Blockchain for Transportation

How can blockchain technology improve the transportation industry?

Prepared by: Citlali Cruz Cruz, UBC Sustainability Scholar, 2019.
Prepared for: Camile Dos Santos Machado, Project Manager, New Mobility, Strategic Planning and Policy, TransLink.

August, 2019

Contents

1. Executive Summary

In the last years, blockchain technology has gained popularity because of its expanded uses in financial services (e.g., bitcoin), real estate, notary services, and the health sector among many others. The transportation industry has started to consider blockchain technology due to the advantages that this technology can bring to the public and private transportation as well as to the supply chain, for example.

Blockchain is a distributed digital ledger that allows participants within a network to enter into peer-to-peer transactions under a set of rules agreed upon by consensus and with no central authority. Its main attributes are:

- **Transparency:** Transactions are visible to all members of a network and each member has a copy of the record of transactions.
- **Traceability**: It creates an immutable and verifiable record of past transactions.
- **Immutability**: It is challenging to change data written in the blockchain.
- **Trust:** The blockchain is based on proven cryptographic technology that ensures the integrity and availability of data.
- **Distributed governance:** Transaction-validating requires agreement of all nodes.
- **Cost-saving:** It eliminates the need for a third party to manage users' relationships.

Such attributes could be used in the transportation sector. For example:

1. Blockchain could ease Mobility as a Service (MaaS)

Mobility as a Service (MaaS) relies on the idea of integrating different modes of transportation in one platform so that users can plan end-to-end trips and pay for private and public transportation services in one single platform.[1] The problem with having only one or a few platform to offer MaaS is that it could bring their market dominance as a consequence of network effects[2], it may also

---

[1] Goodall Warwick, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron, "The Rise of Mobility As A Service-Deloitte Us", Deloitte (2017), accessed July 23, 2019, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transport.

[2] Network effects is a phenomenon that refers to the increase of value of a product for users, as the number of users increases. While network effects are not necessarily harmful, it may be the case that a platform attracts a sufficiently ample number of users to have market power and reduce the possibility of other suppliers to enter the market.

require high costs of managing peer-to-peer relationships, and there would be a lack of control over data sharing. Blockchain technology could be an alternative to solve the mentioned problems since it offers the opportunity to create a mobility ecosystem that is:

- Decentralized: Blockchain allows for peer-to-peer relationships between service providers and users.
- Trustable: Blockchain ensures that terms and conditions are agreed to and legally enforceable.
- Provides a fair data use: Users and service providers agree on what data can be accessed.

2. Blockchain could improve supply chain

Supply chain industries need to be able to provide goods traceability to minimize the impact of food contamination outbreaks, to bring customers certainty on the origin of the products they are consuming, to build trust to speed delivery processes as well as to minimize fraud among different stakeholders that take part in the supply chain. Blockchain technology can offer:

- Traceability: Stakeholders can track their goods from creation to consumer delivery without intermediaries or third parties.
- Transparency: Blockchain can provide consumers with information on where and how products are made.
- Decentralization: Blockchain would eliminate the requirement of a third party to verify documents to double-check payments.
- Trust: Stakeholders do not need to know each other to trust each other.

3. Blockchain could improve the current tolling system

Current tolling systems require the intervention of several different players in order to function: the driver, the gate operator and the financial services company. Additionally, there are different costs associated with the interoperability of different tolling companies. In this regard, it is

COFECE "Rethinking Competition in the Digital Economy",February 2018. Accessed August 12, 2019. https://www.cofece.mx/wp-content/uploads/2018/03/EC-EconomiaDigital_web_ENG_letter.pdf

necessary to reduce the number of participants not only to speed the payment processes, but to reduce the management costs. Blockchain technology could bring:

- Decentralization: Tolling agencies on permissioned blockchain networks could communicate directly with each other, eliminating the need for third party agencies.
- Trust: The use of a private blockchain offers an encrypted secure channel that protects transactions and customer data.
- Consensus: Toll agencies can tailor their business rules for each organization they interact with.
- Transparency: The use of Blockchain technology allows that each tolling company (member of the network) has an updated copy of the record of transactions. Thus, each member shares the same source of information (one single source of truth).

Although Blockchain may bring huge efficiencies to the transportation sector, there are still several challenges and risks that this technology has to overcome prior to its expansion in this and many other industries, such as:

- **Scalability:** Most blockchain platforms cannot support the thousands of transactions per second that a mobility network would require.
- **Lost Private Keys[3]:** A private key is used to ensure the owner of an address can receive funds or data. The loss of a private key means a complete loss of access to funds or data in an account.
- **May lack identity protection:** Public keys function as a pseudonym used to send and receive money or information. This means that every transaction is permanently recorded in the blockchain under the user's public key (pseudonym) and if someone makes the link between a user identity and a public key, it would be possible to have the insight into that user's transactions.

---

[3] As mentioned in section 3, blockchain technology is cryptographically secure, which means that the transfer of data, money or information is ciphered to prevent manipulation or unauthorized access. This process requires the use of private and public keys that work to together to unlock secured data, each user has both. A public key can be shared with the blockchain network, like an address where the user can receive transactions, information, etc. Private Keys are not supposed to be shared and are used to confirm a person's identity, they function as a key to unlock received funds or information. Liquid. "What are public and private keys?". January 31, 2019. Accessed September 5th, 2019. https://blog.liquid.com/what-are-public-and-private-keys.

- **High environmental cost:** The mining[4] process requires a very high use of energy. To give an example, if Bitcoin was a country it would be the 53rd in energy consumption.

---

[4] Mining is the process of adding transactions to the blockchain. The mining process requires the use of a special software to solve complex mathematical problems to approve transactions. It is time consuming and requires a higher electricity usage than typical computer operation.

2. Introduction

The use of the internet and smartphones has transformed the transportation industry in recent years. Technology has had an impact on public transportation, freight and logistics, supply chain, tolling and ride-hailing. For example, today, we can use smartphone apps to plan trips (e.g., Google Maps or transit apps), rent a car or a bicycle (e.g., sharing economy apps such as car2go, Evo or Mobike), hail a ride (e.g., Uber or Lyft) or even pay for public transit (e.g., purchase transit tickets through public transit websites). Technology has resulted in significant benefits for users who can now plan trips in seconds, do not need to buy a car or a bicycle to use one, or can earn additional income by sharing the use of their vehicles. The supply chain field has also experienced significant improvements using technology. The Internet of Things (IoT)[5] has allowed the use of sensors that measure temperature, track location and record speed of movement as well as environmental factors. Moreover, the tracking and authentication of goods has brought great benefits to the freight and logistics industry.[6]

However, recent technological improvements have also outlined different challenges for the transportation sector, such as the lack of data protection for users of different online transport platforms, less competition in the ride-sharing market, or inefficiencies in the supply chain of different products. For example, the use of ride-hailing platforms has helped companies, public authorities and researchers collect data about users' preferences to understand mobility and thereby design smarter transportation systems.[7] However, the amount of data collected and stored by companies is immense, and users do not have any control over it. Once they sign up for an application, they grant access to their personal information and their private data becomes fully

---

[5] "Internet of things is a collection of interconnected physical devices that can monitor, report on and send and exchange data. IoT devices are typically connected to computer systems via data or Wi-Fi networks." Blume Global, "How the Internet of Things is transforming supply chain management". Blume Global. Accessed August 2019. https://www.blumeglobal.com/learning/internet-of-things/

[6] "How the Internet of Things Is Transforming Supply Chain Management." Blume Global. Accessed August 12, 2019. https://www.blumeglobal.com/learning/internet-of-things/

[7] Rainer Lempert (2019). "Shared Mobility Data Sharing, Opportunities for Public-Private Partnerships." April 23, 2019. Accessed August 12, 2019. https://sustain.ubc.ca/sites/default/files/Sustainability%20Scholars/2018_Sustainability_Scholars/Reports/2018-70%20Shared%20Mobility%20Data%20Sharing%20Opportunities_Lempert.pdf

accessible by the private company.[8] Users that want to use any service provided through a platform, private or public, give full access to their data without any other option than trusting the service provider, even when in recent years there have been multiple information breaches.[9] Walmart now has a robot in charge of keeping track of checking isles for out of stock items [10] and Amazon is using machine learning algorithms that work together with robots and humans to pick and pack items faster,[11] yet most supply chain companies are still struggling to implement tracking systems all along the distribution chain. In 2018, an E. Coli outbreak caused the infection of 210 people in 36 different states in the US before companies were able to find the origin of the outbreak. [12]

Transportation challenges outline the need for a technology that allows the participation of multiple players in a trusted, secure and transparent environment to keep improving transportation-related services that benefit users. In that regard, it is worth analyzing blockchain technology's potential to address such transportation challenges.

Over the last decade, the term blockchain has become familiar to most people and the technology has gained popularity because of its expanded uses in the financial (e.g., bitcoin), commercial and health sectors. Today we know that Blockchain is a distributed digital ledger that allows participants within a network to enter into peer-to-peer transactions under a consensual set of rules, and with

---

[8] Jochem Verheul, Max Mijnheer, Joey Ferwerda (2018). "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2019. Accessed August 12, 2019, https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[9] David Lopez and Bilal Farooq. "A Blockchain Framework for Smart Mobility." 2018 IEEE International Smart Cities Conference (ISC2), 2018. Accessed August 12, 2019, https://doi.org/10.1109/isc2.2018.8656927

[10] The Economist. "Amazon and Alibaba are pacesetters of the next supply-chain revolution". July, 2019.

[11] The Economist. "Amazon and Alibaba are pacesetters of the next supply-chain revolution". July, 2019.

[12] Sean Caputo, "Using Blockchain Innovation to Rebuild Trust in the Food Industry", Innovation excellence. Accessed August 12, 2019. https://www.innovationexcellence.com/blog/2019/04/29/using-blockchain-innovation-to-rebuild-trust-in-the-food-industry/

no central authority.[13] Blockchain attributes may be useful to protect user's mobility information, while providing data privacy and transparency,[14] and improving traceability in freight logistics.

This report outlines several current uses of blockchain technology in the transportation sector and how authorities like TransLink may benefit from this technology. It is structured in three main parts. The first one explains what blockchain technology is and describes the attributes that could be useful for the transportation industry. The second part outlines possible uses of blockchain technology to ease Mobility as a Service (Maas), supply chain, and how it can improve the current tolling system. Finally, the third part enlists some challenges and risks of blockchain technology.

---

[13] OECD. "Blockchain and Beyond: Encoding 21st Century Transport". 2018. Accessed August 12, 2019. https://www.itf-oecd.org/blockchain-and-beyond

[14] David Lopez and Bilal Farooq. "A Blockchain Framework for Smart Mobility." 2018 IEEE International Smart Cities Conference (ISC2), 2018. Accessed August 12, 2019, https://doi.org/10.1109/isc2.2018.8656927

3. Background: What is blockchain?

Blockchain is a distributed digital ledger that allows participants within a network to enter into peer-to-peer transactions under a set of rules agreed upon by consensus and with no central authority.[15] Thus, no single participant can exercise control over it, and since it has no central authority, it can only be changed or updated if all participants in the blockchain system agree on by mutual consensus.[16] Every blockchain network has its particular set of rules, and the validation of any transaction depends on the completion of such. [17]

The following more technical definition outlines the main features of the technology:

> *"Blockchain is a peer-to-peer, distributed ledger that is cryptographically-secure, append-only, immutable (extremely hard to change), and updateable only via consensus or agreement among peers."*[18]

- **Peer-to-peer** means that parties can interact directly with each other, without a third party.[19][20]
- **Distributed ledger** means that each party has a copy of the record of transactions.[21]

---

[15] OECD. "Blockchain and Beyond: Encoding 21st Century Transport". 2018. Accessed August 12, 2019. https://www.itf-oecd.org/blockchain-and-beyond

[16] The Economist, "The promise of the blockchain." *The Economist,* October 2015.

[17] Valentin Rakovic, Jovan Karamachoski, Atanasovsk Vladimir, and Liljana Gavrilovska. "Blockchain Paradigm and Internet of Things." Wireless Personal Communications 106, no. 1 (2019): 219–35.Accessed August 12, 2019, https://doi.org/10.1007/s11277-019-06270-9.

[18] Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained". Birmingham- Mumbai: Packt, 2018.

[19] Ibid.

[20] This process is secure since it requires the use of private and public keys that work to together to unlock secured data, each user has both. A public key can be shared with the blockchain network, like an address where the user can receive transactions, information, etc. Private Keys are not supposed to be shared and are used to confirm a person's identity, they function as a key to unlock received funds or information. Liquid. "What are public and private keys?". January 31, 2019. Accessed September 5th, 2019. https://blog.liquid.com/what-are-public-and-private-keys.

[21] Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained". Birmingham- Mumbai: Packt, 2018.

- **Cryptographically-secure** means that the transfer of data, money or information is ciphered to prevent manipulation or unauthorized access. The ledger is very difficult to manipulate, and thus, the record is secured against misuse. [22]

- **Append-only** means that data can only be added.[23]

- Updatable **via consensus** means that there can be updates after all nodes on the network agree on that and added to the blockchain.[24]

The blockchain has three main components: the block, the chain and the network.[25] Transactions are mined in **blocks** that can be inspected by any participant of the network. [26] Blocks are **chained** or linked to each other since each references the hash[27] of the previous block[28] using a mathematical function, creating a sequence. [29] Since blockchain has no central authority, in order to validate a transaction, all nodes in the **network** have to validate it.

---

[22] "*Cryptography is the science of secure communication. It involves taking information and scrambling it in a way that only the intended recipient can understand the information and its intended purpose. Therefore, cryptography seeks to transmit information securely and combats those attempting to manipulate the information*". Wikipedia, "Cryptography". Accessed August 28, 2019.

[23] Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained". Birmingham- Mumbai: Packt, 2018
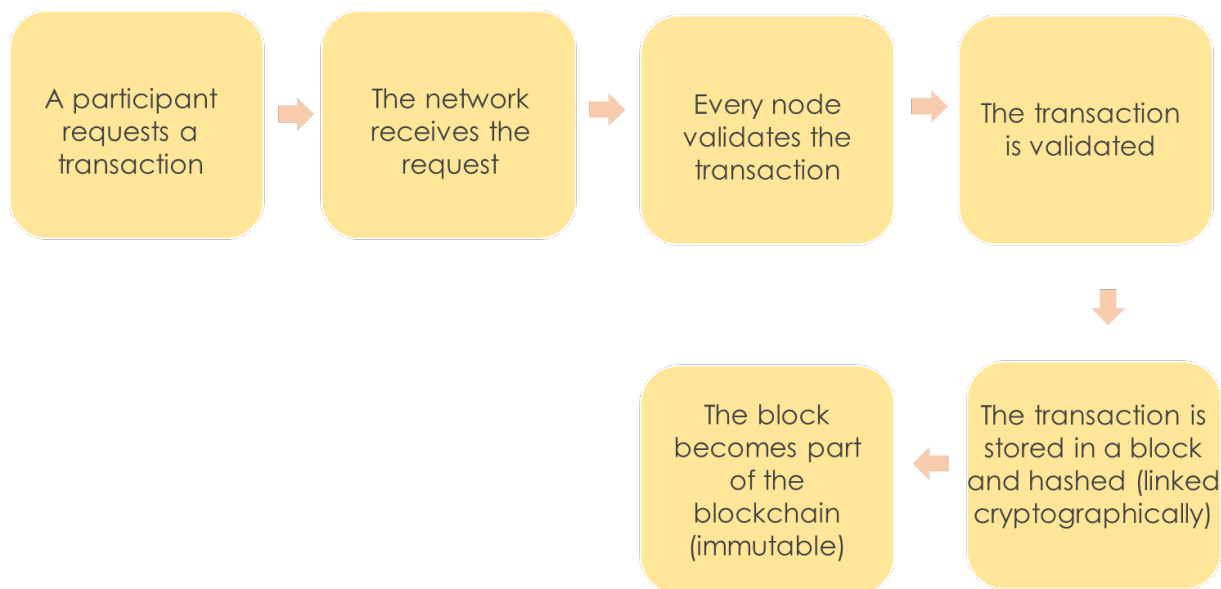
[24] Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained". Birmingham- Mumbai: Packt, 2018

[25] Tiana Laurence, "Blockchain for Dummies". Hoboken, NJ: John Wiley & Sons Inc, 2019.

[26] "How Transparency through Blockchain Helps the Cybersecurity Community." Blockchain Pulse: IBM Blockchain Blog, August 12, 2019. https://www.ibm.com/blogs/blockchain/2019/04/how-transparency-through-blockchain-helps-the-cybersecurity-community/

[27] Hashing is the process of converting information into a fixed size string of text. Lisk, "What is hashing?" Accessed September 9, 2019. https://lisk.io/academy/blockchain-basics/how-does-blockchain-work/what-is-hashing

[28] Valentin Rakovic, Jovan Karamachoski, Vladimir Atanasovski, and Liljana Gavrilovska. "Blockchain Paradigm and Internet of Things." Wireless Personal Communications 106, no. 1 (2019): 219–35. Accessed August 12, 2019. https://doi.org/10.1007/s11277-019-06270-9.

[29] Emily Kotow, "What is Blockchain Hashing?", February 2019. Accessed September 9, 2019. https://hedgetrade.com/what-is-blockchain-hashing/.

Figure 1. Transaction validation process[30]


```
A participant → The network → Every node → The transaction
requests a      receives the   validates the  is validated
transaction     request        transaction
                                                    ↓
The block    ← The transaction is
becomes part   stored in a block
of the         and hashed (linked
blockchain     cryptographically)
(immutable)
```

Based on   Edzo Botjes, "Pulling the Blockchain apart... The transaction life-cycle", August 11, 2017. Accessed September 9, 2019).

Blockchain can record all types of information and automate actions through smart contracts[31], which gives it the flexibility to be used in many different sectors. For the public transportation industry, blockchain can store information regarding trips frequency, trip duration and means of transportation. For the supply chain, it could allow the automatization of payments as well as the storage of valuable information such as warehouses temperature, transit difficulties, among others.

3.1 Types of blockchain

Blockchain technology could be used in any industry. That is why knowing the differences between different types of blockchain will allow to better understand the technology's attributes and

---

[30] Edzo Botjes, "Pulling the Blockchain apart... The transaction life-cycle", August 11, 2017. Accessed September 9, 2019). https://medium.com/ignation/pulling-the-blockchain-apart-the-transaction-life-cycle-7a1465d75fa3

[31] Smart contracts are computer codes that are stored and operate in a blockchain. The content of a contract can be defined by the developer of the blockchain system or the parties that use the system. While contracts are written in paper, smart contracts encode contractual clauses in computer code and exchange them with the blockchain network.

potential uses. This section explains broadly the main differences between three different blockchain types:

Public: Anyone can be a member and view every transaction that happens in the network.[32] It is also anonymous, meaning that the identity of those involved in a transaction is unknown since users are identified with a public key[33], which is a cryptographic code that serves as a digital user ID. Classic examples of public blockchain are [Bitcoin] or Ethereum[34]. Anyone can install a Bitcoin[35] wallet on a computer and start paying or receiving payments with it. Bitcoin does not establish any permissions for their users to do any transactions. Since it is a digital currency, users are able to spend and exchange them for anything they want to purchase.

Private: It is a permissioned blockchain. Thus, participants go under identity verification in order to access the network so that every member knows whom they are doing business with.[36] The information is available only for members, and not to the public. It enables businesses to exchange anything with value, like vehicles, houses, copyrights, images. For example, in Supply Chain management, only corporations involved in the transaction may have access to track goods in the supply chain.[37] Corda[38] and Hyperledger Fabric[39] are examples of private blockchain.

---

[32] Demiro Massessi. "Public Vs Private Blockchain In A Nutshell."Medium. December 12, 2019. Accessed August 12, 2019. https://medium.com/coinmonks/public-vs-private-blockchain-in-a-nutshell-c9fe284fa39f

[33] Jake Frankenfield. "Public Key." Investopedia. Investopedia, March 12, 2019. Accessed August 12, 2019. https://www.investopedia.com/terms/p/public-key.asp

[34] Anant Kadiyala, "Nuances Between Permissionless and Permissioned Blockchains". Accessed August 12, 2019. https://medium.com/@akadiyala/nuances-between-permissionless-and-permissioned-blockchains-f5b566f5d483

[35] A cryptocurrency is a digital asset designed to work as a medium of exchange that uses strong cryptography to secure financial transactions, control the creation of additional units, and verify the transfer of assets. "Cryptocurrency." Wikipedia. Wikimedia Foundation, August 12, 2019. https://en.wikipedia.org/wiki/Cryptocurrency.

[36] Demiro Massessi. "Public Vs Private Blockchain In A Nutshell."Medium. December 12, 2019. Accessed August 12, 2019. https://medium.com/coinmonks/public-vs-private-blockchain-in-a-nutshell-c9fe284fa39f

[37] "Private Blockchain Explained." Mycryptopedia, December 11, 2018. https://www.mycryptopedia.com/private-blockchain-explained/.

[38] "Corda is a private blockchain project that allows companies to build blockchain networks that can facilitate for direct business-to-business transactional and smart contract privacy." Bisola Asolo. "Private Blockchain explained." Accessed Auguts 28, 2019, https://www.mycryptopedia.com/private-blockchain-explained/.

[39] Hyperledger Fabric is an open source blockchain implementation framework that uses smart contract technology and is hosted by The Linux Foundation. "Private Blockchain Explained." Mycryptopedia, December 11, 2018. https://www.mycryptopedia.com/private-blockchain-explained/.

Hybrid: Mix characteristics of public and private. For example, when the identity of members should be verified, but some information is public.

3.2 What are blockchain's main attributes?

Blockchain is characterized by having attributes that can bring a number of efficiencies across different sectors. This section will outline the features of blockchain technology that can bring improvements to the transportation industry:

Transparency: As a distributed ledger it allows that each member of the network has an updated copy of the record of transactions, which are mined in the blocks and can be inspected by any participant of the network. [40] The blocks include very detailed information about accounts balances and transactions value.

Traceability: It creates an immutable, distributed and openly verifiable record of past transactions which is available to all network participants.

Immutability: it is very difficult to change data written in the blockchain.[41] This attribute is key considering that in the current digital world, almost any information can be easily erased, updated or manipulated.[42]

Trust: The blockchain is based on proven cryptographic technology that ensures the integrity and availability of data. As observed in figure 1, any transaction requested by any member of the network is verified prior to being added to the chain.

Distributed governance (consensus): This mechanism ensures that transaction-validating requires agreement of all nodes.[43]

---

[40] "How Transparency through Blockchain Helps the Cybersecurity Community." Blockchain Pulse: IBM Blockchain Blog, August 12, 2019. https://www.ibm.com/blogs/blockchain/2019/04/how-transparency-through-blockchain-helps-the-cybersecurity-community/

[41] Imran Bashir, "Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained". Birmingham- Mumbai: Packt, 2018.

[42] Tatar, Jack. Cryptoassets: the Innovative Investors Guide to Bitcoin and Beyond. McGraw-Hill Education, 2017.

[43] OECD. "Blockchain and Beyond: Encoding 21st Century Transport". 2018. Accessed August 12, 2019. https://www.itf-oecd.org/blockchain-and-beyond.

Cost-saving: Since transactions are peer-to-peer, it eliminates the need for a third party, such as a bank or a specific platform, it eliminates unnecessary costs.

3.3 Bitcoin and blockchain

Many people confuse blockchain and Bitcoin. A way of differencing them is knowing that Bitcoin is a digital currency and that blockchain is the operating system behind it. Blockchain technology attributes are observed in the functioning of bitcoin, for example:

- **Decentralization:** It guarantees that transactions are verified by all users and not by a bank or a third party.[44]
- **Traceability and transparency:** Bitcoin's blockchain keeps track of all users' account balance and records the flow of transactions.
- **Trust:** It guarantees the information is cryptography secured and all computer nodes have a regularly updated and verified record of all transactions within the Bitcoin network, which prevents financial crimes.[45]

3.4 Other uses of blockchain in the public sector

Blockchain technology has a long tradition in the private sector, particularly with the use of cryptocurrencies. However, if used properly, it's a technology that can change how governments serve their citizens.[46] There have been several initiatives from governments to implement blockchain technology in a wide variety of sectors, such as financial services, energy, real estate, telecom, education, healthcare, transportation, etc. For example:

To develop a digital identity record: In 2017, the state of Illinois announced a pilot with a self-sovereign identity ledger that allows individuals to have control over their identity data. In this case, government agencies would verify identity attributes of newborn children such as name, date of birth, sex and then they would input such information in a cryptographically secured software. The use of blockchain technology, in this case, grants users with the right to grant access to such

---

[44] Jack Tatar. Cryptoassets: the Innovative Investors Guide to Bitcoin and Beyond. McGraw-Hill Education, 2017.

[45] Brito, Jerry and Castillo Andrea. "Bitcoin, A primer for Policymakers". Mercatus Center. December 19, 2013. Accessed August 12, 2019, https://www.mercatus.org/system/files/Brito_BitcoinPrimer_v1.3.pdf

[46] The Economist. The promise of the blockchain, the trust machine. October 2015.

information only prior to explicit consent of the guardian or identity holder.[47] This example outlines the potential of blockchain technology to be used in the issuing of other identity documents such as passports or driving licenses.

To track personal records: Estonia's health care system works with a digital health record that can be tracked and reviewed only by authorized individuals. Health providers have created a shared record for every patient. Doctors can access patient's records and view test results, and even see images such as x-rays. Additionally, the system allows them to have national statistics so that the ministry of health can measure trends, track epidemics, etc.[48] Although some countries have already implemented digital access for users and health services providers to medical records, the use of blockchain technology would bring more security and transparency to the process. Blockchain would grant patients the right to grant access to their information, to keep a record of transactions and to avoid data breaches.

To build a land title registry: The UK government partnered with a software company to use blockchain platform Corda to build a proof of concept to ease a house buying process. Land buyers and sellers used their smartphones to do identity verification as well as signing the property transfer agreement. Blockchain technology enabled speedier property transactions, trust, high levels of security, as well as transparency for participants.[49] Future plans intend to digitalize all land titles and record them on a blockchain ledger with all the details related to a property sale.

---

[47] The Illinois Blockchain Initiative. "Illinois Partners with Evernym to Launch Birth Registration Pilot." Medium. The Illinois Blockchain Initiative, August 31, 2017. Accessed August 12, 2019, https://illinoisblockchain.tech/illinois-partners-with-evernym-to-launch-birth-registration-pilot-f2668664f67c.

[48] E-Estonia. Health Records- e-Estonia. E.Estonia. Accessed August 12, 2019. https://e-estonia.com/solutions/healthcare/e-health-record/., 2017.

[49]Tombs, Lauren, and Digital. "Could Blockchain Be the Future of the Property Market?" HM Land Registry, May 24, 2019.Accessed August 12, 2019. https://hmlandregistry.blog.gov.uk/2019/05/24/could-blockchain-be-the-future-of-the-property-market/.

4. How can blockchain technology improve the transportation sector?

The transportation industry has had many significant changes in recent years. The sharing economy has transformed consumer habits and included new service providers. Also, the development of autonomous vehicles and artificial intelligence is bringing significant changes to the passengers' industry and to the supply and logistics industry,[50] for example, some companies have started using algorithms to predict demand and replace products in inventories.[51] All these changes are accompanied by big challenges for service providers such as improving connectivity, speeding the delivery of products, securing user's data, continuing easing payment methods, as well as continuously developing new transportation options. [52]

Blockchain is a technology that could help to address the challenges the transportation sector is facing today. As mentioned above, Blockchain provides trust, transactions are immutable and irreversible, which eliminates the need of a third party to verify transactions like transfer of value and assets.[53] Blockchain also facilitates coordination among parties through smart contracts. This attribute reduces administrative costs for providers since logistical processes agreed among different parties are executed automatically.[54][55] Blockchain also eases information exchange, and

---

[50] The Economist. "Amazon and Alibaba are pacesetters of the next supply-chain revolution". July, 2019.Available https://www.economist.com/special-report/2019/07/11/amazon-and-alibaba-are-pacesetters-of-the-next-supply-chain-revolution

[51] The Economist. "Amazon and Alibaba are pacesetters of the next supply-chain revolution". July, 2019.Available https://www.economist.com/special-report/2019/07/11/amazon-and-alibaba-are-pacesetters-of-the-next-supply-chain-revolution

[52] Tsoniotis, N., Kourtesis, D., Tsiakmakis, S., Christaras, V., Makridis, M., Kounelis, I., Fontaras Feasibility study and prototyping of a blockchain-based transport service pricing and allocation platform. Publications Office of the European Union (2019). DOI:10.2760/60436

[53] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018). Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[54] Transport Systems Catapult. "Blockchain disruption in transport are you decentralised yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf), p 22.

[55] Tsoniotis, N., Kourtesis, D., Tsiakmakis, S., Christaras, V., Makridis, M., Kounelis, I., Fontaras Feasibility study and prototyping of a blockchain-based transport service pricing and allocation platform. Publications Office of the European Union (2019). DOI:10.2760/60436

improves information security, since its cryptographically secure attribute makes it very difficult to access and manipulate.

The introduction of blockchain in the transportation sector is already a reality in many cities, and it has the potential to keep transforming the industry. The following are some examples of its current use.

4.1   Mobility as a Service (MaaS):

Mobility as a Service (MaaS) relies on the idea of integrating different modes of transportation in one platform so that users can plan end-to-end trips and pay for private and public transportation services in one single platform.[56] Any person can use the MaaS platform to use a taxi, bus, carsharing vehicle, subway or any other mode of transportation. The same app would allow users to pre-pay for the service through a monthly subscription or paying one single trip.[57]

This is a trend that is impacting the transportation sector, the city of Helsinki is already implementing this service, but many others such as Los Angeles, Denver, Paris, Barcelona have already piloted local versions that offer integrated transportation in a similar way. However, the use of a platform similar to current sharing economy apps for the implementation of MaaS could imply:

1. **A few platforms may get market dominance as a consequence of network effects.[58][59]** This is, while network effects can be useful since they increase the availability of service while

---

[56] Goodall Warwick, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron, "The Rise Of Mobility As A Service - Deloitte Us", Deloitte (2017), accessed July 23, 2019, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transport.

[57] Goodall Warwick, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron, "The Rise Of Mobility As A Service - Deloitte Us", Deloitte (2017), accessed July 23, 2019, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transport.

[58] Network effects is a phenomenon that refers to the increase of value of a product for users, as the number of users increases. While network effects are not necessarily harmful, it may be the case that a platform attracts a sufficiently ample number of users to have market power and reduce the possibility of other suppliers to enter the market. COFECE "Rethinking Competition in the Digital Economy",February 2018. Accessed August 12, 2019. https://www.cofece.mx/wp-content/uploads/2018/03/EC-EconomiaDigital_web_ENG_letter.pdf

[59] Transport Systems Catapult. "Blockchain disruption in transport are you decentralized yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf), p 20.

the number of users and service providers increase within a platform, they can also hinder competition. For example, it could be difficult for a new company to enter into a market when there is a dominating platform, since gaining users or to expand their network to compete may imply a very high cost. Also if a platform becomes a dominant to provide MaaS services, this last would determine who gets access to provide transport services, what car companies or what bike-sharing apps or taxi companies participate in their platform.[60] This last could lead to a lack of competition and innovation, since it would be difficult for new companies to enter into the market.[61]

2. **The high cost of managing peer-to-peer relationships.[62]** Current ride-hailing and bike sharing companies, and most sharing economy platforms that provide transportation services act as intermediaries between drivers and passengers. They take responsibility for the behaviour of drivers and customers and are also in charge of managing relations between users (passengers or drivers) that exchange value (e.g. a hailing ride service in exchange for money). The prior implies high costs for vehicle operators and passengers who pay commissions for using a determined platform.[63]

3. **The lack of reward for the data that users (drivers and customers) provide when they sign up for the use of a sharing economy platform.[64]** Regularly, users sign up for an application and grant access to their private data, which immediately becomes data fully used by the private companies; users agree on terms and conditions without other option than trusting service providers.[65] Users do not receive a direct payment in reward of their information

---

[60] Transport Systems Catapult. "Blockchain disruption in transport are you decentralised yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf

[61] Ibid.

[62] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p. 35. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[63] DOVU (2018). HOW THE WORLD'S FIRST MOBILITY CRYPTOCURRENCY WILL CREATE A UBIQUITOUS REWARD ECOSYSTEM FOR THE TRANSPORT INDUSTRY. Available WWW.DOVU.IO

[64] Ibid.

[65] Jochem Verheul, Max Mijnheer, Joey Ferwerda (2018). A new Blockchain Platform Designed for the Future of Human Mobility. VMC, available at https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

nor have any negotiation power when granting access to their information through term and conditions clause.

Blockchain represents an opportunity to mitigate the effects of a centralized platform in a MaaS ecosystem. For example, blockchain technology allows peer-to-peer relationships. On the one hand, this attribute allows users and service providers to enter into service provision relationships directly and without the intervention of a third party. Therefore, this mitigates the dominance of a single platform regulating the entrance of service providers into a market.[66] On the other hand, this same attribute, by eliminating the need for a third party, it also alleviates costs related to managing peer-to-peer relationships.[67] Finally, the elimination of a third party and reward mechanisms allow also a fairer negotiation between users and service providers, who can agree on what data can be shared.

Case 1: DOVU. Using blockchain to create a circular ecosystem DOVU in London[68]

- Type of Blockchain: Public based on Ethereum tokens.

DOVU offers a marketplace where all members can exchange peer-to-peer services such as car sharing, and even services such as cleaning or maintenance of vehicles. This platform can be used through a website, using a smartphone, or any device that connects to the internet. In practical terms, this means that users can unlock a shared vehicle from the platform, allow access to car's data while driving, track movements while walking, running, cycling or driving.

Businesses and customers that contribute by sharing their mobility-related data into the mobility ecosystem are rewarded, for example, by sharing the type of vehicle they are driving, the used infrastructure such as roads or bridges and even contextual information such as weather. Individuals and companies are encouraged to exchange value and send and receive payment for

---

[66] Transport Systems Catapult. "Blockchain disruption in transport are you decentralized yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf

[67] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p. 35. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[68] DOVU (2018). HOW THE WORLD'S FIRST MOBILITY CRYPTOCURRENCY WILL CREATE A UBIQUITOUS REWARD ECOSYSTEM FOR THE TRANSPORT INDUSTRY. Available WWW.DOVU.IO

it, creating an equal reward for all users of the platform. Rewards in DOVU are based on Ethereum[69] tokens that are earned and exchanged for mobility products or services within the mobility ecosystem; for example, they could pay for vehicle cleaning or even an insurance service. DOVU uses the profits of the tokens sold to develop the platform and its adoption.

According to the DOVU whitepaper, the data received will be used to improve the transportation ecosystem and therefore improve mobility. For example, while companies that do mapping can use data to improve geo-localization, navigation, or parking, etc.; local government can use data to improve planning decisions.[70] Additionally, the DOVU platform offers control over data for data owners, who can decide when they share their data.

> *"This is a paradigm shift away from blanket acceptance of traditional terms and privacy policies, granting large organisations the permission to use and resell data without few, if any, controls on its use, and with little recourse or cancellation if abused"[71]*

Partners in the ecosystem can define Smart Contracts to set conditions on the use of the data. Blockchain technology puts control of data in the owners, where these last are able to block the use of the data if they breach the agreed terms.

In short, the use of blockchain in this platform offers:

1) A decentralized peer-to-peer community that could link drivers to users, and they would establish their own fares, without an intermediary.

2) Trust. Terms and conditions are agreed upon each transaction. The need for a manager to take responsibility for the behaviour of drivers and customers and supervising the exchange of values is minimized.[72]

---

[69] A cryptocurrency

[70] DOVU (2018). HOW THE WORLD'S FIRST MOBILITY CRYPTOCURRENCY WILL CREATE A UBIQUITOUS REWARD ECOSYSTEM FOR THE TRANSPORT INDUSTRY. Available WWW.DOVU.IO, p.14.

[71] Cryptokita. "DOVU Dedicated Mobility Platform for More Efficient Transportation." DOVU Dedicated Mobility Platform for More Efficient Transportation ~, January 1, 1970. https://cryptokita.blogspot.com/2017/10/dovu-dedicated-mobility-platform-for.html.

[72] DOVU (2018). HOW THE WORLD'S FIRST MOBILITY CRYPTOCURRENCY WILL CREATE A UBIQUITOUS REWARD ECOSYSTEM FOR THE TRANSPORT INDUSTRY. Available WWW.DOVU.IO

3)   A fairer data use. Data exchange is rewarded. Additionally, all ecosystem players can have access to data as agreed by users and service providers.

4)   Transparency. Each user is identified with a "wallet" (a public address on the Ethereum blockchain); therefore, there is complete transparency of tokens flow and contractual terms while the identity of users remains anonym. Each user can decide if they wish to attach and share any personal data to this, based on the rewards offered.[73]

DOVU is already working in London, and its critical challenge prior to the use of blockchain is to nudge the use of this new technology.

Case 2: VMC. Using blockchain to create a mobility marketplace in the Netherlands[74]

- Type of Blockchain: Private based on Hyperledger Indy[75]

VMC wants to transition from a system of ownership and control to a system of sharing and governance. To do this, VMC offers a blockchain platform designed for mobility services that believe in a tokenized, decentralized and autonomous economy.[76] VMC created a marketplace for drivers, passengers, vehicle owners and also insurance agencies to enter into peer-to-peer transactions without an intermediary.

There are two types of entities in the VMC network: Users and nodes. Users can be passengers or drivers (humans or machines), and both can use the network to transfer funds or run smart contracts. VMC is decentralized by design as transactions are validated by specific trusted nodes. The central nodes are hosted by privacy organizations and trusted organizations and every vehicle using VMC check-in terminal will act as a node in the network. This modality of permissioned

---

[73] Cryptokita. "DOVU Dedicated Mobility Platform for More Efficient Transportation." DOVU Dedicated Mobility Platform for More Efficient Transportation ~, January 1, 1970. https://cryptokita.blogspot.com/2017/10/dovu-dedicated-mobility-platform-for.html.

[74] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018. Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[75] Indy allows that for every party the user interacts with, a new Pairwise-Unique Identifier (public key) is used. By having independent pairwise relationships, the ability for others to correlate your activities across multiple interactions is significantly reduced. VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018. Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[76] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018. Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

blockchain[77] aims to ensure security and transaction finality through the use of nodes[78] while also guaranteeing a speedier process.

Regarding the information, VMC stores the information on every trip in a database and opens it for anyone to inspect it and use it.[79] They plan to support a more efficient transport network by enabling everyone in the community to train their own models with the collected data.

VMC works with a mobile driver wallet (an app) that connects all actors in a network and a stable coin called VAI. This wallet can be integrated inside vehicles, for example, to pay for fuel transactions. VMC charges a transaction fee based on the size of the transaction, and its goal is to compensate the energy used by the processors to validate transactions.

Users will be able to request a ride through the VMC mobile application. By sending a request over the network, the vehicles can independently bid on the request. Users can subsequently select which vehicle to use based on price and history of the vehicle.

So far, VMC has already one app that works within this ecosystem. It connects passengers with public transport in the Netherlands. By using the app, VMC aims to improve transportation in areas that lack connection with passenger's demands and to improve the payment system in terms of data management and interoperability.

In short, the use of blockchain in this platform offers:

1) Decentralization: At first, it will operate with nodes owned by VMC. In the second stage, nodes will be replaced by privacy-oriented organizations and selected individuals. In its third and final stage, any individual will serve as a node. Additionally, blockchain

---

[77] Permissioned networks place restrictions on who is allowed to participate in the network

[78] In permissionless blockchain networks such as Ethereum, a smart contract runs in all nodes. When there are many contracts running on the network, performance problems occur and miners within the network may prioritize running smart contracts with higher profits.

[79] Blockchain technology allows the creation of a public database. Blockchain decentralization allows that the database containing information about the trips is distributed to all nodes in the network, without compromising user's information since it is protected to maintain their anonymity. Therefore, only traffic information is stored.

immutability enables parties to interact with each other without having a central authority providing trust.[80]

2) Trust: Blockchain would offer trust through the use of smart contracts. Agreements among actors within the network are self-executed without intermediaries.

3) Transparency: VMC uses Hyperledger Indy to ensure users have complete control over their transaction history.[81] Each user's wallet saves a verified record of transactions which could be shared with tax authorities as a verified history of business trips.

4.2. Supply chain management

The distribution of products is essential for every industry. Going from perishable goods, to Walmart, Amazon or Alibaba deliveries, efficiency in the global supply chain is necessary for the success of many industries. However, most multinational corporations are far from having the efficiency that Walmart and Amazon have these days.[82] Difficulties in the supply chain industry come from a significant number of stakeholders that take part in its different operative transactions.[83][84] Goods are transferred from manufacturers to providers, warehouses, ports[85], and the supply chain can be so complex that when an outbreak of a food-borne disease happens, it

---

[80] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018.Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[81] While public keys are not necessarily linked to a user's real-life identity, every transaction that public keys create can be linked back. This means that if someone were to make the link between you and your public key they would have insight in all your transactions. VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018.Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[82] The Economist. "Where is my stuff, New technologies are modernizing an old-fashioned industry". Accessed August 12, 2019. https://www.economist.com/special-report/2019/07/11/digitisation-is-helping-to-deliver-goods-faster

[83] Deloitte. "Continuous interconnected supply Chain. Using Blockchain & Internet-of-Things in supply chain traceability". Accessed August 12, 2019. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

[84] Transport Systems Catapult. "Blockchain disruption in transport are you decentralized yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf), p 25.

[85] Ibid.

takes weeks for investigators to point out at the source. [86] A good example of this is the 2018 E. coli outbreak. It took so long to trace back the source of the infection that infected over 210 people in 36 different states in the US.[87]

The current transfer of goods requires all stakeholders (ports, banks, customs, etc.) along the supply chain to exchange multiple documents such as deeds of title or bills of landing describing the condition of the goods.[88] Each stakeholder needs to verify the data is accurate prior to the transfer of goods into the next stage.[89] Additionally, trust is an essential component in the supply chain since stakeholders need to trust each other to transfer any kind of information.[90][91] Fraud may happen in supply chain systems; sometimes the parties may include false documentation regarding the origin of the products, the quality or conditions of the products.[92]

In this regard, blockchain emerges as a technology with attributes that can generate high efficiencies in the supply chain industry. With Blockchain technology, it is possible to offer:

---

[86] Goodall Warwick, Tiffany Dovey Fishman, Justine Bornstein, and Brett Bonthron, "The Rise Of Mobility As A Service - Deloitte Us", Deloitte (2017), Accessed July 23, 2019, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transport.

[87] Sean Caputo, "Using Blockchain Innovation to Rebuild Trust in the Food Industry", Innovation excellence. Accessed August 12, 2019. https://www.innovationexcellence.com/blog/2019/04/29/using-blockchain-innovation-to-rebuild-trust-in-the-food-industry/

[88] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p.24. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[89] Deloitte. "Continuous interconnected supply Chain. Using Blockchain & Internet-of-Things in supply chain traceability". Accessed August 12, 2019. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

[90] Deloitte. "Continuous interconnected supply Chain. Using Blockchain & Internet-of-Things in supply chain traceability". Accessed August 12, 2019. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

[91] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p.25. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[92] D. Hesketh, "Weaknesses in the Supply Chain," World Customs Journal, vol. 4, no. 2, pp. 40-20, 2010. In Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p.24. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf, p 25.

1. Traceability: Stakeholders can track their goods from creation to consumer delivery without intermediaries or third parties.[93] Blockchain records can reflect the geographic flow, how products were treated, storage, monitor freezing conditions, track inventory, etc. This attribute creates the ability to respond to critical issues in the supply chain flow rapidly, increasing the competitiveness of companies in the market.[94]

2. Transparency: Blockchain can provide consumers with information on where and how products are made, which empowers consumers.[95] Also, blockchains allow the identification of problems in the supply chain and ease its solution.

3. Decentralization: Blockchain would eliminate the requirement of having a third party to verify documents to double-check payments.[96]

4. Trust: Due to the use of smart-contracts, stakeholders do not need to know each other to trust each other; that is why even first-time interactions between stakeholders along the supply chain become reliable. [97]

Case 3: Walmart Hyperledger Fabric to trace back mangoes and pork

- Type of Blockchain: Private based on Hyperledger Fabric

---

[93] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018). Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[94] Deloitte. "Continuous interconnected supply Chain. Using Blockchain & Internet-of-Things in supply chain traceability". Accessed August 12, 2019. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

[95] Accenture, Accenture Collaborates with Mastercard, Amazon Web Services, Everledger, and Mercy Corps to Increase the Sustainability and Fairness of Global Supply Chains, February 25th, 2019. Accessed August 12, 2019. https://newsroom.accenture.com/news/accenture-collaborates-with-mastercard-amazon-web-services-everledger-and-mercy-corps-to-increase-the-sustainability-and-fairness-of-global-supply-chains.htm

[96] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p.24. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf, p 25.

[97] Transport Systems Catapult. "Blockchain disruption in transport are you decentralised yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf), p 27.

Walmart technology thought of the importance of creating traceability for the entire supply chain. To do so, Walmart partnered with IBM to use Hyperledger Fabric, a type of permissioned Blockchain technology, open-source and vendor-neutral.[98]

Walmart started with two proof of concepts (POCs)[99] projects to demonstrate how blockchain can be used to trace and authenticate food from the farm in a quick and precise manner. The first one was based on tracing the origin of mangoes sold at Walmart US stores, and others to trace pork sold in China stores.

For the mangoes, the experiment consisted of buying a bag of mangoes and asking the Walmart team to identify the farm they came from. Although today regulatory requirements ask for providers, suppliers and distributors to keep a record of each step in the supply chain, this first part required calling and emailing everyone in the chain. The team got an answer in a week (7 days). Walmart technology developed an application focusing on the supply chain system and with the labelling authority to define the attributes required to use blockchain. All suppliers used the new labels and uploaded the data through a web-based interface. This implied to include every stage of the process, including farms, distribution centers, stores and to put the information on the blockchain. To trace the origin took only 2.2 seconds.

For the pork pilot, the importance was in building food trust since there are many frauds on food authenticity. This experiment consisted of collecting information about the animals on a farm in China, then at the slaughterhouse, after through all the transport process and up to the Product Quarantine Certificate Exchange. For each stage, a QR code label was placed at each processing facility. In the end, this process facilitated that any Walmart associate could scan the label in the distribution center, trace back the shipping details, and verify that the product went through the current distribution centers. This process allowed that even veterinary certificates were scanned

---

[98] *The technology needed to be open, since the traceability system was meant to be used by different parties, from Walmart's suppliers to competitors. Additionally, Hyperledger Fabric allows consensus and membership services and uses smart contracts.* Hyperledger. Case Study: How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric. Accessed August 12, 2019. https://www.hyperledger.org/resources/publications/walmart-case-study

[99] POC is a small exercise to test the design idea or assumption. Singaram, Muthu, and Jain, Prathistha. What is the Difference between Proof of Concept and Prototype?, January 13, 2018. Accessed August 12, 2019. https://www.entrepreneur.com/article/307454

and stored on the blockchain as an immutable digital copy that was accessible by any trusted user on the network. Thus, food safety professionals were able to have immediate access to such information anytime. [100]

These experiments showed that once the infrastructure is built, it was straightforward to provide traceability and transparency. Blockchain technology would not only help to trace back food but also to collect information about temperature, freshness, speed of the flow chain and where the supply chain faces obstacles. [101]

In this case, Blockchain offers:[102]

1) Traceability: Stakeholders can track their goods from creation to consumer delivery without intermediaries or third parties. [103]

2) Transparency: it allows the exchange of information on food attributes as it moves along the supply chain. This information can be used to proof origin, guarantee quality, etc.

3) Trust: The pork case allowed stakeholders to verify food authenticity. They could verify animal vaccinations and any other required process through the supply chain.

4) Decentralization: Blockchain allowed that any stakeholder could verify the supply chain process without having to request information from third parties.

4.3 Reducing tolling costs

Today, tolling is paid by card or cash or using tags, and some even charge the owner of the vehicle automatically through a number plate recognition. However, tolling implies the intervention of at least three parties: The driver, the tolling company, the client's bank to issue and verify the payments. The transaction is slow due to the number of actors that intervene in a tolling

---

[100] Frank Yiannas. "A New Era of Food Transparency Powered by Blockchain," Innovations: Technology, Governance, Globalization, MIT Press, vol. 12(1-2): 2018, pages 46-56, Summer-Fa.

[101] Frank Yiannas. "A New Era of Food Transparency Powered by Blockchain," Innovations: Technology, Governance, Globalization, MIT Press, vol. 12(1-2): 2018, pages 46-56, Summer-Fa.

[102] Galvez, Juan F., J.c. Mejuto, and J. Simal-Gandara. "Future Challenges on the Use of Blockchain for Food Traceability Analysis." TrAC Trends in Analytical Chemistry 107 (2018): 222–32. https://doi.org/10.1016/j.trac.2018.08.011.

[103] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018). Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

transaction and because of the payments time validation.[104] Tags have helped to speed the process. However, the problems that have aroused from their use are still significant. [105] Given that tolling systems are very different according to the landscape where they operate (bridges, tunnels, urban or rural, etc.), the cost of tolling also variates according to the processing costs of each company, generating high interoperability costs.[106][107]

Blockchain technology has an opportunity in this field. The use of blockchain for easing payments would allow: Transparency, since the record of transactions could be shared among all participants of the network; trust, since the user identification could be linked to the license plate, easing its validation;[108] it would be cost-saving, since the exchange of funds would be directly between the tolling company and the user, eliminating third parties (decentralization).[109]

Case 4: A Tolling.Network in the United States[110]

- Type of Blockchain: Private based on Hyperledger Fabric

Milligan Partners is a tolling company that, together with Ruuftop.io, a blockchain technology Startup launched Tolling.Network in the United States last January 2019. Blockchain technology would allow that every customer could do transactions directly with the tolling agency, eliminating the intervention of third parties between the customer and the tolling agency and would also eliminate the costs that interoperability between agencies would imply. Through Tolling.Network, each tolling agency could keep operating under their own rules and covering their own costs. The

---

[104] Projectoaken. "When Will Blockchain Applications Have a Current, Valuable and Practical Use Case?" Medium. Medium, March 12, 2019. Accessed August 12, 2019. https://medium.com/@projectoaken/when-will-blockchain-applications-have-a-current-valuable-and-practical-use-case-6c6550b65b4b and MOBI grand challenge Vento, Accessed August 12, 2019https://www.youtube.com/watch?time_continue=245&v=UKRIyl2loas

[105] Matt Milligan. "A Unified Tolling Network." LinkedIn February 19, 2016. Accessed August 12, 2019. https://www.linkedin.com/pulse/unified-tolling-network-matt-milligan/

[106] Ibid.

[107] Rajat Rajbhandari. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018), p. 32. Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

[108] Matt Milligan. "A Unified Tolling Network." LinkedIn February 19, 2016. Accessed August 12, 2019. https://www.linkedin.com/pulse/unified-tolling-network-matt-milligan/

[109] Ibid.

[110] Ibid.

tolling network would be used to improve and ease operations of the different companies through blockchain technology.

Customers would be able to use any toll facility with only one account, using an electronic wallet. Therefore, there would be a peer-to-peer transaction between the customer and the toll agency.

Implementing the Unified Tolling Network would require[111]:

1) user certifications: All participants would get a private digital key that serves as user identification and would allow them to pay with an electronic wallet;

2) asset registration: suppliers and agencies add assets to the system, e.g. transponder supplier would add the sets of inventories as they are sold to the market and customers store their id and license plates in their electronic wallet;

3) a transaction ledger (e-wallet): the agency connects directly with the customer's electronic wallet and initiates a transaction. The customer then approves the transaction, and the payment is processed. Transaction approval could be addressed manually or automatically. [112]

In this case, Blockchain offers:

1) Decentralization: Tolling agencies on permissioned blockchain networks could communicate directly with each other, eliminating the need for third party agencies.

2) Trust: The use of a private blockchain (Hyperledger Fabric) offers an encrypted secure channel that protects transactions and customer data.

3) Consensus: Tolling.Network uses smart contracts to create digital interoperability rules.[113] Each tolling agency can continue implementing its own rules.

---

[111] Matt Milligan. "A Unified Tolling Network." LinkedIn February 19, 2016. Accessed August 12, 2019. https://www.linkedin.com/pulse/unified-tolling-network-matt-milligan/

[112] Milligan Partners. "Reimagining Interoperability: A Unified Tolling Network." Milligan Partners, December 15, 2018. https://milliganpartners.com/unified-tolling-network/.

[113] Charles, Brett. "Tolling.network's Open Source Blockchain For Toll interoperability." January 22, 2019. Accessed August 12, 2019. https://www.enterprisetimes.co.uk/2019/01/22/tolling-networks-open-source-blockc

4) Transparency: The use of Blockchain technology allows that each tolling company (member of the network) has an updated copy of the record of transactions. Thus, each member shares the same source of information (one single source of truth).

5. Risks and Challenges

Blockchain has many attributes that are worth considering in the transport industry and many others. However, its study is still in the early stages, and before expanding its use, it is important to know the consequences of its use as well as the potential risks that its use may imply, such as:

Scalability: Most blockchain platforms cannot support the thousands of transactions per second that a mobility network would require. "For many blockchain applications, a transaction rate of 10 or 20 tx/s is perfectly fine."[114] However, for mobility services, transactions must be instantly since users cannot be expected to wait for a minute just for a transaction to be verified when taking a bus or taxi.[115] A similar example occurs with Bitcoin. While Bitcoin processes 4.6 transactions per second, Visa can do around 1700 per second.[116]

Lost Private Key: A private key is a randomly generated string used to confirm a person's identity, it functions as a key to unlock received funds or information, or to spend cryptocurrencies or tokens stored in a public ledger (e.g. an e-wallet). The loss of a private key means a complete loss of access to funds or data in an account.

May lack identity protection: Although blockchain does not require the user's real data identity linked to public keys, the user identity may not be completely anonymous and untraceable. Public keys function as a pseudonym used to send and receive money or information. This means that every transaction is permanently recorded in the blockchain under the user's public key (pseudonym) and if someone makes a link between a user identity and a public key, it would be possible to have the insight into that user's transactions. To mitigate this, permissioned Hyperledger Indy (used for VMC) emerges as an alternative to give users control over their data by generating pairwise relations to reduce the ability of others to correlate transactions to users. Since

---

[114] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018.Accessed August 12, 2019. https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[115] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018.Accessed August 12, 2019. https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[116] Kenny Li. "The Blockchain Scalability Problem & the Race for Visa-Like Transaction Speed." January 26, 2019. Accessed August 12, 2019. https://hackernoon.com/the-blockchain-scalability-problem-the-race-for-visa-like-transaction-speed-5cce48f9d44.

each transaction has a unique identifier, it is not possible to link different transactions to one only user.[117]

High environmental cost: Consensual blockchain (Proof of Work) mechanism requires that for the addition of a new block to the blockchain, there is validation by all nodes in the network. E.g. Bitcoin and Ethereum. The mining[118] process requires the use of special software to solve complex mathematical problems to approve transactions. This process requires a very high use of energy. To give an example, if Bitcoin was a country, it would be the 53rd in energy consumption. This means Bitcoin uses more energy than countries like Iceland or Austria.[119]

Blockchain technology is looking for new ways to reduce its energy consumption. Some models like Hyperledger, a permissioned blockchain uses Proof of Authority, require that only pre-selected nodes run the chain. The last translates in a high reduction of energy use, although it partially eliminates the decentralization attribute of blockchain.[120]

---

[117] VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018. Accessed August 12, 2019. https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

[118] *A Miner is a type of a node who computes transactions to secure the blockchain.* Christophe Jospe. "When It Comes to Blockchains and Energy Usage." Medium. Nori, July 4, 2019. Accessed August 12, 2019. https://medium.com/nori-carbon-removal/when-it-comes-to-blockchains-and-energy-usage-dca8a76b88e.

[119] Great Wall of Numbers. "How Much Electricity Is Consumed by Bitcoin, Bitcoin Cash, Ethereum, Litecoin, and Monero?" Great Wall of Numbers, August 30, 2018. Accessed August 12, 2019. https://www.ofnumbers.com/2018/08/26/how-much-electricity-is-consumed-by-bitcoin-bitcoin-cash-ethereum-litecoin-and-monero/.

[120] Christophe Jospe. "When It Comes to Blockchains and Energy Usage." Medium. Nori, July 4, 2019. Accessed August 12, 2019. https://medium.com/nori-carbon-removal/when-it-comes-to-blockchains-and-energy-usage-dca8a76b88e.

6. Conclusions

Blockchain technology has many opportunity areas to improve the current mobility ecosystem by giving users more control over their data, introducing new ways of payments, allowing the entrance of more service providers into the transportation market, among many others. However, it is still on an early development stage, and up to now, we cannot foresee its implementation in the short term without the development of its capacity to serve the thousands of users per second that the mobility ecosystem in cities like Vancouver requires.

According to TransLink Regional Transportation Strategy[121], one of TransLink main challenges is to increase walking, cycling, and transit trips up to 50% from total trips by 2045[122] and to reduce the driving distance by a third in order to allow accommodating the population growth in Vancouver. Developing more mobility services and increasing their use is still a priority for TransLink. So far, TransLink has successfully introduced the use of Compass card and allowing transit payments with Visa or Mastercard contactless cards, which eases the payment options for users. In this regard, it would be worth analyzing in the future the use of Blockchain technology specifically as an alternative to bring more payment methods in public transportation, to secure passengers' data and to allow a more integrated transportation ecosystem.

In relation to the use of blockchain technology for supply chain and to improve the current tolling system, blockchain technology offers solutions that go beyond efficiency improvements. In the supply chain industry, the traceability that blockchain can offer could ease the management of food contamination outbreaks, while it offers trust to customers who can verify the provenance of food and eliminates paperwork among different stakeholders in the supply chain. It is worth to pay attention to the inclusion of blockchain in the tolling systems since it seems to bring considerable cost savings regarding the interoperability of tolling agencies.

 Finally, the future introduction of automated vehicles not only in the supply chain but also in the transport of passengers will also bring new opportunities for blockchain technology to continue

---

[121] TransLink, "Regional Transportation Strategy". July 2013. Accessed August 12, 2019. https://www.translink.ca/-/media/Documents/plans_and_projects/regional_transportation_strategy/rts_strategic_framework_07_31_2013.pdf?la=en&hash=0A459174FB44A8870D00EFCE54124A01078D0698

[122] Compared to 2013.

expanding. In that regard, it is important to keep track of new projects in the sector as well as to bring not only transportation authorities and regulators but also current transportation stakeholders to present their opinion on the adoption or experimentation of this new technology. In the short term, the most important is to keep exploring the boundaries of this new technology as well as to evaluate its application to specific problems of the industry.

References

Asolo, Bisola. "Private Blockchain explained." Accessed August 28, 2019,
https://www.mycryptopedia.com/private-blockchain-explained/.

Bashir, Imran. *Mastering Blockchain: Distributed Ledger Technology, Decentralization, and Smart Contracts Explained*. Birmingham- Mumbai: Packt, 2018.

Blume Global. "How the Internet of Things is transforming supply chain management". Blume Global. Accessed August 2019. https://www.blumeglobal.com/learning/internet-of-things/

Botjes Edzo. "Pulling the Blockchain apart... The transaction life-cycle", August 11, 2017. Accessed September 9, 2019). https://medium.com/ignation/pulling-the-blockchain-apart-the-transaction-life-cycle-7a1465d75fa3

Brito, Jerry and Castillo Andrea. "Bitcoin, A primer for Policymakers". Mercatus Center. December 19, 2013. Accessed August 12, 2019,
https://www.mercatus.org/system/files/Brito_BitcoinPrimer_v1.3.pdf

Brett, Charles. "Tolling.network's Open Source Blockchain For Toll interoperability." January 22, 2019. Accessed August 12, 2019. https://www.enterprisetimes.co.uk/2019/01/22/tolling-networks-open-source-blockc

COFECE. "Rethinking Competition in the Digital Economy", in Rethinking Competition in the Digital Economy. February 2018. Accessed August 12, 2019. https://www.cofece.mx/wp-content/uploads/2018/03/EC-EconomiaDigital_web_ENG_letter.pdf

Cryptokita. "DOVU Dedicated Mobility Platform for More Efficient Transportation." DOVU Dedicated Mobility Platform for More Efficient Transportation ~, January 1, 1970. https://cryptokita.blogspot.com/2017/10/dovu-dedicated-mobility-platform-for.html.

Deloitte. "Continuous interconnected supply Chain. Using Blockchain & Internet-of-Things in supply chain traceability". Accessed August 12, 2019. https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-blockchain-internet-things-supply-chain-traceability.pdf

DOVU. "How the world's first mobility cryptocurrency will create a ubiquitous reward ecosystem for the transport industry. 2018". Accessed August 12, 2019. WWW.DOVU.IO

E-Estonia. *Health Records - e-Estonia*. E.Estonia. Accessed August 12, 2019. https://e-estonia.com/solutions/healthcare/e-health-record/., 2017.

Frankenfield, Jake. "Public Key." Investopedia. Investopedia, March 12, 2019. https://www.investopedia.com/terms/p/public-key.asp

Galvez, Juan F., J.c. Mejuto, and J. Simal-Gandara. "Future Challenges on the Use of Blockchain for Food Traceability Analysis." TrAC Trends in Analytical Chemistry 107 (2018): 222–32. https://doi.org/10.1016/j.trac.2018.08.011.

Great Wall of Numbers. "How Much Electricity Is Consumed by Bitcoin, Bitcoin Cash, Ethereum, Litecoin, and Monero?" Great Wall of Numbers, August 30, 2018. Accessed August 12, 2019. https://www.ofnumbers.com/2018/08/26/how-much-electricity-is-consumed-by-bitcoin-bitcoin-cash-ethereum-litecoin-and-monero/.

Illinois Initiative. "Illinois Partners with Evernym to Launch Birth Registration Pilot." Medium. The Illinois Blockchain Initiative, August 31, 2017. https://illinoisblockchain.tech/illinois-partners-with-evernym-to-launch-birth-registration-pilot-f2668664f67c.

Hyperledger. *Case Study: How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric*. Accessed August 12, 2019. https://www.hyperledger.org/resources/publications/walmart-case-study

Lempert, Rainer. "Shared Mobility Data Sharing, Opportunities for Public-Private Partnerships." April 23, 2019. Accessed August 12, 2019. https://sustain.ubc.ca/sites/default/files/Sustainability%20Scholars/2018_Sustainability_Scholars/Reports/2018-70%20Shared%20Mobility%20Data%20Sharing%20Opportunities_Lempert.pdf

Jospe, Christopher. "When It Comes to Blockchains And Energy Usage". Medium, https://medium.com/nori-carbon-removal/when-it-comes-to-blockchains-and-energy-u (accessed August 12, 2019).

Jung, TJ. "How Transparency through Blockchain Helps the Cybersecurity Community." Blockchain Pulse: IBM Blockchain Blog, April 15, 2019. Accessed August 12, 2019. https://www.ibm.com/blogs/blockchain/2019/04/how-transparency-through-blockchain-helps-the-cybersecurity-community/

Kadiyala, Anant. "Nuances Between Permissionless and Permissioned Blockchains". Accessed August 12, 2019. https://medium.com/@akadiyala/nuances-between-permissionless-and-permissioned-blockchains-f5b566f5d483

Laurence, Tiana. *Blockchain for Dummies*. Hoboken, NJ: John Wiley & Sons Inc, 2019.

Li, Kenny. "The Blockchain Scalability Problem & the Race for Visa-Like Transaction Speed." January 26, 2019. Accessed August 12, 2019. https://hackernoon.com/the-blockchain-scalability-problem-the-race-for-visa-like-transaction-speed-5cce48f9d44.

Lopez, David, and Bilal Farooq. "A Blockchain Framework for Smart Mobility." *2018 IEEE International Smart Cities Conference (ISC2)*, 2018. https://doi.org/10.1109/isc2.2018.8656927.

Massessi, Demiro. "Public Vs Private Blockchain In A Nutshell." Medium. December 12, 2019. Accessed August 12, 2019. https://medium.com/coinmonks/public-vs-private-blockchain-in-a-nutshell-c9fe284fa39f

Milligan, Matt. "A Unified Tolling Network." LinkedIn February 19, 2016. Accessed August 12, 2019. https://www.linkedin.com/pulse/unified-tolling-network-matt-milligan/

OECD. "Blockchain and Beyond: Encoding 21st Century Transport". 2018. Accessed August 12, 2019. https://www.itf-oecd.org/blockchain-and-beyond

Projecto Aken. "When Will Blockchain Applications Have a Current, Valuable and Practical Use Case?" Medium. Medium, March 12, 2019. https://medium.com/@projectoaken/when-will-blockchain-applications-have-a-current-valuable-and-practical-use-case-6c6550b65b4b.

Rakovic, Valentin, Jovan Karamachoski, Vladimir Atanasovski, and Liljana Gavrilovska. "Blockchain Paradigm and Internet of Things." *Wireless Personal Communications*106, no. 1 (2019): 219–35. https://doi.org/10.1007/s11277-019-06270-9.

Rajbhandari, Rajat. "Exploring Blockchain – Technology behind Bitcoin and Implications for Transforming Transportation". Texas A&M Transportation Institute (2018). Accessed August 12, 2019. https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-17-13-F.pdf

Singaram, Muthu, and Jain, Prathistha. What is the Difference between Proof of Concept and Prototype ?, January 13, 2018. Accessed August 12, 2019. https://www.entrepreneur.com/article/307454

The Economist. "Amazon and Alibaba are pacesetters of the next supply-chain revolution". July, 2019. https://www.economist.com/special-report/2019/07/11/amazon-and-alibaba-are-pacesetters-of-the-next-supply-chain-revolution

The Economist. "The promise of the blockchain, the trust machine". October 2015.

The Economist. "Where is my stuff, New technologies are modernizing an old-fashioned industry". Accessed August 12, 2019. https://www.economist.com/special-report/2019/07/11/digitisation-is-helping-to-deliver-goods-faster

Tatar, Jack. *Cryptoassets: the Innovative Investors Guide to Bitcoin and Beyond*. McGraw-Hill Education, 2017.

Tombs, Lauren, and Digital. "Could Blockchain Be the Future of the Property Market?" HM Land Registry, May 24, 2019. https://hmlandregistry.blog.gov.uk/2019/05/24/could-blockchain-be-the-future-of-the-property-market/.

TransLink, "Regional Transportation Strategy". July 2013. Accessed August 12, 2019. https://www.translink.ca/-/media/Documents/plans_and_projects/regional_transportation_strategy/rts_strategic_framework_07_31_2013.pdf?la=en&hash=0A459174FB44A8870D00EFCE54124A01078D0698

Transport Systems Catapult. "Blockchain disruption in transport are you decentralised yet?" June 2018. Accessed August 12, 2019. https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2018/06/06105742/Blockchain-Disruption-in-Transport-Concept-Paper.pdf

Tsoniotis, N., Kourtesis, D., Tsiakmakis, S., Christaras, V., Makridis, M., Kounelis, I., Fontaras "Feasibility study and prototyping of a blockchain-based transport service pricing and allocation platform". Publications Office of the European Union (2019). DOI:10.2760/60436

Verheul, Jochem; Mijnheer, Max, and Ferwerda, Joey. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2019. Accessed August 12, 2019, https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

VMC.AI. "A new Blockchain Platform Designed for the Future of Human Mobility". VMC 2018. Accessed August 12, 2019 https://vmc.ai/wp-content/uploads/2019/01/whitepaper.pdf

Warwick, Goodall; Dovey, Tiffany Fishman; Bornstein, Justine, and Bonthron, Brett. "The Rise Of Mobility As A Service- Deloitte Us", Deloitte (2017), accessed July 23, 2019, https://www2.deloitte.com/insights/us/en/deloitte-review/issue-20/smart-transport.

Wikipedia. *Cryptocurrency*. Wikimedia Foundation, August 12, 2019. https://en.wikipedia.org/wiki/Cryptocurrency.

Yiannas, Frank. "A New Era of Food Transparency Powered by Blockchain," Innovations: Technology, Governance, Globalization, MIT Press, vol. 12(1-2): 2018, pages 46-56, Summer-Fa.