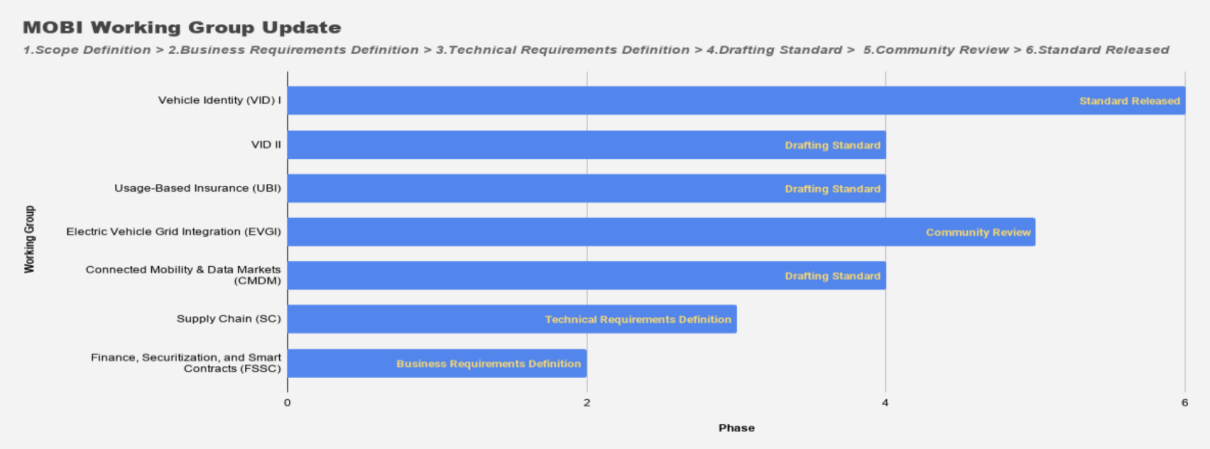


Figure 24 : MOBI Working Group Phase Update — As of September 10, 2020 (137)

This figure shows the different working groups of the MOBI consortium and at what stage they are.

Vehicle Identity Working Group: VID is simply a digital identity that can be cryptographically verified. The VID working group aims to create a blockchain based digital passport for each vehicle and a digital twin to represent it. In this way, important events are recorded throughout the life cycle of the vehicles and a remote control is provided to the vehicles. All vehicle history and data flow are transparently monitored and securely stored with blockchain technology. (141) This system creates an infrastructure for autonomous vehicles in the future supported by IoT technology.

RENAULT GROUP

Renault Group has been continuing its blockchain technology initiatives since 2015. Early studies were related to securely sharing real-time data and transactions in finance. (142) RCI bank, owned by the Renault group, has joined a consortium that conducts financial and technological research in the light of blockchain technology known as R3CEV. (143)

The Renault group started to create a digital car passport for each vehicle by using blockchain technology in collaboration with Microsoft and VISEO in 2017. As part of the project, Microsoft provides access to the Microsoft Azure blockchain technology used to develop and deploy the solution, while blockchain consulting firm VISEO oversees the overall technological implementation and user design of the project. (144) In this way, customers will be able to record all vehicle information and important events in the vehicle's life cycle in a secure and tamper-proof digital vehicle maintenance book.

Information on the events a vehicle has experienced during its use has spread to different areas such as insurers, manufacturers or repair shops. This causes a trust problem between the parties in selling a used vehicle. However, if the vehicle's history is recorded in a digital book that will not be manipulated, authorized car buyers can transparently access all the information of the car they will buy.

One of the other blockchain initiatives of the Renault Group is to document the compatibility between parts and components in the vehicle from design to production, and to facilitate the tracking of the process from the part manufacturer to the vehicle

manufacturer and to ensure the security of the transactions. It is a digital project called XCEED and involves different players in the automotive industry such as Continental, Faurecia, Plastic Omnium and Saint-Gobain. Launched in 2019, XCEED briefly tracks and documents the legal compliance of vehicle parts digitally. (145)

In the automotive industry, where legal regulations, component complexity and costs are increasing, this project aims to increase efficiency and reduce the response time to regulatory authorities. This project is carried out in cooperation with IBM using the Hyperledger fabric blockchain infrastructure. A trial was conducted at the Renault Douai plant with several equipment manufacturers and processed more than one million documents with 500 transaction verifications per second. (146)

MERCEDES BENZ

Together with cloud-based contracts company Icertis, Mercedes Benz announced in 2019 that it has developed a prototype based on blockchain technology to make transaction and contract flow safer and more transparent in increasingly complex supply chains. In addition, the system is to ensure that the standards in the supply chain such as human rights, working conditions, environmental protection, safety and business ethics are controlled in accordance with predetermined contractual obligations. With a transparent tracking system, if any stakeholder does not fulfill the terms of the contract, it is easily detected by the system. According to Sabine Angermann, Head of Purchasing and Supplier Raw Materials at Mercedes-Benz, documents are sent to all stakeholders to provide trust based supply chain network, a more sustainable and ethical communication will be established and purchasing processes will become simpler and faster. (147)

Another application in the supply chain is the transparent monitoring of raw materials or components. It is aimed to clarify origin of the incoming parts and to reduce the complexity in the processes. The quality of the data and the collaboration between suppliers make these processes feasible. (147)

Ocean Protocol, the decentralized data exchange protocol that focuses on data collection, sharing and monetization, announced a pilot project in collaboration with Mercedes-Benz's manufacturer Daimler AG in 2020. The pilot project will include Ocean Protocol's newly

launched "Compute-to-Data" protocol to protect the confidentiality of Daimler's data and will allow the information to be analyzed by third parties. (148)

TOYOTA

Toyota Financial Services joined the R3CEV Consortium in 2016. In the long term, Toyota aims to reduce costs, increase efficiency and make financial transactions more transparent by leveraging blockchain technology for automotive supply chain management and connected vehicle systems. (149)

In 2017, Toyota Research Institute announced that it will leverage blockchain and distributed ledger technology to develop a new mobility ecosystem that will drive autonomous driving technology. Together with TRI, MIT Media LAB and different industry partners, they have established a digital environment where autonomous vehicles and car sharing processes will share test data and evaluate and control of them. According to Chris Ballinger, director of mobility services and chief financial officer at TRI, hundreds of billions of data must be stored, processed and calculated for autonomous vehicles to reach the desired level, and these processes can be managed securely and efficiently with blockchain technology. (150)

With an open source approach to software tools, TRI invites other industry leaders to join the consortium who provide mobility services, work with autonomous vehicles and deal with technological issues such as blockchain. TRI plans to establish a secure environment in data and information sharing between stakeholders with blockchain technology and prevent fraud risks. It also aims to eliminate 3rd party institutions that cause additional fees during transactions. (150)

Some of industry partners; (151)

- *BigChain DB:* Creating data exchange for sharing driving and autonomous vehicle testing data.
- *Oaken Innovations:* Working on application about P2P Car Sharing, mobility token payment and car access.
- *Commuterz:* P2P Carpooling Solution - GEM; Working on Insurance Management Solutions.

- *Aioi Nissay Dowa:* Working on Usage based Insurance Platform.
- *Toyota Financial Services:* Developments for Financial Tools.

TRI continues to work with different industry partners to research the new mobility ecosystem in 3 key areas and develop applications and models.

- Driving / Testing data sharing
- Vehicle / Travel share transactions
- Usage-based insurance

Toyota Systems, IT arm of Toyota Motors, announced in a press release in October 2020 that it has been experimenting with blockchain technology. The firm plans to develop and test digital currency as part of a new pilot project with Japanese cryptocurrency exchange DeCurret. Decurret gets attention as a startup that has received more than $50 million investment. As a result of trials, it is aimed to make payments easier with a digital currency belonging to the company. After evaluating the data it has obtained, Toyota aims to create its own digital currency that will be used in supply chain and B2B (business-to-business) transactions in the future. (152)

According to the press release, the project will involve 2,500 employees at Toyota Systems and will require creating a platform with digital currency payments for employee benefits. According to the statement, the digital currency can be exchanged for gifts or benefit points listed in the catalog.

Toyota Blockchain Lab, a virtual organization consisting of six Toyota group companies, was established in April 2019 to follow the possibilities of blockchain technology, gather information, experiment and take initiatives. (153)

Toyota has been actively researching the blockchain industry since starting its own Toyota Blockchain Lab. Topics of the trials conducted within the Toyota Blockchain Lab; Digital identity for customers-suppliers-tools, diversification of financing methods, efficiency and traceability of business processes in the supply chain, digitization of contracts, improvement of personal information management, P2P blockchain. (153)

HYUNDAI

Hyundai Commercial, interested in the financial services field of Hyundai, announced at the conference "IBM Think 2019" held in 2019 that it will cooperate with IBM to create and develop business models with blockchain technology. As a result of the collaboration, the finance ecosystem in Hyundai Commercial's supply chain will be remodeled with Hyperledger Fabric blockchain technology. Real-time traceability and tamper-proof data flow, one of the most important features of blockchain technology, will provide an environment of trust for automobile manufacturers, dealers and distributors in the chain. By creating an automated system, data sharing in the chain is aimed to be efficient and fast. (154)

In the same conference, Hyundai Card, another affiliate of Hyundai's financial services, stated that they will work on the chatbot in cooperation with IBM to provide customers with a higher quality support system with its artificial intelligence and machine learning infrastructure. The chatbot named Hyundai Card Buddy simplifies complex customer service needs with IBM Watson's artificial intelligence algorithm and creates an environment to quickly answer frequently asked questions. (155)

Hdac Technology, the blockchain arm of South Korea's largest automaker Hyundai Motor Group, announced a $10 million blockchain investment fund in October 2019. The funds will help launch the main network of the project, develop decentralized applications, support new industry initiatives, and create a cryptocurrency compensation system. (156)

Hdac and its supporter Hyundai announced in 2019 that they had completed a proof-of-concept (PoC). The firm also revealed details of its new Proof of Stake (PoS) based blockchain platform for building smart homes, payments, and Internet of things (IoT) projects. PoC will provide data integrity, security and real-time monitoring of automobile manufacturing. The company plans to achieve these goals with its new blockchain platform called 'Friday'. On the other hand, Friday Consensus is a scalable, secure and decentralized consensus algorithm. Aim is that make smart contracts scalable and fast, making them suitable for IoT and payment services. (157)

Blockchain audit firm CertiK and Hdac signed a contract for collaboration after serving out a control in the Hdac's Friday desing. With this partnership, they aim to provide high levels of security, quality design and storage space in blockchain-based IoT systems. (158)

Hyundai Autoever, an ICT company of Hyundai Motor Group, entered the blockchain industry in 2019. Hyundai Autoever announced it will work with Lambda 256 and Blocko to track the history of used cars like a digital car passport with blockchain technology. Through this, 3 companies plan to jointly develop and promote various businesses in the automotive industry, including building a blockchain platform. As the first step of this plan, they aim to develop a BaaS platform that enables fast and easy implementation of blockchain technology. In this way, solutions such as block chain in SCM, smart contract and crypto wallet are offered to businesses. (159)

Hyundai aims to use blockchain technology to pair electric vehicles with smart devices. In this way, car users will be able to benefit from performance tuning technologies in the vehicle via a smartphone. With blockchain technology, the settings made by the drivers will be stored on secure servers. Drivers will be able to adjust seven performance characteristics of the motor, such as maximum torque output, acceleration and deceleration capabilities, regenerative braking capability, maximum speed limit, responsiveness, and energy use in climate control. (160)

Hyundai embraces the blockchain and crypto industry with three trademark registrations. According to news in the South Korean media house Chosun, Hyundai BS & C's CEO Chung Dae-sun says that they applied to intellectual property authorities for brands Altum, Atolo and Rizon. Hdac and BS&C Hyundai plan to launch a blockchain ecosystem. The firm claims to provide services such as crypto trading, crypto ATMs, crypto-related hardware, crypto issuance, and that these services can include essential functions such as Dapp, storage and transmission, which are essential for a Proof-of-Stake ecosystem. (161)

BMW GROUP

In 2018, Automotive firm BMW announced that it will use blockchain technology to track odometers of its rental vehicles in collaboration with London-based blockchain startup DOVU. One of the important sources of income for BMW is corporate car rental. It wants to benefit from blockchain in matters such as determining the mileage and damage amount

of vehicles. DOVU, which started working with BMW, opened ERC-20 tokens and blockchain-based odometers for testing purposes. Announcing that the first pilot implementation took 10 weeks, the officials stated that new blockchain studies will be actively carried out at the BMW Company's headquarters in London. (162)

In VeChain Summit 2018, the BMW Group announced that they are working together with VeChain for the blockchain-based VerifyCar application. The main purpose of VerifyCar application is to record historical information of each vehicle and events encountered in its life cycle as an immutable digital passport. In this way, sellers can transparently transfer the entire history of their cars to the buyer in second-hand car sales. Some information of the car such as accident, damage, maintenance, mileage and service are stored and verified on private secure servers with blockchain technology. (163)

In March 2020, the famous car manufacturer BMW announced the PartChain project. According to this announcement, the platform called PartChain was successfully tested by BMW in 2019 for the purchasing and tracking processes of the front lights of cars. PartChain uses the Hyperledger Fabric blockchain technology as well as Amazon Web Services and Microsoft Azure cloud services. PartChain offers blockchain technology in an increasingly complex international supply chain network in the automotive industry. It aims to ensure that the automotive part or component in the supply chain can be monitored transparently in real time and data flow is securely maintained. Andreas Wendt, head of purchasing and procurement at BMW AG, announced that 10 suppliers were selected for the project, but more members will join in the coming years. The company aims to ensure the safe data and information flow in the supply chain in the long term. (164)

In the last quarter of 2019, BMW and logistics provider DHL worked on a blockchain proof of concept for a real-time tracking system across the supply chain network of parts shipped from Malaysia. In the platform, stakeholders can transparently access the data they are authorized to. Thanks to the visibility of orders in the supply chain, where there is a data flow that cannot be manipulated, they aim to reduce costs and reach efficiency in inventory management. (165)

BMW develops pilot projects to prevent fraud, ensure the digital documentation process and track the sources of raw materials such as cobalt and wolframite, which are difficult to traceable because they come from the mines of different countries. (163)

BMW, for drivers of electric cars and plug-in hybrids, carries out the ChargeChain project in order to carry out the charging processes in a most comfortable way. When drivers use any charging station that they are not authorized to, their transactions are guaranteed with smart contracts. Thanks to the blockchain technology, intermediary banks are not required for the monetary transactions of charging stations. (163)

FORD

The need for batteries used in electric cars is increasing. Companies strive to extract raw materials such as cobalt used in battery production in the most efficient way and to supply them safely. In January 2019, IBM announced a plan to establish a consortium, whose members are Ford, Huayou Cobalt, LG Chem and RSC Global, and whose objectives will ensure transparency in the supply chain of cobalt and some minerals. According to the announcement, cobalt mined in the Huayou area goes to LG land in South Korea to be used in battery production. Later, the battery goes to the Ford manufacturing facility for assembly. The supply chain process of cobalt is monitored in real time and an atmosphere of trust is established between stakeholders. (166)

Ford announced in October 2019 that it has pilot projects using blockchain and geofencing technology to promote cleaner air flow in city centers and to make vehicles run more efficiently in low-emission city centers. Tests are carried out in London and Valencia to maximize the environmental benefits of Transit Custom Plug-In Hybrid vehicles being tested in Cologne. Emission test data and green mil data in real use cases of energy-saving vehicles are tracked and secured with blockchain technology. (167)

TESLA

Cargo Smart Company announced in April 2020 that they launched a blockchain pilot project leveraging Hyperledger Fabric with Tesla, Cosco Shipping Lines and Shanghai International Port. The first pilot project was planned between ocean carriers and terminal operators to speed up Tesla's cargo release process. The verification steps of sea waybills in ocean carriers, consignees and shipping agents are optimized with blockchain technology. Trucks receive their cargo faster from the terminal and senders view the entire process transparently. In complex global maritime transport, it is aimed to prepare an efficient and real-time control platform by ensuring the digitalization of documents, data and processes.

After the successful pilot, it is aimed to spread the technology to different terminals and to ensure the active participation of all stakeholders throughout the supply chain. (168)

GENERAL MOTORS

In April 2020, General Motors did a patent application called "Decentralized Distributed Map Using Blockchain" to the Patent and Trademark Office in US to use the blockchain in self-driving cars. It is aimed to secure the infrastructure of the maps prepared in self-driving vehicles with blockchain. Thus, the system, which enables route creation by moving away from barriers, thanks to the data flow from GPS and sensors, remains connected to a decentralized database. The data that analyzes and applies the most suitable environmental conditions for the vehicle is stored with blockchain technology in an immutable way. After transferring the information of the navigation maps created with the data collected from the environment while the vehicles are in motion, the system checks whether there is any inconsistency between the data. (169)

DAIMLER

Founded in 2018, Daimler Mobility Blockhain Factory explores blockchain technology in depth and seeks solutions on how to integrate it into processes. At the same time, pilot applications are prepared in different use cases; (170)

- *Mobility Services* (Pay per Use, Dynamic Leasing, Hardware Wallet, Smart Contracts, Digital Booking and Invoicing Process)
- *SmartVIN* (Digital Car Passport: Entire History of odometer readings, delivery data, registration data, maintenance data etc.)
- *Supply Chain* (Smart Contracts among shareholders, transparent information flow etc.)
- *Tokenization* (BBVA; Reward tokens for staff, Commerzbank; Daimler Truck Wallet to make payment with e-euros)

There are 4 startups examining blockchain technology on the platform; (171)

- *51 Nodes:* Blockchain programming and architecture, *Spherity:* Digital Identity
- *BlockchainHELIX:* Know your customer logic in blockchain technology
- *Riddle & Code:* Hardware wallet for calling up vehicle data

LAMBORGHINI

Global CRM firm Salesforce announced in November 2019 that it will provide Hyperledger based blockchain service to giant automotive firm Lamborghini. According to the statement, blockchain technology will be used for verification of Lamborghini heritage cars quickly and securely. The certificate documents of all transactions in the resale of Lamborghini cars can be monitored and verified by blockchain service. According to the statement, when a Lamborghini is sold, approximately 1000 certification reviews are conducted in Lamborghini headquarters in Italian Sant'Agata Bolognese. In order to record and verify the full history of Lamborghini vehicles, it is necessary to work with many different partners such as photographer, auction houses, dealers, repair shops, media sources during the certification process. Ownership of the cars and other service records are all recorded in an immutable way in the blockchain system and fraud attempts are prevented. In August 2019, the Lamborghini Aventador S with street art design received Sales Force blockchain certification to be protected in Monterey Car Week. (172)

VOLKSWAGEN

Volkswagen announced in April 2019 that they launched a pilot project with Technology Company Minespider using blockchain technology in the raw material supply chain. It is aimed to transparently trace the supply chain process from the origin point of the raw material to the production site, to ensure safety conditions, to eliminate bottlenecks, and to comply with social and ecological standards. Suppliers that meet more than two-thirds of the lead starter battery requirements will be involved in the pilot project. In the future, Volkswagen group aims to step into more pilot projects to optimize and secure supply chain processes. (173)

In April 2019, Volkswagen became a member of an open industry collaboration platform established by Ford Motor Company, Huayou Cobalt, IBM, LG Chem and RCS Global in order to supply strategic minerals by following the ethical rules. With this participation, Volkswagen will benefit from transparently monitoring all supply transactions of the important minerals used in car production and cobalt used in the production of lithium-ion batteries for electric vehicles throughout the supply chain and getting accurate information about the origin of the raw material. Efficiency, sustainability and transparency in the global

mineral supply chain provide significant gains for automobile companies and comply with the responsible sourcing standards set by the OECD. (174)

PORSCHE

In a press release in February 2018, Porsche announced that collaboration with Berlin-based startup XAIN, they have begun testing blockchain applications on vehicles. Among the use cases, there are applications based on encrypted data logging, such as temporary access rights, locking and unlocking to vehicles via an application, improving autonomous driving functions. According to Oliver Döring, Financial Strategist at Porsche, with blockchain, important steps can be taken to meet customer needs by providing more secure and faster data flow. Cars can be commanded directly through the blockchain, without the need for a routing server or an online connection. Application have tested, the remote opening and closing time of the vehicles is approximately 6 times less, and it is completed in 1.6 seconds securely and encrypted. By storing immutable data, access authorization transactions can be viewed in real time and digital documentations are provided. According to Uwe Michael, Vice President Electric / Electronic Systems at Porsche, with smart contracts that do not need intermediaries, identification and payment transactions at charging stations can be carried out in a safer and easier way. (175)

Porsche has created a prototype with Dutch and German blockchain experts to quickly and easily pay parking fees with blockchain technology. Porsche act as a gateway who unlocks the virtual vehicle for service providers. With RFID, electromagnetic waves and blockchain technology, vehicles do not go to any payment point when leaving the parking lot, the parking fee is sent directly to the blockchain wallet and the transaction is securely recorded. (176)

Gapless, one of the startups that Porsche has invested $5.9 million in, gives vehicle owners the chance to access and manage the information of all their vehicles digitally. All past transactions of the vehicles are securely stored. The system notifies the drivers for events like service appointments automatically. Third party companies such as insurance companies are included in the ecosystem and a comprehensive digital network is created. (177)

In the Blockchain Expo Amsterdam 2019, Porsche's Claudia Welch said Porsche has developed a pilot project based on the Ethereum structure of blockchain technology. The main purpose of this project is to monitor and securely record the leathers used in vehicles throughout the supply chain. In order to manage process more efficiently, efforts to reach agreements with the suppliers on the chain continue. (178)

In the December of 2018, Porsche and BBVA announced that acquisition term loan can be arranged through blockchain technology. Porsche successfully closed a $170 million loan backing strategic acquisition with BBVA by using blockchain technology. With blockchain, negotiation processes are automated and operational risks are reduced. Customer satisfaction increases due to the faster financial transactions and safer documentation processes. Long-term strategic relations between the two institutions are strengthened in an environment of trust. (179)

In the November of 2020, Porsche and Circularise announced that they will use blockchain technology to track plastics used in the automotive industry with suppliers Borealis, Covestro and Domo Chemicals. Circularise set up a system to track materials and CO2 footprints with a digital definition throughout the supply chain. Each material group is copied to the blockchain by digital twin technology, which carries information such as origin and batch. With the digital twin technology, companies can reflect their physical procurement processes to the virtual environment and update their production processes. With the participation of different stakeholders in the supply chain, the process is implemented in a transparent manner. Thanks to the system, it is aimed that producers make better decisions and maintain the ecological balance while ensuring the sustainability of the material flow. (180)

6.4 Blockchain-Based Automotive Supply Chain

6.4.1 Existing Automotive Supply Chain

The events taking place in the automotive supply chain during the process of raw material extraction and reaching the customer are in a complex structure because they are multi-stage and difficult to follow. Parts, components, information and money transfers take place between stakeholders such as suppliers at different levels, transporters, warehouse, local

authorities, manufacturers, banks, distributors, ports, shippers, dealers, customers, while material, human, technology and management resources must be managed efficiently. Resources and components involved in all activities carried out in the supply chain process are converted into products and delivered to the customer at the last stage. Each link of the chain regularly monitors each other and provides feedback. Throughout the chain, stakeholders have to establish strong communication with each other and properly manage business processes such as production and stock management, distribution, procurement, sales, marketing and customer relations.

Relationship between Tier1 and OEM

There are numerous information flow between Tier1 supplier that enlarge the added value of products and OEM in the global supply chains ; inventory situation, number of sales and forecast data, order status for tracking, manufacturing/delivery schedule, performance metrics (quality data, operation efficiency, machine setup time, on time delivery, lead times etc.)

The supply chain network of the automotive industry has a tiered structure similar to the figure shown below.

Figure 25 : Automotive Supply Chain (181)

Tier 3 Suppliers: Tier 3 level companies manufacture and supply the most basic parts or components used in automobile manufacturing. For example, processed components and

materials such as glass and steel, processed raw materials such as metal and plastic, cables, gaskets, buttons, brackets etc. Its customers include Tier 1, Tier 2 and OEM. Firms such as U.S. Steel, Kobelco, Fuyao Glass, or Fengfan are examples of Tier 3. (182)

Tier 2 Suppliers: Tier 2 level companies supply parts or components used in car production to Tier 1 level companies such as pump units, electric motors or bearing assemblies, car window motors, door handle mechanisms, or heat exchangers. However, as Tier 2 companies specialize in their own field, they supply parts or components not only to the automobile industry but also to companies in other sectors. Firms such as Osram, ITR USCO, Minth Group, Stanadyne, and Zexel are examples of Tier 2. (182)

Tier 1 Suppliers: Tier 1 level companies supply important parts, components or systems directly to the OEM such as powertrains, suspensions, chassis, entire engines, gearbox. These specialist companies have a long lasting and strong relationship with OEMs. Some companies are able to service multiple OEMs and even have the capacity to manufacture a car like an OEM. Firms such as Borg-Warner, Bosch, Continental, Hitachi are examples of Tier1. (182)

OEMs: These manufacturers design cars, manage the procurement process, manufacture original equipment, assemble the final product, distribute cars, and deal with customer relations. Some software in the design part is made by the suppliers. OEMs manufacture the final cars in their own factories, but sometimes purchase the final car from other manufacturers and put a label on the car. (183)

3PLs: 3PLs will distribute the produced vehicles to storage centers and vehicle distribution centers located at numerous locations. Then, the vehicles are sent to the dealers according to the sales amount and inventory status. (181)

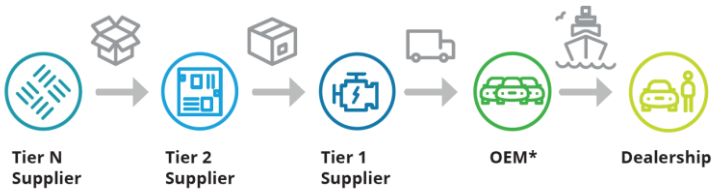
Dealers: Retail centers, which are mostly independent of the car manufacturer and whose job is to sell vehicles to customers, are called dealers. Dealers also deal with activities such as after-sales customer service and maintenance and repair of vehicles. (183)

6.4.2 Design of Blockchain-Enabled Automotive Supply Chain

The impressive technological steps brought by Industry 4.0 have started to transform the automotive industry from different angles, and major systems such as business models,

human resources and supply chain continue to be affected by these changes. Key strategies such as stock and demand management, just in time, quality management and customer relations on the supply chain require significant visibility and a fast response system. For the strategies to continue in the global automotive supply chain in an appropriate way, it is necessary to identify the problems encountered, to provide feedback and to detect the source of the problems quickly. For example, OEMs do not have an adequate tracking system for the operations and procurement process of most tier 3 suppliers, especially depending on the quality and utilization capacity of the raw materials. Blockchain technology is a considerable potential, especially to establish a trust-based relationship between stakeholders in the automotive supply chain, to manage strategies efficiently, and to increase the traceability of material, information and money flows.

Automotive Supply Chain Today



Automotive Supply Chain Tomorrow

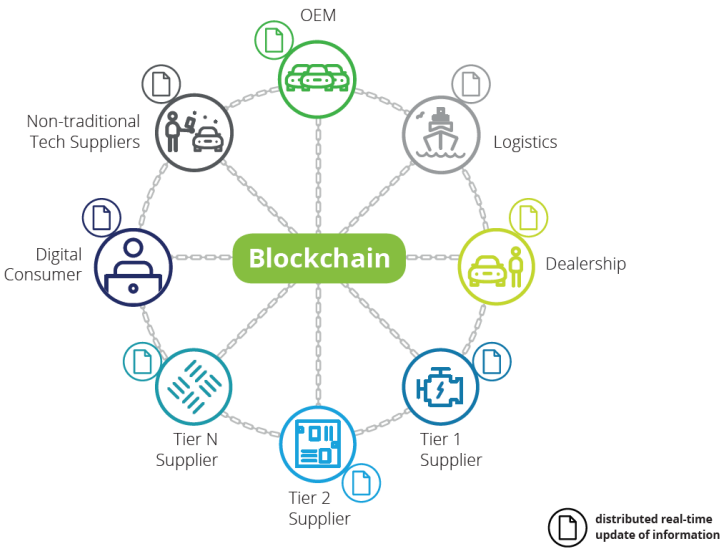


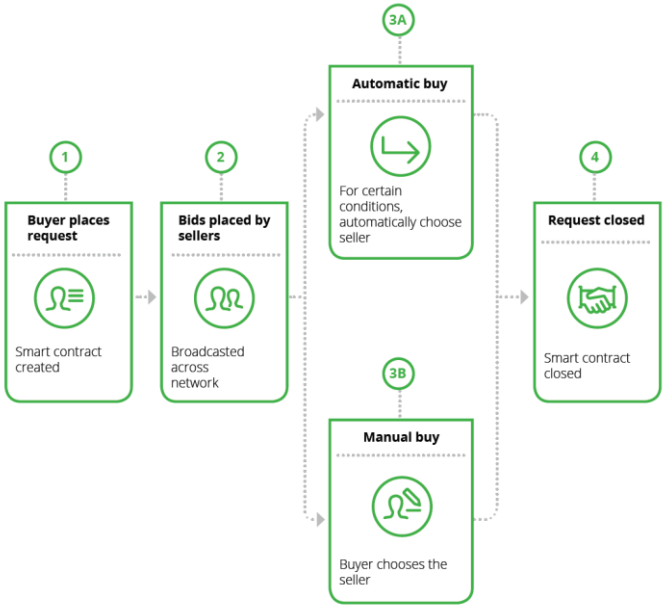
Figure 26 : Automotive Supply Chain Today & Tomorrow (184)

In the tomorrow case; data is shared between stakeholders in the supply chain in real time, and smart contracts with predetermined rules are used to manage transactions. Data or transaction transfers between stakeholders are securely recorded and copied to stakeholders in a decentralized database.

In a blockchain-based platform, there is a strong communication network between stakeholders. Suppliers can contact among themselves, or OEMs quickly flow data and information with all suppliers. Visibility in terms of product origin and quality is increased at all levels and the system is monitored transparently in real time. Documents such as product information, invoices and contracts used in the processes are digitally managed and stored in a tamper-proof way. All transactions and ownership information are recorded on a decentralized platform and distributed to stakeholders. With real-time data updates provided by blockchain, the costs of recall operations, analytical forecasts and rapid feedback are significantly improved and risk potentials are reduced.

Smart contracts that can be used for raw material or part transfer automatically perform important functions such as purchasing, demand management, payment among stakeholders. Supply, demand, stock and payment information, government resource policies should be updated to the smart contract system. Smart contracts save time and money and thus, ensure the efficient implementation of the procurement process. It prevents conflicts by removing intermediaries from processes and creates a trust infrastructure.

It is not always easy to determine who is responsible for the problems, disruptions, delays or bottlenecks that occur in the automotive supply chain, which has many different stakeholders and has a global trade flow. Blockchain technology provides real-time tracking in the supply chain and, thus location and ownership information is transferred to smart contracts. As a result, the responsible persons are determined and the penal clauses previously added to the smart contract are automatically applied.



1.Oem creates a request to buy raw material identifying some criteria such as delivery date, quality, price, payment method etc.

2.Suppliers are updated of the request and submit bid including details

3.Supplier is chosen by method of automatic (e.g. First supplier to meet OEM's requirements) or manual

Figure 27 : Using Smart Contract Technology in Procurement of the Raw Material (184)

The diagram shows how to quickly supply products and prepare an automated contract for OEMs having different suppliers, using blockchain technology and smart contract structure.

Major Gains

Traceability

- Monitoring the life cycle of every part from raw material to the final product, recording every step and proving its originality.
- Digital display of parts' production, maintenance, quality control, shipment and assembly information.
- When product arrive its destination, automatic and digital sharing of its certificates and invoices.
- OEMs ability to adequately monitor the tier 3 level suppliers' operations (raw material quality and capacity, procurement process etc.).
- With real-time traceability, problems and sources of problems in the supply chain can be identified quickly (Find the responsible supplier, find the problematic product, find the problematic process).

Trust

- Smart contracts provide automatic and reliable transactions between stakeholders in product transfer and payment processes without the need for intermediaries.
- Ensuring an environment of trust between stakeholders arising from transparent monitoring and recording of material, information and money flow between stakeholders.

Visibility and Communication

- Providing significant efficiency in supply chain processes such as inventory management, distribution, logistics or production due to rapid communication between stakeholders.
- Correct management of supply-demand relationship and production forecasts by increasing visibility in production.
- Thanks to the high degree of control power in the supply processes, rapid response to market changes, ensuring customer satisfaction and increasing brand image.
- Fast detection of vehicles containing damaged parts, reporting to the service and tracking the process status.

Security

- Unable to hack data and records thanks to its decentralized ledger structure.
- Prevention of manipulation and corruption processes due to chain linking of cryptographic encrypted data.
- Monitoring transactions and data flow according to authorization or access permission.
- Ensuring the management and storage of high-volume transactions in connected vehicles that generate 25 GB of data per hour.

7. Economic Analysis of Creation of Blockchain-Based Automotive Supply Chain

7.1 General Framework of Supply Flow

There are around 2000 large parts or components in the production of an average vehicle. However, these parts and components contain many small parts in themselves. Therefore, around 30,000 parts are used in the production of the average a vehicle. In the production of a standard vehicle, there are approximately 5000 different welding processes to assemble parts together. (185)

An Example: More than half of the parts in vehicles manufactured in the UK in 2017 are imported. For example; Land Rover Model; Power steering systems, engine block, torque converter in Germany, electronic control units in Romania, shock absorbers in Poland, Coolant Hoses in Czech, Front Lighting in France, Ventilation Ireland, Exhaust Manifold in Hungary etc.) (186)

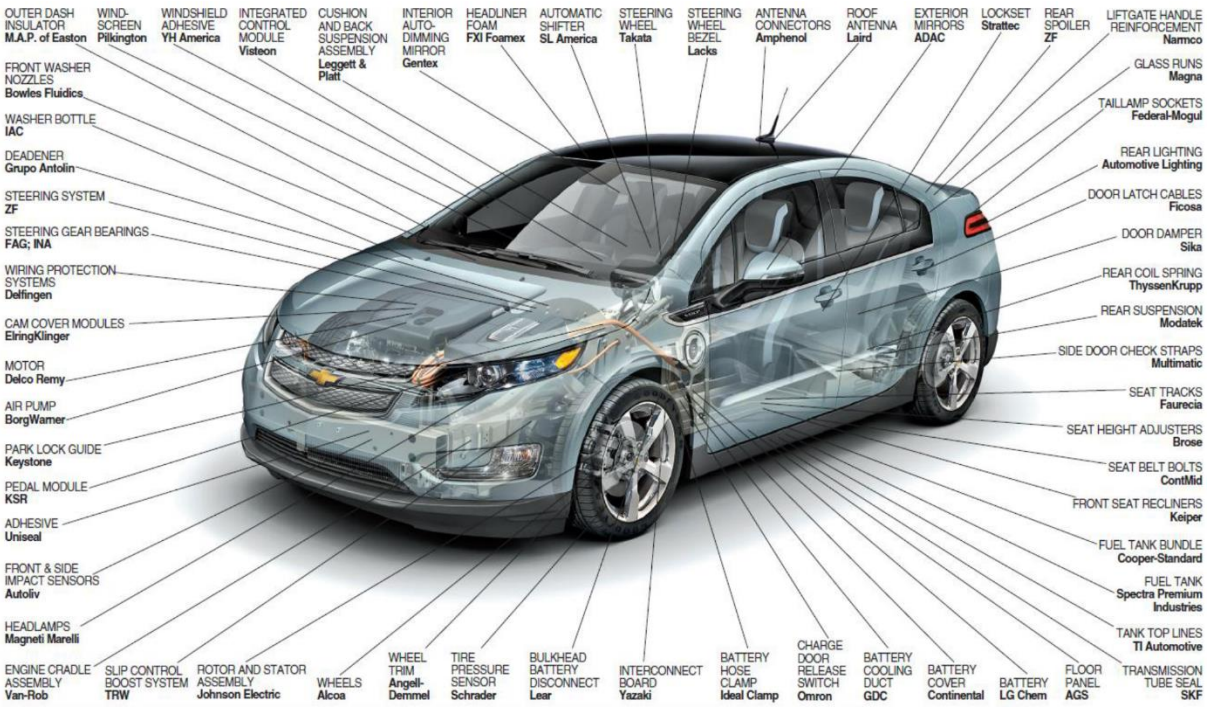


Figure 28 : Main Suppliers of the Important Parts used in the Production of the 2011 Model Chevrolet Volt (187)

According to Statista: In 2019, approximately 95 million motor vehicles were produced worldwide. Roughly 26.5% of vehicle production took place in China, 13.3% in the US, 10.5% in Japan and 5.9% in Germany. (188) ***According to OICA:*** In 2017, Toyota produced about 10.5 million vehicles, Volkswagen about 10.4 million, Hyundai about 7.2 million, GM about 6.9 million, Ford about 6.4 million and Nissan 5.8 million. (189)

This huge flow of parts and components in the automotive supply chain is vital. Thousands of different suppliers, manufacturers, 3PLs or dealers must work together efficiently on this network. Otherwise, different parameters such as production delays, shortage of inventory, uncertainty in part quality can cause many important problems such as decrease in revenue and loss of customers.

Blockchain technology have many use cases in the supply chain, and usage scenarios vary according to the needs of companies. Stakeholders such as suppliers, logistic providers, OEMs, dealers, digital customers and recall services, who carry out numerous transactions within the supply chain, are located in many different regions. Parts and product flows in global supply chains can accommodate different stakeholders as well; transporters and distributors, 3PLs and freight forwarders, warehouses, custom and local authorities, financial institutions, export ports-import ports and terminals, ocean carriers etc. The diversity of stakeholders varies depending on the structure of the vehicles produced and the capabilities, ecosystem or assets of the manufacturers.

Supply chain processes that can benefit most from blockchain technology can be listed as follows;

1) Tracking a specific raw material along the supply chain

- Tier3-Logistic Provider-Tier2
- Tier3-Logistic Provider-Tier1
- Tier3-Logistic Provider-OEM

2) Tracking a specific part or component throughout the supply chain

- Tier2-Logistic Provider-Tier1
- Tier2-Logistic Provider-OEM
- Tier1-Logistic Provider-OEM

3) Tracking the vehicles produced throughout the supply chain

- OEM-Logistic Provider-Dealer
- OEM-Logistic Provider-Dealer-Digital Customer
- OEM-Logistic Provider-Dealer-Digital Customer- Recall

4) Tracking a specific series of vehicles to be produced along the supply chain

- Tier3-LP-Tier2-LP-Tier1-LP-OEM
- Tier3-LP-Tier2-LP-Tier1-LP-OEM-Dealer
- Tier3-LP-Tier2-LP-Tier1-LP-OEM-LP-Dealer-Digital Customer

7.2 General Framework of Economic Analysis

7.2.1 Forrester Case Study - Total Economic Impact of IBM Blockchain

In the study conducted by Forrester, blockchain use case data of 6 IBM customers were taken into account. The customers are; Alectra Utilities, Interac Cooperation, Chainyard, we.trade, SecureKey, Global Transport and Logistics Company. The blockchain use cases of the interviewed companies are different and the implementation processes have not been fully completed yet. (190)

The designed benefit and cost modules have been prepared by utilizing from the different blockchain use cases of the interviewed companies and generalized in a simple framework. For this reason, the stated parameters may differ in the calculations of companies that want to benefit from blockchain solutions.

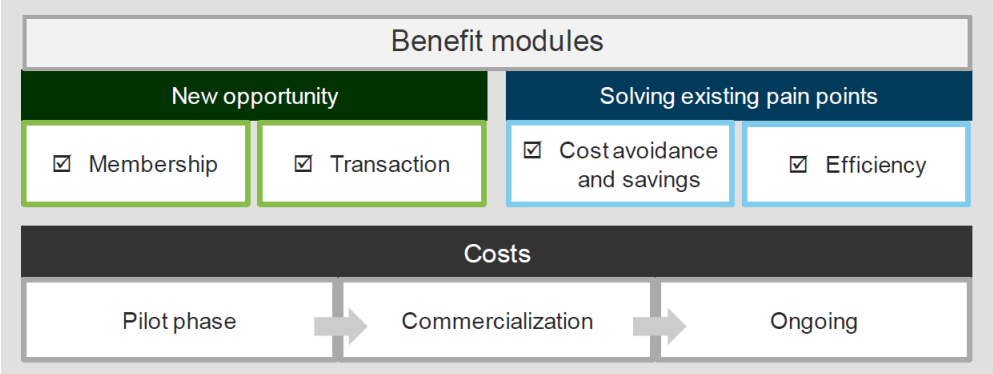


Table 4 : Forrester Case, Benefit and Cost Modules (190)

According to the study prepared by Forrester after the negotiations with the companies, the general benefit and cost parameters of the companies are as follows.

Benefit Modules

Membership Revenue: The company that creates the blockchain network can receive membership fees from other companies participating in the network and create a source of income.

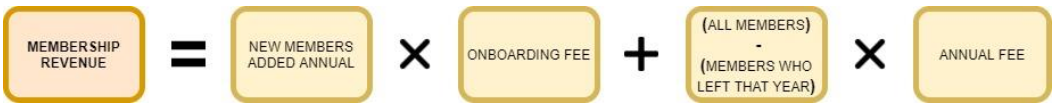


Figure 29 : Forrester Case, Membership Revenue

Transaction Revenue: The company that creates the blockchain network can charge a fee per transaction made by other companies participating in the network and generate a source of income.

Figure 30 : Forrester Case, Transaction Revenue

Capex and Opex Savings: The company that creates the blockchain network can access the resources of other companies participating in the network and benefit from common use. This situation enables companies to save capital and operating expenses. The level of savings to be achieved varies according to the type, size or frequency of investments that companies will avoid thanks to blockchain. Infrastructure costs are grouped into taxes, shipping, special accessories and special tests, and are calculated as 30% of capital expenses. Operating costs are calculated as 20% of the sum of capital and infrastructure costs.

Figure 31 : Forrester Case, Capex-Opex Savings

Efficiency Savings: Improved documentation processes, simplified new platform and reduced worker requirements provided by blockchain technology offer companies with additional efficiency.

Figure 32 : Forrester Case, Efficiency Savings

Streamlined Documentation: Companies that adapt blockchain technology manage their documentation processes in an immutable, controlled and digital manner. In this way, both the error correction costs of the documentation in the old system are avoided and the documentation costs of the old system are reduced with the digital infrastructure.

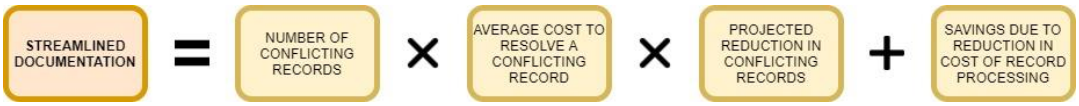


Figure 33 : Forrester Case, Streamlined Documentation Saving

Reduced Legacy System: The license or usage costs of the system or software used in processes such as monitoring, tracking and invoicing are removed with blockchain technology provided by IBM, or their usage areas are reduced.

Figure 34 : Forrester Case, Reduced Legacy System

Labor Cost Reduction: Companies using the IBM blockchain system benefit from improvements in documentation processes (reduced paperwork, number of inconsistent records, number of conflicting records) and resource utilization(reduced number of checkpoints, human error), resulting in a reduction in labor costs in finance and legal departments.

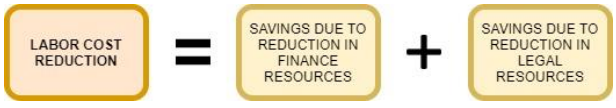


Figure 35 : Forrester Case, Labor Cost Reduction

Cost Modules

Pilot Phase Costs: During the pilot phase, companies can pay consulting fees to IBM to produce a viable idea, design or a prototype. In this process, companies create cost space by assigning project-based tasks to their internal IT and legal, business employees. The pilot phase usually drives between 6 months and 1 year.

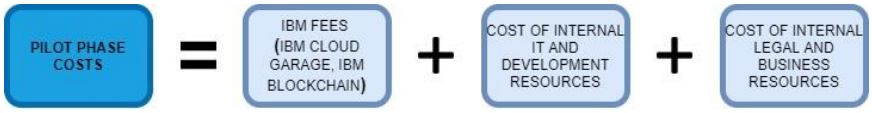


Figure 36 : Forrester Case, Pilot Phase Costs

Commercialization Phase Costs: In this phase, companies can participate in IBM design workshops to adopt their ideas and develop supportive ideas. More internal resources (IT, legal and business) and more intensive work are needed to develop a fully commercialized product. In addition, companies may have to bear some costs in finding and including members to blockchain network (including marketing, admin, contract negotiation etc.). The contract phases with the members who will join the network must be managed well. Commercialization phase drives about 1-1.5 years.

Figure 37 : Forrester Case, Commercialization Phase Costs

Ongoing Phase Costs: In this phase, companies pay a fee to IBM both for license and for benefiting from new updates. In order to operate the software processes of blockchain technology and to continue the governing and legal processes, fees continue to be paid to the internal resources. Companies may have to bear some costs in finding and including members to blockchain network (including marketing, admin, contract negotiation etc.), and there may be costs to create an ecosystem in the blockchain network. (Managing member relations, organizing activities and workshops, members' commitment etc.)

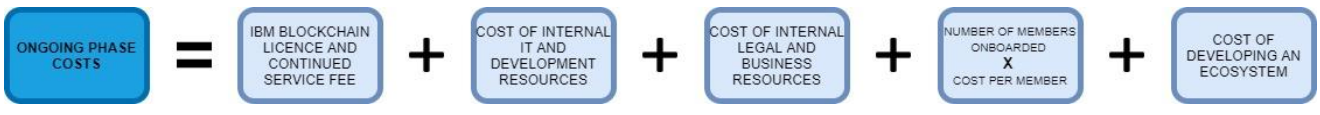


Figure 38 : Forrester Case, Ongoing Phase Costs

7.3 Sample Case: An Automotive Firm Integrating Blockchain-Driven Supply Chain

-For the analysis and calculations to be made in this part, the general calculation logic of Forrester shown above will be taken as the basis. Some calculation methods have altered from diverse angles and alternative parameters have added.

-Various parameters will be used while conducting economic analysis. Parameters and data used in calculations may vary depending on the businesses and the blockchain use cases. For this reason, calculation methods can be changed or parameters can be decreased and increased in line with the goal of companies. Businesses do not have to use all parameters together.

-The data used in the calculations are estimated, not based on any real case.

Parameters

Revenue	Cost
R1 Blockchain Revenues	**C1 Pilot Phase**
1.1 Membership Revenue	**1.1 Design**
1.1.1 Onboarding Fee	1.1.1 Design Thinking workshop
1.1.2 Annual Fee	1.1.2 Architectural consultancy
1.2 Transaction Revenue	1.1.3 Software development fee paid to IBM
1.2.1 Price per Transaction	**1.2 Cost of internal IT/developers' pilot efforts**
	1.2.1 IT/dev/engineering employee fee involved in pilot phase
R2 Capex Opex Saving	**1.3 Cost of internal governance model/legal pilot efforts**
2.1 Shared Resources Saving(worker,plant,warehouse)	1.3.1 Legal, business owners, IT management fee developing governance model/involved in contract negotiation
2.2 Opex Saving	
2.3 Tax Saving	**C2 Commercialization Phase**
2.4 Transportation Saving	**2.1 Blockchain**
2.5 Testing Saving	2.1.1 Blockchain full development fee to IBM
	2.1.2 IBM Blockchain license fee
R3 Efficiency Saving	**2.2 Cost of internal IT/developers' commercialization efforts**
3.1 Streamlined Documentation	2.2.1 IT/dev/engineering employee fee involved in commercialization phase
3.1.1 Reduce Conflict Records	**2.3 Cost of internal governance model/legal commercialization efforts**
3.1.2 Reduce Record Cost	2.3.1 Legal, business owners, IT management fee developing governance model/involved in contract negotiation
3.2 Reduced Legacy System	**2.4 Cost of member onboarding**
3.2.1 Saving Software Licence of Tracking and Billing	2.4.1 Cost of onboarding members (including marketing, admin, contract negotiation)
3.3 Labor Cost Reduction	
3.3.1 Saving Finance Employee solving conflict	**C3 Ongoing Phase**
3.3.2 Saving Legal Employee solving conflict	**3.1 Blockchain**
3.4 Fraud Avoidance	3.1.1 IBM Blockchain license fee
3.4.1 Reduce Fraud Transaction	3.1.2 Continued Blockchain software development fee
3.5 Reduce Time to Market	**3.2 Cost of internal IT/dev/engineering resources to run blockchain**
3.5.1 Saving Late Market Inventory Cost	3.2.1 IT/dev/engineering employee fee involved in ongoing phase
3.5.2 Increase Number of Reached Customer	**3.3 Cost of internal governance model/legal resources to run blockchain**
3.6 Reduce Global Trade Cost	3.3.1 Legal, business owners, IT management fee developing governance model/involved in contract negotiation
3.6.1 Acquiring new partners	**3.4 Cost of member onboarding**
	3.4.1 Cost of onboarding member (including marketing, admin, contract negotiation, other)
	3.5 Ecosystem development (workshops, organizing activities, member relations, community boards, other)

Table 5 : Parameters of Example Project

Membership Revenue

Membership revenues from stakeholders (suppliers, logistic providers, OEMs, dealers etc.) participating in the supply chain network can be calculated as follows.

Assumption: The company that wants to adapt blockchain technology to the supply chain earns income from the stakeholders that will join the network. The number of members added varies by years.

	A	B	C	D	E	F
1						
2	**R1 Blockchain Revenues**					
3						
4	**R1.1 Membership Revenue**					
5	Registration Fee	5000				
6	Ongoing Annual Fee	8000				
7						
8						
9		**6-12 Months**	**12-24 Months**	**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
10	**New Actor**	2	2	3	3	4
11	**Total Actor**	=B10	=B11+C10	=C11+D10	10	14
12						
13	**Revenue**	**=B5*B10+B6*B11**	**=B5*C10+B6*C11**	**=B5*D10+B6*D11**	**=B5*E10+B6*E11**	**=B5*F10+B6*F11**

Table 6 : Membership Revenue Calculation of Example Project

Transaction Revenue

Transaction revenues from stakeholders participating in the supply chain network can be calculated as follows.

Assumption: The company that wants to adapt blockchain technology to the supply chain earns income from the stakeholders making transactions in the network. The number of transactions made with blockchain technology increases according to the number of members added yearly and the development of the system.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2	R1 Blockchain Revenues				6-12 Months	12-24 Months	Year2-Year3	Year3-Year4	Year4-Year5								
3				Total Transaction Number	=SUM(D18:E18)	=SUM(D26:G26)	=SUM(D34:I34)	=SUM(D42:M42)	=SUM(D50:Q50)								
4	R1.2 Transaction Revenue																
5	Transaction fee($)	0,5		Revenue	=E3*B5	=F3*B5	=G3*B5	=H3*B5	=I3*B5								
6																	
7																	
8																	
9																	
10																	
11				Actor1	Actor2	Actor3	Actor4	Actor5	Actor6	Actor7	Actor8	Actor9	Actor10	Actor11	Actor12	Actor13	Actor14
12		6-12 Months															
13			Operations per actor	15000	15000												
14			Step per operation	1	1												
15			Transactions per step	2	2												
16																	
17			Transactions per actor (monthly)	=D13*D14*D15	=E13*E14*E15												
18			**Transactions per actor Year 1**	**=D17*12**	**=E17*12**												
19																	
20		12-24 Months															
21			Operations per actor	25000	25000	15000	15000										
22			Step per operation	1	1	1	1										
23			Transactions per step	2	2	2	2										
24																	
25			Transactions per actor (monthly)	=D21*D22*D23	=E21*E22*E23	=F21*F22*F23	=G21*G22*G23										
26			**Transactions per actor Year 2**	**=D25*12**	**=E25*12**	**=F25*12**	**=G25*12**										
27																	
28		Year2-Year3															
29			Operations per actor	30000	30000	15000	15000	8000	4000	4000							
30			Step per operation	1	1	1	1	1	1	1							
31			Transactions per step	2	2	2	2	2	2	2							
32																	
33			Transactions per actor (monthly)	=D29*D30*D31	=E29*E30*E31	=F29*F30*F31	=G29*G30*G31	=H29*H30*H31	=I29*I30*I31	=J29*J30*J31							
34			**Transactions per actor Year 3**	**=D33*12**	**=E33*12**	**=F33*12**	**=G33*12**	**=H33*12**	**=I33*12**	**=J33*12**							
35																	
36		Year3-Year4															
37			Operations per actor	40000	40000	20000	20000	10000	4000	3000	3000	1500	1500				
38			Step per operation	1	1	1	1	1	1	1	1	1	1				
39			Transactions per step	2	2	2	2	2	2	2	2	2	2				
40																	
41			Transactions per actor (monthly)	=D37*D38*D39	=E37*E38*E39	=F37*F38*F39	=G37*G38*G39	=H37*H38*H39	=I37*I38*I39	=J37*J38*J39	=K37*K38*K39	=L37*L38*L39	=M37*M38*M39				
42			**Transactions per actor Year 4**	**=D41*12**	**=E41*12**	**=F41*12**	**=G41*12**	**=H41*12**	**=I41*12**	**=J41*12**	**=K41*12**	**=L41*12**	**=M41*12**				
43																	
44		Year4-Year5															
45			Operations per actor	60000	60000	30000	30000	20000	8000	6000	6000	3000	3000	1000	1000	1000	1000
46			Step per operation	1	1	1	1	1	1	1	1	1	1	1	1	1	1
47			Transactions per step	2	2	2	2	2	2	2	2	2	2	2	2	2	2
48																	
49			Transactions per actor (monthly)	=D45*D46*D47	=E45*E46*E47	=F45*F46*F47	=G45*G46*G47	=H45*H46*H47	=I45*I46*I47	=J45*J46*J47	=K45*K46*K47	=L45*L46*L47	=M45*M46*M47	=N45*N46*N47	=O45*O46*O47	=P45*P46*P47	=Q45*Q46*Q47
50			**Transactions per actor Year 5**	**=D49*12**	**=E49*12**	**=F49*12**	**=G49*12**	**=H49*12**	**=I49*12**	**=J49*12**	**=K49*12**	**=L49*12**	**=M49*12**	**=N49*12**	**=O49*12**	**=P49*12**	**=Q49*12**

Table 7 : Transaction Revenue Calculation of Example Project

CAPEX-OPEX Savings

The company that wants to create blockchain based supply chain network can access the resources of other companies participating in the network and benefit from common use. This situation enables companies to save capital and operating expenses. CAPEX-OPEX saving can be calculated as follows.

Assumption: The level of savings to be achieved varies according to the type, size or frequency of investments that companies will avoid thanks to blockchain. Operating costs are calculated as 20% of the sum of capital and infrastructure costs.

	A	B	C	D	E
1					
2	**R2 Capex Opex Saving**				
3			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
4					
5		Shared Resources(worker,plant,warehouse) Saving	50000	75000	100000
6		Transportation Saving	50000	75000	100000
7		Reprocess or Testing Saving	30000	50000	70000
8		Hardware or Technological Expenses Saving	30000	50000	70000
9		Tax Saving	50000	50000	50000
10		**Capex Saving**	**=SUM(C5:C9)**	**=SUM(D5:D9)**	**=SUM(E5:E9)**
11		**Opex Saving**	**=C10*0,3**	**=D10*0,3**	**=E10*0,3**
12					
13		**Total Capex And Opex Saving**	**=SUM(C10:C11)**	**=SUM(D10:D11)**	**=SUM(E10:E11)**

Table 8 : Capex-Opex Savings Calculation of Example Project

Efficiency Savings

The company that wants to create blockchain based supply chain network can reach different efficiency solutions. Improved documentation processes, simplified new platform and reduced worker requirements provided by blockchain technology offer companies with additional efficiency.

Assumption: The company that wants to adapt blockchain technology to the supply chain earns income from efficiency. The level of savings to be achieved varies depending on different solutions.

	A	B	C	D	E	F
1						
2	**R3 Efficiency Saving**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
3						
4			**Total Efficiency Benefit**	**=D25+D33+D50+D62+D85**	**=E25+E33+E50+E62+E85**	**=F25+F33+F50+F62+F85**
5						
6						
7						
8						
9	**3.1 Streamlined Documentation**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
10						
11			Number of Document	30000000	30000000	30000000
12						
13			Percentage of Facing Conflicting Document	0,01	0,01	0,01
14			Number of Facing Conflicting Document	=D11*D13	=E11*E13	=F11*F13
15			Percentage of blockchain solution for conflicting transaction	0,1	0,3	0,5
16			Cost for solving conflicting Document	1	1	1
17						
18			**Saving Conflict Records**	**=D14*D15*D16**	**=E14*E15*E16**	**=F14*F15*F16**
19						
20			Cost per documentation process	0,05	0,05	0,05
21			Percentage reduction in cost per documentation process replaced by blockchai	0,3	0,6	0,9
22						
23			**Saving Record Cost**	**=D11*D20*D21**	**=E11*E20*E21**	**=F11*F20*F21**
24						
25			**Benefit Coming From Saving Streamlined Documentation**	**=D18+D23**	**=E18+E23**	**=F18+F23**
26						
27						
28	**3.2 Legacy System**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
29						
30			Existing Legacy System (License) Cost	100000	100000	100000
31			Percentage of Legacy System replaced by blockchain	0,3	0,6	0,9
32						
33			**Benefit Coming From Saving Software Licence of Tracking,Billing,Invoicing**	**=D30*D31**	**=E30*E31**	**=F30*F31**
34						
35						
36	**3.3 Labour**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
37						
38			Number of Finance Employee solving conflict	3	3	3
39			Finance Employee Annual Compensation	36000	36000	36000
40			Reduction to finance employee dedicated to resolving conflicting records	0,2	0,5	0,8
41						
42			**Saving Finance Employee solving conflict**	**=D38*D39*D40**	**=E38*E39*E40**	**=F38*F39*F40**
43						
44			Number of Legal Employee solving conflict	3	3	3
45			Legal Employee Annual Compensation	36000	36000	36000
46			Reduction to Legal employee dedicated to resolving conflicting records	0,2	0,5	0,8
47						
48			**Saving Finance Employee solving conflict**	**=D44*D45*D46**	**=E44*E45*E46**	**=F44*F45*F46**
49						
50			**Benefit Coming From Labor Cost Reduction**	**=D42+D48**	**=E42+E48**	**=F42+F48**
51						
52						

Table 9 : Efficiency Savings Calculation of Example Project, Part1

53	**3.4 Fraud Avoidance**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
54						
55			Number of Transaction with Supplier	5000000	5000000	5000000
56			Percentage of Facing Fraud in Transaction	0,01	0,01	0,01
57			Number of Fraud Transaction	=D55*D56	=E55*E56	=F55*F56
58			Percentage of blockchain solution for fraud transaction	0,1	0,3	0,5
59						
60			Cost For solving Fraud Problem	30	30	30
61						
62			**Benefit coming from reduction in Fraud Transaction**	**=D57*D58*D60**	**=E57*E58*E60**	**=F57*F58*F60**
63						
64						
65	**3.5 Reduce Time to Market**			**Year2-Year3**	**Year3-Year4**	**Year4-Year5**
66						
67			Number of Transaction to Dealer	200000	200000	200000
68			Percentage of Delay caused by uncontrolled and poor communication	0,03	0,03	0,03
69			Number of Delay Transaction	=D67*D68	=E67*E68	=F67*F68
70			Percentage of blockchain solution for delay transaction	0,1	0,3	0,5
71						
72			Extra density and holding cost in production	50	50	50
73						
74			**Benefit coming from reduction in delay**	**=D69*D70*D72**	**=E69*E70*E72**	**=F69*F70*F72**
75						
76			Number of Customer to be reached	5000000	5000000	5000000
77			Increase in percentage of vehicle production	0,01	0,01	0,01
78			Number of new customer to be reached	=D76*D77	=E76*E77	=F76*F77
79			Percentage of blockchain benefit for achiving new customer	0,005	0,007	0,009
80						
81			Profit from per new customer	1000	1000	1000
82						
83			**Profit coming from total new customer**	**=D78*D81*D79**	**=E78*E81*E79**	**=F78*F81*F79**
84						
85			**Benefit Coming From Reduction in Time to Market**	**=D74+D83**	**=E74+E83**	**=F74+F83**

Table 10 : Efficiency Savings Calculation of Example Project, Part2

Pilot Phase Costs

During the pilot phase, companies can pay consulting fees, internal IT and legal, business employees' fees. The pilot phase usually drives between 6 months and 1 year.

Assumption: The pilot phase drives 6 months

	A	B	C	D
1				
2	**C1 Pilot Phase Cost**			
3	**=C9+C17+C25**		**0-6 Months**	**6-12 Months**
4				
5		IBM Design Thinking workshop	30000	
6		Architectural consultancy	10000	
7		Software development fee paid to IBM	250000	
8				
9		**C1.1 Design Cost**	**=SUM(C5:C7)**	
10				
11				
12		Number of Technical Employees involved Pilot Phase	7	
13		Duration of the pilot phase engagement (Month)	6	
14		Percent of technical employees' time spent on the pilot	0,4	
15		IT/dev/engineering employee monthly compensation	6000	
16				
17		**C1.2 Cost of internal IT/developers' pilot efforts**	**=C12*C13*C14*C15**	
18				
19				
20		Number of Legal and Business Employees involved Pilot Phase	3	
21		Duration of the pilot phase engagement (Month)	6	
22		Percent of legal and business employees' time spent on the pilot	0,4	
23		Legal, business owners, IT management monthly compensation	5000	
24				
25		**C1.3 Cost of internal governance model/ legal employee pilot efforts**	**=C20*C21*C22*C23**	

Table 11 : Pilot Phase Costs Calculation of Example Project

Commercialization Phase Costs

During the commercialization phase, companies can pay consulting fees, internal IT and legal, business employees' fees, finding member fees etc. The commercialization phase usually drives between 1 and 1.5 years.

Assumption: The commercialization phase drives 18 months

	A	B	C	D	E
1					
2	**C2 Commercialization Phase Cost**				
3	**=C9+C17+C25+C31**				
4			**6-24 Months**	**Year2-Year3**	**Year3-Year4**
5					
6		Blockchain full development fee to IBM	1000000		
7		IBM Blockchain license fee	=20000*1,5		
8					
9		**C2.1 Blockchain Dev. And licence Cost**	**=SUM(C6:C7)**		
10					
11					
12		Number of Technical Employee Involved Commer. Phase	7		
13		Duration of the commercialization phase engagement (months)	18		
14		Percent of time dedicated to commercialization effort	0,4		
15		IT/dev/engineering employee monthly compensation	6000		
16					
17		**C2.2 Cost of internal IT/developers' commercialization efforts**	**=C12*C13*C14*C15**		
18					
19					
20		Number of Legal and business Employees involved Commer. Phase	3		
21		Duration of the governance model development and contract negotiation (months)	18		
22		Percent of employees' time spent on the commer.	0,4		
23		Legal, business owners, IT management annual compensation	5000		
24					
25		**C2.3 Cost of internal governance model/legal commercialization efforts**	**=C20*C21*C22*C23**		
26					
27					
28		Number of blockchain members onboarded for commercialization	='R1.1 Membership '!C10+'R1.1 Membership '!B10		
29		Cost of onboarding one member	2000		
30					
31		**C2.4 Cost of member onboarding for commercialization (marketing, admin, contract negotiation)**	**=C28*C29**		

Table 12 : Commercialization Phase Costs Calculation of Example Project

Ongoing Phase Costs

During the ongoing phase, companies can pay consulting fees, internal IT and legal, business employees' fees, finding member fees, ecosystem development fees etc.

Assumption: The ongoing phase drives 3 years to calculate NPV.

	A	B	C	D	E	F	G
1							
2	**C3 Ongoing Phase Cost**						
3							
4	**Year2-Year3**	**=E11+E19+E27+E33+E36**					
5	**Year3-Year4**	**=F11+F19+F27+F33+F36**					
6	**Year4-Year5**	**=G11+G19+G27+G33+G36**			**Month24-Month36**	**Year3-Year4**	**Year4-Year5**
7							
8				Continued IBM blockchain software development fee	200000	200000	200000
9				IBM Blockchain license fee	30000	30000	30000
10							
11				**C3.1 Blockchain Dev. And licence Cost**	**=SUM(E8:E9)**	**=SUM(F8:F9)**	**=SUM(G8:G9)**
12							
13							
14				Number of Technical Employee Involved Ongoing Phase	3	3	3
15				Duration of the commercialization phase engagement (months)	12	12	12
16				Percent of time dedicated to ongoing effort	0,3	0,3	0,3
17				IT/dev/engineering employee monthly compensation	6000	6000	6000
18							
19				**C3.2 Cost of internal IT/developers' commercialization efforts**	**=E14*E16*E17*E15**	**=F14*F16*F17*F15**	**=G14*G16*G17*G15**
20							
21							
22				Number of Legal Employees involved Ongoing Phase	2	2	2
23				Duration of the governance model development and contract negotiation (months)	12	12	12
24				Percent of employees' time spent on the ongoing Phase	0,3	0,3	0,3
25				Legal, business owners, IT management annual compensation	5000	5000	5000
26							
27				**C3.3 Cost of internal governance model/legal ongoing efforts**	**=E22*E23*E24*E25**	**=F22*F23*F24*F25**	**=G22*G23*G24*G25**
28							
29							
30				Number of blockchain members onboarded for ongoing	='R1.1 Membership '!D10	='R1.1 Membership '!E10	='R1.1 Membership '!F10
31				Cost of onboarding one member	2000	2000	2000
32							
33				**C3.4 Cost of member onboarding for ongoing (marketing, admin, contract negotiation)**	**=E30*E31**	**=F30*F31**	**=G30*G31**
34							
35							
36				**C3.5 Ecosystem development (workshops, member relations, community boards, other)**	**100000**	**100000**	**100000**

Table 13 : Ongoing Phase Costs Calculation of Example Project

Dashboard of the Project

All data in the dashboard come from yellow colored cells in other excel sheets.

	A	B	C	D	E	F	G
1							
2		Every parameter calculation in revenue and cost coming from other excel segments					
3		(pilot,commercialization,ongoing,membership,transaction,capex&opex,efficiency)					
4							
5							
6		BENEFIT	6-12 Months	12-24 Months	Year2-Year3	Year3-Year4	Year4-Year5
7							
8		**R1- Blockchain Revenues**	**=SUM(C9:C10)**	**=SUM(D9:D10)**	**=SUM(E9:E10)**	**=SUM(F9:F10)**	**=SUM(G9:G10)**
9		R1.1 Membership Revenue	='R1.1 Membership '!B13	='R1.1 Membership '!C13	='R1.1 Membership '!D13	='R1.1 Membership '!E13	='R1.1 Membership '!F13
10		R1.2 Transaction Revenue	='R1.2 Transaction'!E5	='R1.2 Transaction'!F5	='R1.2 Transaction'!G5	='R1.2 Transaction'!H5	='R1.2 Transaction'!I5
11							
12		**R2- Capex Opex Saving**			**=SUM(E13:E14)**	**=SUM(F13:F14)**	**=SUM(G13:G14)**
13		R2.1 Capex Saving			='R2 Capex Opex'!C10	='R2 Capex Opex'!D10	='R2 Capex Opex'!E10
14		R2.2 Opex Saving			='R2 Capex Opex'!C11	='R2 Capex Opex'!D11	='R2 Capex Opex'!E11
15							
16		**R3- Efficiency Saving**			**=SUM(E17:E21)**	**=SUM(F17:F21)**	**=SUM(G17:G21)**
17		R3.1 Benefit Coming From Saving Streamlined Documentation			='R3 Efficiency'!D25	='R3 Efficiency'!E25	='R3 Efficiency'!F25
18		R3.2 Benefit Coming From Saving Software Licence of Tracking,Billing,Invoicing			='R3 Efficiency'!D33	='R3 Efficiency'!E33	='R3 Efficiency'!F33
19		R3.3 Benefit Coming From Labor Cost Reduction			='R3 Efficiency'!D50	='R3 Efficiency'!E50	='R3 Efficiency'!F50
20		R3.4 Benefit coming from reduction in Fraud Transaction			='R3 Efficiency'!D62	='R3 Efficiency'!E62	='R3 Efficiency'!F62
21		R3.5 Benefit Coming From Reduction in Time to Market			='R3 Efficiency'!D85	='R3 Efficiency'!E85	='R3 Efficiency'!F85
22							
23							
24							
25		COST	0-6 Months	6-24 Months	Year2-Year3	Year3-Year4	Year4-Year5
26							
27		**C1 Pilot Phase**	**=SUM(C28:C30)**				
28		C1.1 Design	='C1 Pilot'!C9				
29		C1.2 Cost of internal IT/developers' pilot efforts	='C1 Pilot'!C17				
30		C1.3 Cost of internal governance model/legal pilot efforts	='C1 Pilot'!C25				
31							
32		**C2 Commercialization Phase**		**=SUM(D33:D36)**			
33		C2.1 Blockchain Development And licence Cost		='C2 Commercialization'!C9			
34		C2.2 Cost of internal IT/developers' commercialization efforts		='C2 Commercialization'!C17			
35		C2.3 Cost of internal governance model/legal commercialization efforts		='C2 Commercialization'!C25			
36		C2.4 Cost of member onboarding for commercialization efforts		='C2 Commercialization'!C31			
37							
38		**C3 Ongoing Phase**			**=SUM(E39:E43)**	**=SUM(F39:F43)**	**=SUM(G39:G43)**
39		C3.1 Blockchain Dev. And licence Cost			='C3 Ongoing'!E11	='C3 Ongoing'!F11	='C3 Ongoing'!G11
40		C3.2 Cost of internal IT/developers' commercialization efforts			='C3 Ongoing'!E19	='C3 Ongoing'!F19	='C3 Ongoing'!G19
41		C3.3 Cost of internal governance model/legal ongoing efforts			='C3 Ongoing'!E27	='C3 Ongoing'!F27	='C3 Ongoing'!G27
42		C3.4 Cost of member onboarding for ongoing			='C3 Ongoing'!E33	='C3 Ongoing'!F33	='C3 Ongoing'!G33
43		C3.5 Ecosystem development (workshops, community boards, other)			='C3 Ongoing'!E36	='C3 Ongoing'!F36	='C3 Ongoing'!G36

Table 14 : Dashboard of Project, Part1

	A	B	C	D	E	F	G
1							
2		Every parameter calculation in revenue and cost coming from other excel segments					
3		(pilot,commercialization,ongoing,membership,transaction,capex&opex,efficiency)					
4							
5							
6		BENEFIT	6-12 Months	12-24 Months	Year2-Year3	Year3-Year4	Year4-Year5
7							
8		**R1- Blockchain Revenues**	**$386.000**	**$1.002.000**	**$1.343.000**	**$1.811.000**	**$2.892.000**
9		R1.1 Membership Revenue	$26.000	$42.000	$71.000	$95.000	$132.000
10		R1.2 Transaction Revenue	$360.000	$960.000	$1.272.000	$1.716.000	$2.760.000
11							
12		**R2- Capex Opex Saving**			**$273.000**	**$390.000**	**$507.000**
13		R2.1 Capex Saving			$210.000	$300.000	$390.000
14		R2.2 Opex Saving			$63.000	$90.000	$117.000
15							
16		**R3- Efficiency Saving**			**$983.200**	**$2.048.000**	**$3.112.800**
17		R3.1 Benefit Coming From Saving Streamlined Documentation			$480.000	$990.000	$1.500.000
18		R3.2 Benefit Coming From Saving Software Licence of Tracking,Billing,Invoicing			$30.000	$60.000	$90.000
19		R3.3 Benefit Coming From Labor Cost Reduction			$43.200	$108.000	$172.800
20		R3.4 Benefit coming from reduction in Fraud Transaction			$150.000	$450.000	$750.000
21		R3.5 Benefit Coming From Reduction in Time to Market			$280.000	$440.000	$600.000
22							
23							
24							
25		COST	0-6 Months	6-24 Months	Year2-Year3	Year3-Year4	Year4-Year5
26							
27		**C1 Pilot Phase**	**$426.800**				
28		C1.1 Design	$290.000				
29		C1.2 Cost of internal IT/developers' pilot efforts	$100.800				
30		C1.3 Cost of internal governance model/legal pilot efforts	$36.000				
31							
32		**C2 Commercialization Phase**		**$1.448.400**			
33		C2.1 Blockchain Development And licence Cost		$1.030.000			
34		C2.2 Cost of internal IT/developers' commercialization efforts		$302.400			
35		C2.3 Cost of internal governance model/legal commercialization efforts		$108.000			
36		C2.4 Cost of member onboarding for commercialization efforts		$8.000			
37							
38		**C3 Ongoing Phase**			**$436.800**	**$436.800**	**$438.800**
39		C3.1 Blockchain Dev. And licence Cost			$230.000	$230.000	$230.000
40		C3.2 Cost of internal IT/developers' ongoing efforts			$64.800	$64.800	$64.800
41		C3.3 Cost of internal governance model/legal ongoing efforts			$36.000	$36.000	$36.000
42		C3.4 Cost of member onboarding for ongoing			$6.000	$6.000	$8.000
43		C3.5 Ecosystem development (workshops, community boards, other)			$100.000	$100.000	$100.000

Table 15 : Dashboard of Project, Part2

Net Present Value Calculation of the Project

Net present value is a method used when comparing investments or trying to understand the value of an investment. The difference between the investment's cash-inflow and cash-outflow over time is calculated, then converted into its present equivalent at an interest rate appropriate to the investment's risk level and thus the net present value is found.

Assumption: In order to make a more realistic analysis, the inputs and outputs of the investment are calculated monthly. The investment value calculated on a monthly basis has been reduced to its present value with a monthly discount rate, 0.95%.

NPV formulation in the excel file; (TOPLA = SUM)

- *0-5 Months;* Membership Revenue – Pilot Phase Cost
- *6-11, 12-23 Months;* (Membership Revenue + Transaction Revenue) – (Commercialization Phase Cost)
- *24-35, 36-47, 48-59 Months;* (Membership Revenue + Transaction Revenue + Capex-Opex Savings + Efficiency Savings) – (Ongoing Phase Cost)

Return on Investment (ROI): Return on Investment (ROI) is a measure used to evaluate the efficiency of an investment or to compare investments. ROI calculates the return on an investment against the investment cost. To calculate the ROI, the return of an investment is divided by the cost of the investment.

Payback Period: The payback period for an investment is a numerical value that indicates how long the total capital spent for the investment can be recovered. In other words, it is the time that must pass before the net cash inflows to be provided by the investment to cover the investment amount.

Discount Rate: While the discount rate is the interest rate that the Federal Reserve applies on overnight loans to banks, it is also the rate of return used to determine what future cash flows are worth today. It is used to calculate the return of the project by including the investment risk.

Formulation of Net Present Value of Example Project

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
2	Monthly Calculation in revenue and cost coming from other excel segments (pilot,commercialization,ongoing,membership,transaction,capex&opex,efficiency)															
3																
4																
5			Formulation ; TOPLA = SUM													
6	Discount Rate Yearly	0,12														
7	Discount Rate Monthly	=(1+B6)^(1/12)-1														
8																
9																
10		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
11																
12	Membership Revenue	0	0	0	0	0	0	='R1.1 Membership '!$B$13/6	='R1	='R1.	='R1.	='R1.	='R1.	='R1.1 Membership '!$C$13/12	='R1.	='R1.1
13	Transaction Revenue	0	0	0	0	0	0	='R1.2 Transaction'!$E$5/6	='R1	='R1.	='R1.	='R1.	='R1.	='R1.2 Transaction'!$F$5/12	='R1.	='R1.2
14	Capex Opex Savings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Efficiency Benefit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16																
17	**Revenue**	=TOPLA(B12:B15)	=TOP	=TOP	=TO	=TOI	=TOP	=TOPLA(H12:H15)	=TOI	=TOP	=TOP	=TOP	=TOF	=TOPLA(N12:N15)	=TOP	=TOPL
18	**Cumulative Total Revenue**	=TOPLA(B17:BI17)														
19																
20	Pilot Cost	='C1 Pilot'!$A$3/6	='C1	='C1	='C1	='C1	='C1 F	0	0	0	0	0	0	0	0	0
21	Commercialization Cost	0	0	0	0	0	0	='C2 Commercialization'!$A$3/18	='C2	='C2	='C2	='C2	='C2	='C2 Commercialization'!$A$3/18	='C2	='C2 C
22	Ongoing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23																
24	**Cost**	=TOPLA(B20:B22)	=TOP	=TOP	=TO	=TOI	=TOP	=TOPLA(H20:H22)	=TOI	=TOP	=TOP	=TOP	=TOF	=TOPLA(N20:N22)	=TOP	=TOPL
25	**Cumulative Total Cost**	=TOPLA(B24:BI24)														
26																
27	**Profit**	=B17-B24	=C17	=D17	=E1	=F17	=G17	=H17-H24	=I17	=J17-	=K17	=L17	=M1	=N17-N24	=O17	=P17-
28	**Cumulative Profit**	=B27	=C27	=D27	=E2	=F27	=G27	=H27+G28	=I27	=J27	=K27	=L27	=M2	=N27+M28	=O27	=P27+
29	**Total Profit**	=TOPLA(B27:BI27)														
30																
31	**ROI**	=B29/B25														
32																
33	Discount Factor	=1/(1+$B$7)^B10	=1/(1	=1/(1	=1/(	=1/(:	=1/(1	=1/(1+$B$7)^H10	=1/(:	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1+$B$7)^N10	=1/(1	=1/(1-
34	**Discounted Profit**	=B27*B33	=C27	=D27	=E2	=F27	=G27	=H27*H33	=I27	=J27	=K27	=L27	=M2	=N27*N33	=O27	=P27*
35	Cumulative Discounted Profit	=B34	=C34	=D34	=E3	=F34	=G34	=H34+G35	=I34	=J34	=K34	=L34	=M3	=N34+M35	=O34	=P34+
36	**NPV 5 Year**	=TOPLA(B34:BI34)														
37																
38	**Discounted Cost**	=B24*B33	=C24	=D24	=E2	=F24	=G24	=H24*H33	=I24	=J24	=K24	=L24	=M2	=N24*N33	=O24	=P24*
39	**Cumulative Total Disc. Cost**	=TOPLA(B38:BI38)														
40																
41	**Discounted NPV ROI**	=B36/B39														

Table 16 : NPV Formulation of Example Project, Part 1

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
11																									
12	='R1	='R1	='R1	='R1	='R1	='R1.	='R1	='R1.1	='R1.1	='R1.1 Membership '!$D$13/12	='R1.1	='R1.1	='R1	='R1.1	='R1.	='R1.	='R1.	='R1.	='R1.	='R1.	='R1.	='R1.1 Membership '!$E$13/12	='R1	='R1	='R1
13	='R1	='R1	='R1	='R1	='R1	='R1.	='R1	='R1.2	='R1.2	='R1.2 Transaction'!$G$5/12	='R1.2	='R1.2	='R1	='R1.2	='R1.	='R1.	='R1.	='R1.	='R1.	='R1.	='R1.2	='R1.2 Transaction'!$H$5/12	='R1	='R1	='R1
14	0	0	0	0	0	0	0	0	0	='R2 Capex Opex'!$C$13/12	='R2 C	='R2 C	='R2	='R2 C	='R2	='R2	='R2	='R2	='R2	='R2 C	='R2 C	='R2 Capex Opex'!$D$13/12	='R2	='R2	='R2
15	0	0	0	0	0	0	0	0	0	='R3 Efficiency'!$D$4/12	='R3 E	='R3 E	='R3	='R3 E	='R3	='R3	='R3	='R3	='R3	='R3 E	='R3 E	='R3 Efficiency'!$E$4/12	='R3	='R3	='R3
16																									
17	=TOI	=TOI	=TOI	=TOI	=TOI	=TOP	=TOI	=TOPL	=TOP	=TOPLA(Z12:Z15)	=TOP	=TOP	=TOI	=TOP	=TOF	=TOI	=TOI	=TOF	=TOF	=TOP	=TOP	=TOPLA(AL12:AL15)	=TOI	=TO	=TO
18																									
19																									
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	='C2	='C2	='C2	='C2	='C2	='C2	='C2	='C2 C	='C2 C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	='C3 Ongoing'!$B$4/12	='C3 C	='C3 C	='C3	='C3 C	='C3	='C3	='C3	='C3	='C3	='C3 C	='C3 C	='C3 Ongoing'!$B$5/12	='C3	='C3	='C3
23																									
24	=TOI	=TOI	=TOI	=TOI	=TOI	=TOP	=TOI	=TOPL	=TOP	=TOPLA(Z20:Z22)	=TOP	=TOP	=TOI	=TOP	=TOF	=TOI	=TOI	=TOF	=TOF	=TOP	=TOP	=TOPLA(AL20:AL22)	=TOI	=TO	=TO
25																									
26																									
27	=Q1	=R1	=S17	=T17	=U1	=V17	=W1	=X17-X	=Y17-	=Z17-Z24	=AA1	=AB1	=AC1	=AD1	=AE1	=AF1	=AG1	=AH1	=AI1	=AJ1	=AK1	=AL17-AL24	=AM	=AN	=AC
28	=Q2	=R2	=S27	=T27	=U2	=V27	=W2	=X27+	=Y27	=Z27+Y28	=AA2	=AB2	=AC2	=AD2	=AE2	=AF2	=AG2	=AH2	=AI2	=AJ2	=AK2	=AL27+AK28	=AM	=AN	=AC
29																									
30																									
31																									
32																									
33	=1/(:	=1/(:	=1/(:	=1/(:	=1/(:	=1/(1	=1/(:	=1/(1+	=1/(1	=1/(1+$B$7)^Z10	=1/(1	=1/(1	=1/(:	=1/(1	=1/(1	=1/(1	=1/(:	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1+$B$7)^AL10	=1/(:	=1/(:	=1/(
34	=Q2	=R2	=S27	=T27	=U2	=V27	=W2	=X27*	=Y27	=Z27*Z33	=AA2	=AB2	=AC2	=AD2	=AE2	=AF2	=AG2	=AH2	=AI2	=AJ2	=AK2	=AL27*AL33	=AM	=AN	=AC
35	=Q3	=R3	=S34	=T34	=U3	=V34	=W3	=X34+	=Y34	=Z34+Y35	=AA3	=AB3	=AC3	=AD3	=AE3	=AF3	=AG3	=AH3	=AI3	=AJ3	=AK3	=AL34+AK35	=AM	=AN	=AC
36																									
37																									
38	=Q2	=R2	=S24	=T24	=U2	=V24	=W2	=X24*	=Y24	=Z24*Z33	=AA2	=AB2	=AC2	=AD2	=AE2	=AF2	=AG2	=AH2	=AI2	=AJ2	=AK2	=AL24*AL33	=AM	=AN	=AC
39																									
40																									
41																									

Table 17 : NPV Formulation of Example Project, Part 2

	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**
11																				
12	='R1.	='R1	='R	='R1	='R1.	='R1.1	='R1.	='R1.	='R1.1 Membership '!$F$13/12	='R1.	='R1.	='R1.1	='R1.	='R1.	='R1.1	='R1.	='R1.	='R1.	='R1.1	='R1.1
13	='R1.	='R1	='R	='R1	='R1.2	='R1.2	='R1.	='R1.	='R1.2 Transaction'!$I$5/12	='R1.	='R1.	='R1.2	='R1.	='R1.	='R1.2	='R1.	='R1.	='R1.	='R1.2	='R1.2
14	='R2	='R2	='R	='R2	='R2 (	='R2 C	='R2	='R2	='R2 Capex Opex'!$E$13/12	='R2 (	='R2 (	='R2 C	='R2	='R2	='R2 C	='R2	='R2	='R2	='R2 C	='R2 C
15	='R3	='R3	='R	='R3	='R3 E	='R3 E	='R3	='R3	='R3 Efficiency'!$F$4/12	='R3 E	='R3 E	='R3 E	='R3	='R3	='R3 E	='R3	='R3	='R3	='R3 E	='R3 E
16																				
17	=TOF	=TO	=TC	=TOI	=TOP	=TOPI	=TOF	=TOP	=TOPLA(AX12:AX15)	=TOP	=TOP	=TOP	=TOP	=TOF	=TOP	=TOP	=TOP	=TOP	=TOP	=TOPL
18																				
19																				
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	='C3	='C3	='C	='C3	='C3 (	='C3 (	='C3	='C3	='C3 Ongoing'!$B$6/12	='C3 (	='C3 (	='C3 (	='C3	='C3	='C3 (	='C3	='C3	='C3	='C3 (	='C3 (
23																				
24	=TOF	=TO	=TC	=TOI	=TOP	=TOPI	=TOF	=TOP	=TOPLA(AX20:AX22)	=TOP	=TOP	=TOP	=TOP	=TOF	=TOP	=TOP	=TOP	=TOP	=TOP	=TOPL
25																				
26																				
27	=AP1	=AQ	=AF	=AS1	=AT1	=AU1	=AV1	=AW	=AX17-AX24	=AY1	=AZ1	=BA1	=BB1	=BC1	=BD1	=BE1	=BF1	=BG1	=BH1	=BI17
28	=AP2	=AQ	=AF	=AS2	=AT2	=AU2	=AV2	=AW	=AX27+AW28	=AY2	=AZ2	=BA2	=BB2	=BC2	=BD2	=BE2	=BF2	=BG2	=BH2	=BI27
29																				
30																				
31																				
32																				
33	=1/(1	=1/(	=1/	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1+$B$7)^AX10	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1	=1/(1
34	=AP2	=AQ	=AF	=AS2	=AT2	=AU2	=AV2	=AW	=AX27*AX33	=AY2	=AZ2	=BA2	=BB2	=BC2	=BD2	=BE2	=BF2	=BG2	=BH2	=BI27
35	=AP3	=AQ	=AF	=AS3	=AT3	=AU3	=AV3	=AW	=AX34+AW35	=AY3	=AZ3	=BA3	=BB3	=BC3	=BD3	=BE3	=BF3	=BG3	=BH3	=BI34
36																				
37																				
38	=AP2	=AQ	=AF	=AS2	=AT2	=AU2	=AV2	=AW	=AX24*AX33	=AY2	=AZ2	=BA2	=BB2	=BC2	=BD2	=BE2	=BF2	=BG2	=BH2	=BI24
39																				
40																				
41																				

Table 18 : NPV Formulation of Example Project, Part 3

Monitoring of Net Present Value of Example Project

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1																
2	Monthly Calculation in revenue and cost coming from other excel segments (pilot,commercialization,ongoing,membership,transaction,capex&opex,efficiency)															
3																
4																
5																
6	Discount Rate Yearly	12,00%														
7	Discount Rate Monthly	0,95%														
8																
9																
10		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
11																
12	Membership Revenue	0	0	0	0	0	0	4333,333	4333,333	4333,333	4333,333	4333,333	4333,333	3500	3500	3500
13	Transaction Revenue	0	0	0	0	0	0	60000	60000	60000	60000	60000	60000	80000	80000	80000
14	Capex Opex Savings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Efficiency Benefit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16																
17	**Revenue**	**0**	**0**	**0**	**0**	**0**	**0**	**64333,33**	**64333,33**	**64333,33**	**64333,33**	**64333,33**	**64333,33**	**83500**	**83500**	**83500**
18	**Cumulative Total Revenue**	**$14.748.000**														
19																
20	Pilot Cost	71133,33333	71133,33	71133,33	71133,33	71133,33	71133,33	0	0	0	0	0	0	0	0	0
21	Commercialization Cost	0	0	0	0	0	0	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67
22	Ongoing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23																
24	**Cost**	**71133,33333**	**71133,33**	**71133,33**	**71133,33**	**71133,33**	**71133,33**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**
25	**Cumulative Total Cost**	**$3.187.600**														
26																
27	**Profit**	**-71133,33333**	**-71133,3**	**-71133,3**	**-71133,3**	**-71133,3**	**-71133,3**	**-16133,3**	**-16133,3**	**-16133,3**	**-16133,3**	**-16133,3**	**-16133,3**	**3033,333**	**3033,333**	**3033,333**
28	**Cumulative Profit**	**-71133,33333**	**-142267**	**-213400**	**-284533**	**-355667**	**-426800**	**-442933**	**-459067**	**-475200**	**-491333**	**-507467**	**-523600**	**-520567**	**-517533**	**-514500**
29	**Total Profit**	**$11.560.400**														
30																
31	**ROI**	**362,67%**														
32																
33	Discount Factor	1	0,9906	0,981289	0,972065	0,962928	0,953877	0,944911	0,936029	0,927231	0,918515	0,909882	0,901329	0,892857	0,884465	0,876151
34	**Discounted Profit**	**-71133,33333**	**-70464,7**	**-69802,4**	**-69146,3**	**-68496,3**	**-67852,5**	**-15244,6**	**-15101,3**	**-14959,3**	**-14818,7**	**-14679,4**	**-14541,4**	**2708,333**	**2682,876**	**2657,658**
35	Cumulative Discounted Profit	-71133,33333	-141598	-211400	-280547	-349043	-416895	-432140	-447241	-462201	-477019	-491699	-506240	-503532	-500849	-498191
36	**NPV 5 Year**	**$7.405.666**														
37																
38	**Discounted Cost**	**71133,33333**	**70464,71**	**69802,37**	**69146,25**	**68496,31**	**67852,47**	**76033,85**	**75319,17**	**74611,2**	**73909,88**	**73215,16**	**72526,96**	**71845,24**	**71169,92**	**70500,95**
39	**Cumulative Total Disc. Cost**	**$2.572.432**														
40																
41	**Discounted NPV ROI**	**287,89%**														

Table 19 : NPV Monitoring of Example Project, Part 1

	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
11																		
12	3500	3500	3500	3500	3500	3500	3500	3500	3500	5916,667	5916,667	5916,667	5916,667	5916,667	5916,667	5916,667	5916,667	5916,667
13	80000	80000	80000	80000	80000	80000	80000	80000	80000	106000	106000	106000	106000	106000	106000	106000	106000	106000
14	0	0	0	0	0	0	0	0	0	22750	22750	22750	22750	22750	22750	22750	22750	22750
15	0	0	0	0	0	0	0	0	0	81933,33	81933,33	81933,33	81933,33	81933,33	81933,33	81933,33	81933,33	81933,33
16																		
17	**83500**	**83500**	**83500**	**83500**	**83500**	**83500**	**83500**	**83500**	**83500**	**216600**	**216600**	**216600**	**216600**	**216600**	**216600**	**216600**	**216600**	**216600**
18																		
19																		
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	80466,67	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	36400	36400	36400	36400	36400	36400	36400	36400	36400
23																		
24	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**80466,67**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**
25																		
26																		
27	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**3033,333**	**180200**	**180200**	**180200**	**180200**	**180200**	**180200**	**180200**	**180200**	**180200**
28	**-511467**	**-508433**	**-505400**	**-502367**	**-499333**	**-496300**	**-493267**	**-490233**	**-487200**	**-307000**	**-126800**	**53400**	**233600**	**413800**	**594000**	**774200**	**954400**	**1134600**
29																		
30																		
31																		
32																		
33	0,867916	0,859757	0,851676	0,843671	0,835741	0,827885	0,820103	0,812394	0,804758	0,797194	0,789701	0,782278	0,774925	0,767641	0,760425	0,753277	0,746197	0,739183
34	**2632,677**	**2607,931**	**2583,418**	**2559,134**	**2535,08**	**2511,251**	**2487,646**	**2464,263**	**2441,1**	**143654,3**	**142304**	**140966,4**	**139641,4**	**138328,8**	**137028,6**	**135740,6**	**134464,7**	**133200,8**
35	-495559	-492951	-490367	-487808	-485273	-482762	-480274	-477810	-475369	-331714	-189410	-48444	91197,41	229526,2	366554,8	502295,4	636760,1	769960,9
36																		
37																		
38	**69838,27**	**69181,82**	**68531,54**	**67887,37**	**67249,25**	**66617,14**	**65990,96**	**65370,68**	**64756,22**	**29017,86**	**28745,1**	**28474,91**	**28207,26**	**27942,12**	**27679,47**	**27419,3**	**27161,57**	**26906,26**
39																		
40																		
41																		

Table 20 : NPV Monitoring of Example Project, Part 2

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ
10	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
12	5916,667	5916,667	5916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	7916,667	11000	11000	11000
13	106000	106000	106000	143000	143000	143000	143000	143000	143000	143000	143000	143000	143000	143000	143000	230000	230000	230000
14	22750	22750	22750	32500	32500	32500	32500	32500	32500	32500	32500	32500	32500	32500	32500	42250	42250	42250
15	81933,33	81933,33	81933,33	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	170666,7	259400	259400	259400
17	**216600**	**216600**	**216600**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**354083,3**	**542650**	**542650**	**542650**
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36400	36566,67	36566,67	36566,67
24	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36400**	**36566,67**	**36566,67**	**36566,67**
27	**180200**	**180200**	**180200**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**317683,3**	**506083,3**	**506083,3**	**506083,3**
28	**1314800**	**1495000**	**1675200**	**1992883**	**2310567**	**2628250**	**2945933**	**3263617**	**3581300**	**3898983**	**4216667**	**4534350**	**4852033**	**5169717**	**5487400**	**5993483**	**6499567**	**7005650**
33	0,732235	0,725352	0,718534	0,71178	0,70509	0,698462	0,691897	0,685393	0,678951	0,672569	0,666247	0,659985	0,653781	0,647636	0,641548	0,635518	0,629544	0,623627
34	**131948,7**	**130708,5**	**129479,9**	**226120,7**	**223995,3**	**221889,8**	**219804,1**	**217738,1**	**215691,4**	**213664**	**211655,6**	**209666,2**	**207695,4**	**205743,1**	**203809,2**	**321625,1**	**318602**	**315607,2**
35	901909,6	1032618	1162098	1388219	1612214	1834104	2053908	2271646	2487337	2701001	2912657	3122323	3330019	3535762	3739571	4061196	4379798	4695405
38	**26653,35**	**26402,82**	**26154,64**	**25908,8**	**25665,27**	**25424,03**	**25185,05**	**24948,32**	**24713,82**	**24481,52**	**24251,4**	**24023,45**	**23797,63**	**23573,95**	**23352,36**	**23238,78**	**23020,34**	**22803,96**

Table 21 : NPV Monitoring of Example Project, Part 3

	BA	BB	BC	BD	BE	BF	BG	BH	BI
10	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**
12	11000	11000	11000	11000	11000	11000	11000	11000	11000
13	230000	230000	230000	230000	230000	230000	230000	230000	230000
14	42250	42250	42250	42250	42250	42250	42250	42250	42250
15	259400	259400	259400	259400	259400	259400	259400	259400	259400
17	**542650**	**542650**	**542650**	**542650**	**542650**	**542650**	**542650**	**542650**	**542650**
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	36566,67	36566,67	36566,67	36566,67	36566,67	36566,67	36566,67	36566,67	36566,67
24	**36566,67**	**36566,67**	**36566,67**	**36566,67**	**36566,67**	**36566,67**	**36566,67**	**36566,67**	**36566,67**
27	**506083,3**	**506083,3**	**506083,3**	**506083,3**	**506083,3**	**506083,3**	**506083,3**	**506083,3**	**506083,3**
28	**7511733**	**8017817**	**8523900**	**9029983**	**9536067**	**10042150**	**10548233**	**11054317**	**11560400**
33	0,617765	0,611958	0,606206	0,600508	0,594864	0,589272	0,583733	0,578246	0,572811
34	**312640,6**	**309701,9**	**306790,9**	**303907,2**	**301050,6**	**298220,8**	**295417,6**	**292640,8**	**289890,1**
35	5008046	5317748	5624539	5928446	6229496	6527717	6823135	7115776	7405666
38	**22589,61**	**22377,28**	**22166,94**	**21958,58**	**21752,18**	**21547,72**	**21345,18**	**21144,54**	**20945,79**

Table 22 : NPV Monitoring of Example Project, Part 4

Results of Example Case in 5th Year

The total revenue of the investment at the end of 5 years is $14.748.000, while the total cost is $3.187.600. Depending on these data, the total profit is calculated as $11.560.400.

After the profit calculated on a monthly basis is reduced to its present value with a monthly discount rate of 0.95%, it is found to be $7.405.666.

As a result, the return on the investment calculated with the discount rate included will be approximately 287.89%. Looking at the ratio in the financial aspect, it is understood that the company has to invest the project.

The first positive value of the cumulative discounted profit in the excel table can be considered while calculating the payback time of the investment. Accordingly, the firm recoups its investment in the 26th month and starts to make a profit.

After 5th Year

After the 26th month, the system continuously brings positive profit every month. The most important sources of income are membership, transaction, capex-opex savings and efficiency savings. However, assuming that the old system has completely changed with the blockchain system after the 5th year, capex-opex and efficiency savings should not be taken into account. Because the old system is not exist anymore, the efficiencies brought by the new system are not included in the calculation. That's why, the system's income sources after the 5th year; Membership income and commission income per transaction between stakeholders. On the other hand, the expenses are the same as the overhead expenses in the ongoing phase; blockchain development and license cost, cost of internal employees IT / developers / governance, cost of member onboarding for ongoing, ecosystem development cost.

After the system settling in 5th year and adapting more stakeholders to the supply chain, it is reasonable to reduce transaction costs to $0.1/per.

If number of transactions and members remain the same in 6th year and transaction fee is changed to $0.1:

Membership Revenue will be $132.000, Transaction Revenue will be $552.000 and Ongoing Cost will be $438.800.

In this case, the annual profit will be roughly $245,200, while the monthly profit will be $20,433.

After the 6th year, both revenues and costs will change as more members will join the blockchain-driven supply chain and more transactions will be made. However, the system will continuously generate a certain amount of profit each year financially, most importantly, a complete control will be ensured in the supply chain and the number of error will be reduced, speed, quality and customer satisfaction will increase.

7.4 How Firm Overcome the Blockchain Investment

Firms can access the financial support necessary to establish a comprehensive blockchain-driven supply chain in different ways. In order to fund investment opportunities and minimize the information asymmetry (imbalance due to stronger side), the options specified in the Pecking Order Theory can be selected.

Firm should first use its internal cash flow or retained earnings to finance their R&D investments. The reasons can be that it does not require collateral and does not cause financial distress for the firm. Firms benefiting internal sources give strong capital image to their competitors, financial institutions and customers. However, this may have some major drawbacks;

- Opportunity cost which means abandoning more profitable investments in order not to consume internal cash resources.
- If a firm spend capital for current investment, it can face a cash problem later because there is uncertainty in future cash flow.
- It requires smooth investment path over time.

The firm may choose to take a debt or issue shares by using external sources to finance the investment. But in this case, since external users will undertake too much risk, they demand

higher returns, furthermore they do not have enough information as much as the internal managers about the firm's strategy, which indicates information asymmetry. Debt holders (financial institutions) and shareholders (venture capitalist, angel investor, crowfunders) do not give importance to the future and performance of the firm in comparison with the managers. While taking a loan has monthly obligations, also there is a possibility of falling share prices in issuing equity. However, firms primarily aim to choose debt between two choices because the cost of debt is lower than the cost of equity. Additionally, R&D investments are likely to be subject to credit rationing for a number of reasons (financial institutions restricting loan supply despite high demand). This may have some major drawbacks;

- Significant asymmetric information between the company and the finance provider.
- Limited availability of tangible collateral assets to secure loans.
- Limited incentives to disclose the contents of the project, due to risk of expropriation of knowledge.
- The returns to high tech investments are skewed.

7.5 Project Management of the Sample Blockchain Case

Terms

BAC: It shows the budget required to complete each task.

BCWS (PV): Approved budget that is planned in advance for any date of the project.

BCWP (EV): It is the total value of the works completed at any time of the project according to the approved budget.

ACWP (AV): It is the sum of the resources spent for all work completed at any point in the project.

Scheduled Variance (EV-PV), SPI (EV/PV): It shows how far ahead or behind the project is according to the approved plan. If SPI>1 indicates that project is ahead of the planned process. SPI=1 on schedule, SPI<1 means behind of schedule.

Cost Variance (EV-AV), CPI (EV/AV): It Indicates whether the project cost is above or below the planned budget. If CPI> 1, the cost of the work performed is below the planned budget. CPI=1 on budget, CPI<1 means overrun so loss of value.

CEAC (BAC/CPI): The estimated cost at completion

TEAC (Total Duration/SPI): The forecasting of time at completion

Assumptions

The timeline or roadmap can be drawn by considering the blockchain-driven supply chain investment, for which benefit and cost analysis was made above, as a 5-years project.

Since the activities or business processes in the blockchain project are not fully known, activities have been created under the name of process according to the phases of the human resources used as input. The input data is put according to human resources in other excel sheets.

The project has a cost entry throughout 5 years. Pilot phase; 6 Months, Commercialization Phase; 18 Months, Ongoing Phase; 36 Months. There is a finish to start relationship between pilot and commercialization phases. In other words, after all activities in the pilot phase are completed, then the commercialization phase will start. In these 2 phases, internal activities are carried out in parallel with the operations of IBM. Ongoing phase has to start after activity D and G, but it can continue with activity F. Therefore, there is no obvious critical path. The monthly delay penalty of the project is $1,000. There is no monthly overhead cost in the project.

Fixed cost = $448.000

- Commercialization Phase; IBM Blockchain Licence Fee ($30.000), Cost of Onboarding Member ($8.000).
- Ongoing Phase; IBM Blockchain Licence Fee ($90.000), Cost of Onboarding Member ($20.000), Cost of Ecosystem Development ($300.000)

The project starts on January 1, 2021, and the status of the project is analyzed and interpreted on August 30, 2022.

Timeline of the Project

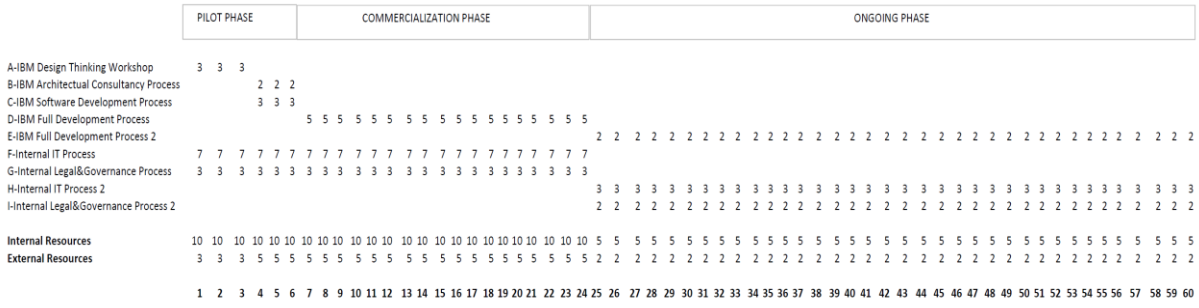


Table 23 : Timeline of Example Project

Status: IBM firm, which provides consultancy to blockchain integration, experiences some problems such as human, equipment, time, money resources etc. in the software development of pilot phase and in full software development of commercialization phase. Accordingly, internal IT employees in the company have to slow down their work. As a result, the latest state of activities in 30 August 2022 (end of month 20) is as follows.

	Start	End	Duration	Status	BAC	BCWS(PV)	BCWP(EV)	ACWP(AV)	SV	SPI	CV	CPI
A	Jan 21	March 21	3	Completed	$30.000	$30.000	$30.000	$30.000	$0	1,00	$0	1,00
B	Apr 21	July 21	3	Completed	$10.000	$10.000	$10.000	$20.000	$0	1,00	-$10.000	0,50
C	Apr 21	July 21	3	Completed	$250.000	$250.000	$250.000	$300.000	$0	1,00	-$50.000	0,83
D	July 21	Dec 22	18	In progress	$1.000.000	$777.700	$670.000	$720.000	-$107.700	0,86	-$50.000	0,93
E	Jan 23	Dec 25	36	To do	$600.000							
F	Jan 21	Dec 22	24	In progress	$403.200	$336.000	$302.400	$275.000	-$33.600	0,90	$27.400	1,10
G	Jan 21	Dec 22	24	In progress	$144.000	$120.000	$144.000	$200.000	$24.000	1,20	-$56.000	0,72
H	Jan 23	Dec 25	36	To do	$194.400							
I	Jan 23	Dec 25	36	To do	$108.000							
Tota	**60**	**Months**			**$2.739.600**	**$1.523.700**	**$1.406.400**	**$1.545.000**		**0,92**		**0,91**

Table 24 : Earned Value Report of Example Project

According to the Earned Value Report, in August 30 2022,

- Activities A and B were completed as planned. B is over of budget.
- E, H and I activities have not been started yet.
- Activities C were completed as planned on time, but $ 300.000 was spent. C is over of budget.
- While 77% (PV) of activity D should have been completed, 67% (EV) was completed and $ 720.000 (AV) was spent. Moreover, the price of 67% completion should be $ 670.000. Activity D is both behind of schedule and over of budget.

The total duration of activity D is 18 months, and in August 2022 it should be in 14th months. We can understand that 77% of it should be completed with the 14months/18months calculation. If 67% of activity D was completed in August 2022, the money spent for 67% completion should be $670.000 with the $1.000.000 * 0.67 calculation.

- While 83% of activity F should have been completed, 75% was completed and $ 275.000 was spent. Moreover, the price of 75% completion should be $ 302.400. F is under of budget but behind of schedule.
- While 83% of activity G should have been completed, 100% was completed and $200.000 was spent. But, the price of 100% completion should be $144.000. G is ahead of schedule but over of budget.

Last Status:

Overall SPI = BCWP/BCWS = $1.406.400/$1.523.700 = 0.92

Overall CPI = BCWP/ACWP = $1.406.400/$1.545.000 = 0.91

If the project is going in this speed, cost and resources, what would be the estimated cost for the remaining work?

ETC = (BAC-EV)/CPI = ($2.739.600 - $1.406.600) / 0.91 = **1.465.055 (Estimated cost of the remaining project)**

Revised:

CEAC = ETC+AV = 1.465.055 + $1.545.000 = **$3.010.000 (renewed estimated cost of the total project)**

CEAC = BAC/CPI = $2.739.600/0.91 = **$ 3.010.000 (renewed estimated cost of the total project)**

TEAC = Total Duration/SPI = 60/0.92 = **65 Months (renewed estimated completion time of the total project)**

Price = CEAC + TEAC*Overhead Cost + Fixed Cost + Penalty

Price = $3.010.000 + 0 + $448.000 + 5months*$1.000 = **$3.463.000 (renewed estimated total cost of the project)**

Refined (Crash Activity D):

If Activity D goes with this speed (SPI=0.86), it will last 21 months (18 Months / 0.86) instead of 18 months. If 3 more IBM employees are hired for the same fee (per person $11.000 monthly) in August 2022 to speed up the activity D that is late due to some problems; the total additional employee cost for activity D will be $132.000. ($11.000 Monthly*4 Months left*3 employees).

SPI = (1+1+1+1+0.9+1.2) / 6 = **1,02** --- CPI = **0,91** (the same with revised one)

CEAC = $3.010.000

TEAC = Total Duration/SPI = 60/1.02 = **59**

Price = CEAC + TEAC*Overhead Cost + Fixed Cost + Penalty + Additional HR Cost

Price = $3.010.000 + 0 + $448.000 + 0 + $132.000 = **$3.590.000 (after D activity is accelerated, renewed estimated total cost of the project)**

7.6 Application of Bass Diffusion Model in the European Electric Vehicle Market After Blockchain Project

Bass diffusion model tries to find how a new product or untested innovation will affect the population in market and how sales will change. According to the model, customer types are divided into two; Innovators who take action when the product is first launched by advertising or personal selling, and imitators who act later by observation or communication among people. There should be no substitutes product for this model, and the innovation offered shows an increase sales volume of overall market level, not a single firm's. However, if the first company to benefit from this technology can maintain its uniqueness, it can take this calculation into account.

Since a company that fully integrates blockchain technology can avoid many costs, it can focus on different innovations or add products that offer a higher quality customer

experience in the vehicle without reducing or increasing the sales price of the vehicle. On the other hand, the implementation of digital passport or digital wallet innovations that I mentioned in the blockchain use cases in the automotive sector can increase the sales amount and affect the market shares. So how will these innovation initiatives change estimated sales volumes and affect market share?

An Example; One of the following situations may cause a change in market share.

- The reflection of a previously untested innovation in the unchanged electric vehicle price on the market by taking cost advantage of blockchain technology.
- The reflection of the integration of a full range digital passport or digital wallet into the electric vehicle by benefiting blockchain technology, artificial intelligence and internet of things.

A new innovation team in the R&D department of ABC firm, has recently filed a patent for a potentially breakthrough innovation, which could allow the development of unique technology in driver experience. This system could replace existing technology in electric vehicle without requiring modifications. Given that ABC is a medium firm, awareness and availability would limit the market it could actually serve to 10% of the total addressable market.

	A	B
1		
2	Total Electric Vehicle Sales in Europe Yearly	1500000
3	ABC Manufacturer EV Sales Number Yearly	200000
4	**ABC Manufacturer Market Share**	**=B3/B2**
5		
6		
7	m(Potential of innovative EV Purchaser)(addressable market)	1000000
8	p(coefficient of innovation)(monthly)	0,004
9	q(coefficient of imitation)(monthly)	0,04
10	Innovation Project diffusion(monthly)	24
11	**Number of new customer after innovation**	**=B7*(1-EXP(-(B8+B9)*B10))/(1+B9/B8*EXP(-(B8+B9)*B10))**
12	Rate of Serviceable market of ABC company	0,1
13	**Number of new customer of ABC company**	**=B11*B12**
14		
15	**ABC Manufacturer New Market Share**	**=(B3+B13)/(B2+B13)**

	A	B
1		
2	Total Electric Vehicle Sales in Europe Yearly	1.500.000
3	ABC Manufacturer EV Sales Number Yearly	200.000
4	**ABC Manufacturer Market Share**	**13,3333%**
5		
6		
7	m(Potential of innovative EV Purchaser)(addressable market)	1.000.000
8	p(coefficient of innovation)(monthly)	0,004
9	q(coefficient of imitation)(monthly)	0,04
10	Innovation Project diffusion(monthly)	24
11	**Number of new customer after innovation**	**145.621**
12	Rate of Serviceable market of ABC company	10,0%
13	**Number of new customer of ABC company**	**14.562**
14		
15	**ABC Manufacturer New Market Share**	**14,1666%**

Table 25 : Bass Diffusion Calculation of Blockchain-Driven Innovation

The number of potential buyers who can buy electric vehicle having unique technology in 2 years after the innovation is approximately 145.621 people. However, the company's production and technology capacity can only reach 10% of potential buyers. Therefore, the company sells this vehicle to 14,562 people within 2 years after diffusion.

If we assume that the production capacities and market shares of companies selling electric vehicles to Europe in 2 years have not increased at all or increased at the same rate;

As ABC firm will reach 14,562 new customers from outside the market due to innovation, its market shares will change. According to the calculation, after innovation, ABC automotive company's share in the electric vehicle market in Europe may increase by about 1%.

Among the total buyers, the number of customers who will buy this product as innovators is estimated to be 582 (145.621*p), and the number of imitator customers to be 5820 (145.621*q). The remaining customers are the types of customers called late majority and late adopters.

7.7 Strategic Comments for the Blockchain Project in the Automotive Industry

The one of the major goals of strategy is achieving a superior profitability. In order to achieve this goal in the automotive sector, sustainable technology infrastructures that hold emergent technologies together should be integrated presently. Thus, intention will be actualized for full automation in the near future.

How to Reach Competitive Advantage

The aimed strategic choices requires a persistent and profound understanding of the competitive advantage environment (threats/opportunities) and requires an objective appraisal of the firm's resources and competencies (strengths/weaknesses). For this reason, firms should focus on demand analysis, understand the expectations and desires of customers, and on the other hand, plan how to survive by analyzing competition in the market.

Companies want to reach competitive advantage by having an effective strategy. In order to gain competitive advantage, it is necessary to focus on how relationships with companies, customers and suppliers create value and how this value is shared among them. Value creation is the difference between the maximum fee that the customer will pay for the product to firm and the lowest fee that the supplier will accept to sell the raw material to firm. (Customer willingness to pay - Supplier opportunity cost). Therefore, managing relations with suppliers and customers with transparent, traceable and real-time data sharing will create an effective competitive advantage for the company in the market. In order to

keep the competitive advantage sustainable, it is necessary to focus on technology that is valuable, rare or bringing reasonable returns in the short term, while in the long term investing in a technology that cannot be imitated and fully integrates with the organization's structure. In fact, companies mainly focus on the benefit differentiation or cost leadership strategies, while providing competitive advantage. Some companies prefer to use these two strategies together. (Ambidexterity) Companies that cannot use these two strategies stuck in the middle and follow a failed process. This strategic choice varies according to the company's needs, infrastructure, relationship with the environment and the mature level of the market.

It is the first mover to bring a new technology to the market and has a proactive structure. The first mover allow company to build strong position in technology development. By adopting technology early, the company takes advantage of the learning economy and makes it more threatening to competitors. Because according to the law of experience, as the cumulative output increases over time, the effort and cost spent per output decreases. The reason is that the employees and company organization structure will be integrated with technology by time, therefore, the error rate decreases, productivity and speed increases.

Strategic Outlook in Automotive Industry

The bargaining power of suppliers in the automotive industry is low. Because there are numerous small-medium scale suppliers, and manufacturers can switch from one supplier to another. However, the switching cost of this transition may be high. Because there is an already established production and infrastructure system and transportation network. In addition, while supplier companies do not pose a threat to forward integration, manufacturer companies have the potential to incorporate small-medium scale suppliers into their own structures by vertical integration. Thus, companies avoid transaction costs, provide a high level of control in the production flow, and prevent confidential information leakage.

While individual customers are the majority in the automotive sector, there are also different types of customers such as businesses, commercial and governments where many mass sales are made. Despite the high number of individual customers, the low switching cost (easy to pass different car brand) and the presence of organizations that make bulk purchases increase the bargaining power of the customers. The buyers are price sensitive, because customers can easily choose another auto company when facing new innovation or lower

price. In order to achieve customer loyalty and satisfaction, companies focus on offering high quality products at competitive prices and different technological innovations.

Mistakes of Strategic Choices in Automotive Industry

Automobile companies with many different suppliers must have high visibility in the supply flow and active communication with stakeholders in order to meet the quality and compliance standards of the parts and components supplied. However, establishing a traceability system in the automotive sector is unfortunately both very expensive and difficult to achieve. Therefore, companies are faced with many different problems such as wrong or poor quality parts, lack of communication, delays that affect profitability directly, and accordingly, they have to bear extra costs to fix this situation.

Companies focus on different benefit differentiations in order to create new values, gain customer satisfaction and experience, provide competitive advantage and increase market share. For example, high-quality designs, innovative designs, rare technology, passenger safety, environment friendliness, fuel-efficiency and several other points. However, most of these innovations can negatively reduce the profit margins of companies in the automotive industry, where the cost of competition is high and price sensitive. The choice of making a product that is non-compatible with a dominant design requires high investment in research and development and degree of vertical integration. When companies resort to these initiatives at high scales and with insufficient infrastructure, they may face default risk and costly problems in the long run.

Blockchain-driven Strategic Action in Automotive Industry

Competition among automotive companies with high capital leverage is always at an advanced level, while growth rate in the sector has reached the maturity phase. Intense competition always forces companies to innovate. However, when the sector approaches a phase of maturity, that means, cost leadership is significant to do changes in market share. A price-based competition does not grow the automotive sector, on the contrary, it causes a decrease in the profit margin of the companies. Therefore, companies have to target initiatives to reduce their costs instead of lowering their sales prices. However, companies that want to achieve cost advantage have to produce their products of the same quality at lower costs. To achieve this goal, strong control in the supply chain is required. Thus,

companies that reach a competitive advantage can increase their market shares by exploiting superior consumer surplus.

Thanks to blockchain technology and innovations, more effective use of primary activities in the value chain (inbound-outbound logistic, operations, marketing and sales, service) is provided and cost advantage can be obtained. In particular, parameters such as capacity utilization, linkage among activities, timing of market entry, and interrelationship between business units, dynamic workflow, economic of scale, flexible resource usage, strong coordination and visibility of transactions can be managed more effectively. Most importantly, falling transaction cost leads to an unbundling of value chain positively, that's means, faster product innovations, cheaper infrastructure and better customer relationship management.

In the long run, blockchain technology, which has been comprehensively integrated into the automotive supply chain, will create more governable, efficient and flexible value chain which can affect the hard-shifting market shares in the automotive industry. Thanks to the changes in value and supply chain, procurement, storage, transfer and sales costs are reduced, the rate of error is minimized, the number of production and the amount of sales increases, and customer satisfaction increases with quality service, thus it is created a competitive advantage that can change market shares.

8. Conclusion

As blockchain technology is suitable for the utilization in the several areas, technological infrastructure works have been begun for influential projects in different sectors. Especially, well-known firms are leading the way for blockchain technology by stepping into comprehensive projects and collaborations. Many companies in the various industries are trying to learn and adopt the technology by developing pilot projects. According to the giant research firms mentioned in the thesis, blockchain technology will touch more fields in the near future and will continue to be exploited. Blockchain technology brings different kinds of benefits to the automotive supply chain by collaborating with internet of things and artificial intelligence. Combined with Industry 4.0 technologies, blockchain will be a crucial step for the transition to full automated manufacturing and flawless supply chain by deeply affecting the industries. Many automotive companies have started blockchain projects and continue to make significant investments in order to use the supply chain where includes the large number of suppliers and numerous part flows, more effectively, more securely and more transparently. By analyzing the current market and competition in the automotive industry, it is possible to figure out that blockchain technology will brings different gains that will shape roles in the competition and it is easy to say that blockchain technology will be asset for the main activities of the automotive value chain.

As can be seen from the results of the sample case analyzed in the study, when the blockchain technology is considered as a 5-years investment, it creates significant income sources for the companies by giving the return of the investment quickly. In addition, the companies can respond to the market faster and detect origin of error before irreversible damage, since they have a more efficient and highly controlled supply chain. Thus, while keeping the supplier relations at a high level that directly affect the cost and time, on the other hand, customer satisfaction that affects the image of the company and competition in the market is achieved to superiority.

By exploiting to this dissertation, companies that want to integrate blockchain technology can analyze which paths they should follow and see the market situation on the up-to-date projects. Considering the financial calculations and strategic comments made in the study, companies can form the basis for the benefit and cost analysis of their blockchain investment. On the other hand, this study is thought to be an academic source for future

research and projects related to blockchain-based supply chain, and relationship between industry 4.0 and blockchain.

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