

Trafif & Blockchain

An Exploration of Blockchain Data Management for the Finnish Transport Safety Agency

Margaret Kapitany, Toni Kokkonen,
Kai-Ling Yim & Joonas Leimola

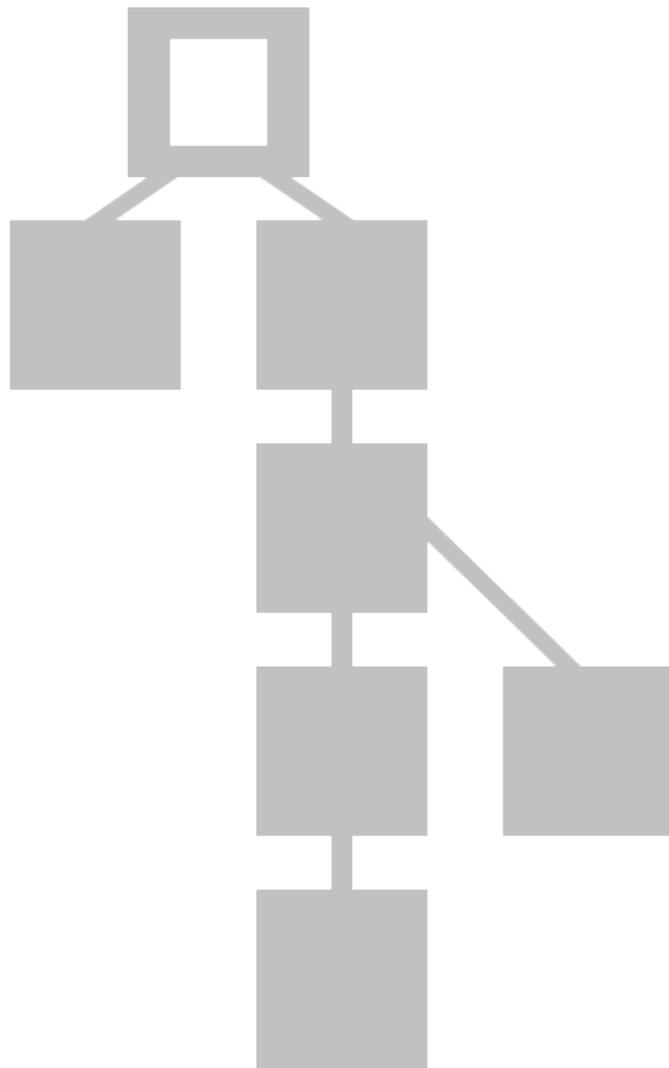
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Yhteyshenkilö Jonne Saarinen	Raportin kieli englanti
<p>Tiivistelmä</p> <p>Lohkoketju on kuin hajautettu tilikirja, joka koostuu toisiinsa linkitetyistä kirjauksista. Kirjausten avulla voidaan pitää kirjaa omistajuuden muutoksista monenvälisessä verkostossa. Lohkoketju voi lisätä turvallisuutta ja läpinäkyvyyttä, nopeuttaa transaktioita ja yksinkertaistaa liiketoiminnan prosesseja. Lohkoketjuteknologia on kuitenkin vasta kehittymässä, ja sen tulevaisuus on vielä epävarma. Tämän vuoksi lohkoketjun toteuttaminen on kallista vaatimusten muuttuessa nopeasti.</p> <p>Tällä hetkellä lohkoketjun kypsyytaso on matala: Sitä ei ole toistaiseksi sovellettu käytäntöön missään valtionhallinnossa. Monet startup-yritykset ja valtiot tutkivat parhaillaan lohkoketjua ja testaavat konseptin toimivuutta. Merkittävimpiä lohkoketjupilotteja ovat Ruotsin ja Georgian maarekisterit, Viron e-oleskelulupa ja lohkoketjun legitimointi Delawaren osavaltiossa Yhdysvalloissa.</p> <p>Lohkoketjun käyttäminen vaatii järjestelmien yhteentoimivuutta, sääntelyn noudattamista ja useiden osapuolten yhteistyötä. Trafin järjestelmät eivät toistaiseksi ole yhteensopivia uudemman teknologian kanssa. Suomen valtio ei myöskään ole vielä säätänyt lohkoketjua koskevaa lainsäädäntöä eikä kryptografisten tiivisteiden käyttäminen todentamisessa ole lainmukaista. Näistä syistä Trafi ei tällä hetkellä voi hyödyntää lohkoketjuteknologiaa.</p> <p>Jos lohkoketju on tulevaisuudessa edelleen ajankohtainen ja Trafin järjestelmiä päivitetään, tulee vielä huomioida kolme seikkaa, ennen kuin lohkoketjua voidaan hyödyntää Trafissa. Ensinnäkin sidosryhmien kanssa täytyy tehdä yhteistyötä, koska muutoin hajautetun lohkoketjun edut jäävät Trafilta saavuttamatta. Toiseksi tulee huomioida, että lohkoketjuun siirtyminen saattaa muuttaa liiketoiminnan prosesseja huomattavasti, joten nämä prosessit täytyy määritellä uudelleen. Viimeisimmäksi täytyy ottaa huomioon, että turvallinen tunnistaminen on yksi lohkoketjun sovellusten avainelementeistä. Tämän vuoksi on luotava sähköisen tunnistautumisen valtuutusjärjestelmä, jota lohkoketjun osapuolet voivat käyttää.</p> <p>Esineiden internetin kaltaisista muista uusista teknologioista on tehty ennusteita, joiden perusteella voidaan arvioida, että lohkoketjuun liittyvää sääntelyä kehitetään seuraavan viiden vuoden kuluessa. Siihen mennessä on luultavasti kertynyt lisää kokemuksia myös lohkoketjuteknologian käytännöllisyydestä, kustannuksista ja luotettavuudesta. Trafin kannattaa tarkastella lohkoketjua uudelleen vuoden 2020 jälkeen, koska tällä hetkellä lohkoketju on teknologiana vielä raakile, lainsäädäntö on vasta vireillä ja Trafin järjestelmät kehitysvaiheessa.</p>	

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Keywords ICT, blockchain, digital ownership, circle of trust	
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<p>Abstract</p> <p>Blockchain is a decentralized ledger with linked records for tracking changes of ownership within a multi-party network. It can increase security, transparency, speed of transactions, as well as simplify business processes. However, it is still an emerging technology with an uncertain future which means that it is expensive to implement due to rapidly changing requirements.</p> <p>Currently, the maturity level of blockchain is low: there are no existing live applications of blockchain within governments. There are many startups and governments that are doing proof-of-concepts and research on this area, with the most notable pilots of blockchain including the land registries in Sweden and Georgia, e-residency in Estonia, and blockchain legitimization in the state of Delaware (USA).</p> <p>Requirements for using blockchain include interoperability between systems, compliance with regulation and the collaboration with various stakeholders. Yet, Trafi's systems are not made for interoperability with newer technology. Additionally, the lack of blockchain-specific government regulation and non-existing legality of using cryptographic hashes for authentication entails that Trafi cannot pursue blockchain at this current time.</p> <p>If blockchain remains relevant, and Trafi's systems are updated, three steps need to be done before blockchain can be utilized. First, collaboration with stakeholders is mandatory, otherwise the benefits of a decentralized blockchain cannot be attained by Trafi. Second, moving to blockchain may change business processes significantly: these processes will need to be redefined. Last, secure identification is one of the key elements of blockchain applications: a system for digital identification authorization must be created for parties to use on the blockchain.</p> <p>Based on the projections of other new technologies such as IoT, the regulation for blockchain is estimated to be developed over the next 5 years. By that time, there should also be more evidence on the technology's usefulness, costs and robustness: Trafi should re-examine blockchain after 2020 due to blockchain's current low maturity, Trafi's developing systems and pending blockchain regulation.</p>	

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INTRODUCTION





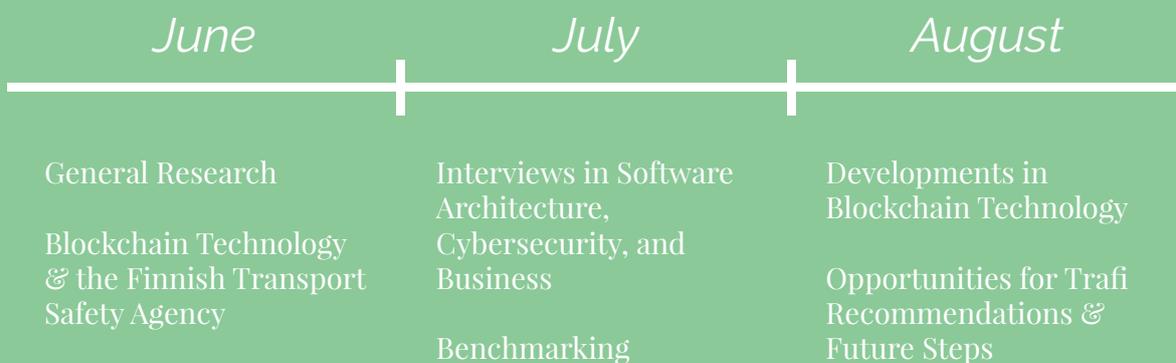
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Goals & Scope
Report Context

About the Project

This report is part of our team's project within Aalto University School of Business' Information Technology Program. In partnership with Trafi, the Finnish Transport Safety Agency, we will be applying the concepts taught over the course of the program towards our research in studying the possibilities of using blockchain management. The purpose of this project is to research and identify applications of blockchain management applicable to the Finnish Transport Safety Agency. We aim to understand the processes, technology, risks and problems that should be taken into consideration before considering further investment.

The project team engaged in interviews with stakeholders within Trafi including ICT Services, IT Architecture and upper management. This provided valuable opportunities to further understand the current architecture and processes of Trafi. The value of the described solution will be significant for Trafi as it looks to find new avenues for continuing its ongoing innovation. We will seek to propose recommendations that provide the highest value and benefits for the Finnish government, its citizens and society. Blockchain is rapidly developing; however, given its technological maturity, further research before action is warranted.

Project Plan



Goals & Scope

Our goals are to deliver a summary of blockchain management, existing applications and additional information regarding technical and legal specifications. We will highlight specific applications within governments that are in line with Trafi's current IT strategy and future projections, as they will be sources for blockchain implementation best practices. Our research areas can be condensed into following research. As the questions above show, the emphasis is on the business benefits rather than on the detailed technology - whether Trafi should consider investing into further research and development at its current stage.

What is blockchain and how mature is the technology?

Where and how have other organizations utilized blockchain?

What are the opportunities that blockchain offers?

Report Structure

Our report consists of five parts. First, the context of the project is introduced. The second part discusses blockchain technology, and its benefits and risks. The third part shows different blockchain applications that are piloted in other countries. Then, our view shifts towards blockchain's opportunities for Trafi and the required actions for possible future implementation. Finally, requirements, future strategy and topics for further study are introduced.

Our research started with general research to understand current blockchain technology. Additionally, Trafi's employees were interviewed to gain an understanding of Trafi's current situation. Information regarding the current state of governmental progress in blockchain pilots was collected and systematically broken down. At last, we reached our recommendations, critical conditions for implementation and final conclusion for Trafi.

Report Context

About ITP

Information Technology Program (ITP) is an academic summer program that is organized by Aalto University School of Business in partnership with companies. ITP aims to provide students a strong applied understanding of IT, design and the digital world (Aalto University, 2017). ITP offers three simultaneous tracks including Information & Service Business, Strategy & Experience Design, and Digital & Interactive Entertainment.

The Project Team

Our project team, also named as Team The Fate of the Furious, is part of the Information & Service Business track provided by ITP. Our team consists of a group of undergraduate students with diverse backgrounds and interest in IT: Margaret Kapitany, Toni Kokkonen, Kai-Ling Yim and Joonas Leimola. More information about each team members is provided to the right.

About Trafi

Trafi (The Finnish Transport Safety Agency) develops the safety of the Finnish transport system, promotes environmentally friendly transport solutions and is responsible for transport system regulatory duties. Trafi issues permits, regulations, approvals and decisions, prepares legal rules regarding the transport sector; arranges examinations, handles transport sector taxation & registration, provides reliable information services; oversees the transport market as well as compliance with rules & regulations governing the transport system; participates in international co-operation; ensures the functionality of the transport system; creates opportunities for innovative development of intelligent transport; and informs the public of transport-related choices.

Meet the Team



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BLOCKCHAIN



An aerial photograph of a city, likely San Francisco, showing a mix of high-rise buildings and residential areas. A prominent green semi-transparent rectangle is overlaid on the right side of the image, containing white text. The background shows a cityscape with a highway interchange and various buildings under a cloudy sky.

Technology

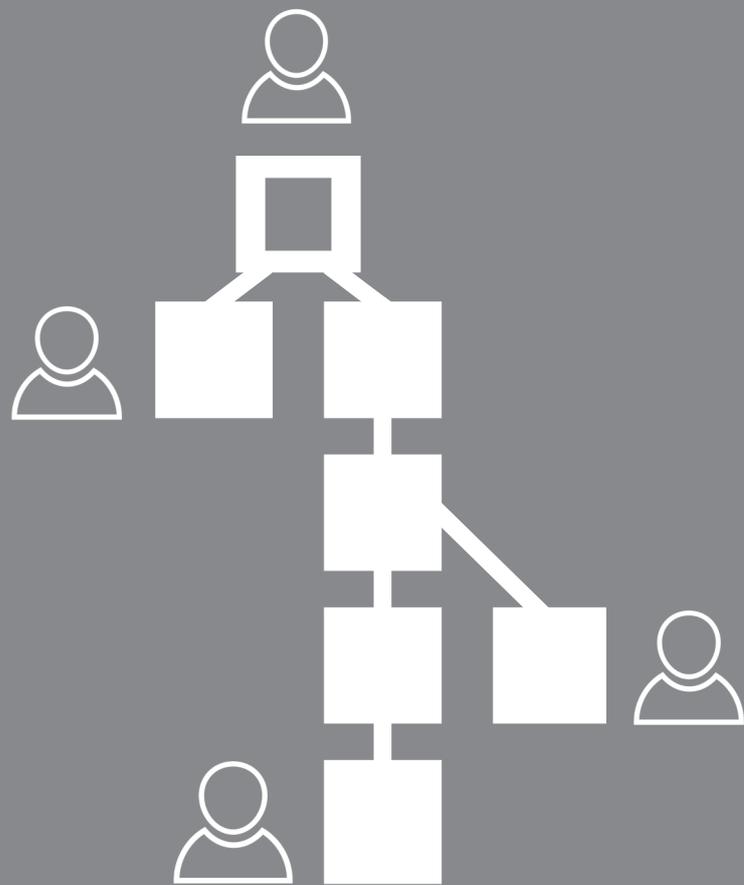
How it works

History

Benefits & Risks

Reasoning

Blockchain is a
decentralized ledger
with linked records
for tracking changes
of ownership within a
multi-party network



About the Technology

How it started

Blockchain started as an idea from cryptography enthusiasts in the 90s, with the main points of interest in the privacy sphere and the public - private key asymmetric encryption models. The first beta application of a blockchain was Hashcash, initially meant to be an anti spam countermeasure, where a computer's CPU (core processing unit) would expend a small amount of computing resources to generate a hash: a string of data created through a mathematical algorithm that maps data to a small string of characters. Hashes are designed to be a one-way function, such that they can be linked with the data they represent, but nothing else. The recipient using Hashcash could verify that the sender had spent time creating the email, instead of just sending out thousands of emails every minute as a spammer would (hashcash.org). Hashcash didn't survive for long, but it ended up being the basis for internal workings of modern blockchain.

Today, blockchain can be defined as a decentralized ledger with linked records for tracking changes of ownership within a multiparty network. The modern definition and conceptual models of blockchain were

proposed by Satoshi Nakamoto in a white paper published in 2008, which explained the underlying mechanism of hashing functions.

Verification of a blockchain's security is conducted by the stakeholders who choose to host the blockchain: distributed computing resources verify the hashes of new blocks containing data as they are created. Depending on the distribution of resources and how often new blocks are created, it can become an expensive endeavor.

In every blockchain there are two main types of blocks: the first block and the rest, as known as normal blocks. The first block, known as the genesis block, differs from all the rest by because it cannot refer back to the previous block's hash. The very first block in Bitcoin was time stamped with the text "The Times 03/Jan/2009 Chancellor on brink of second bailout for banks" (Blockexplorer.com, 2017).

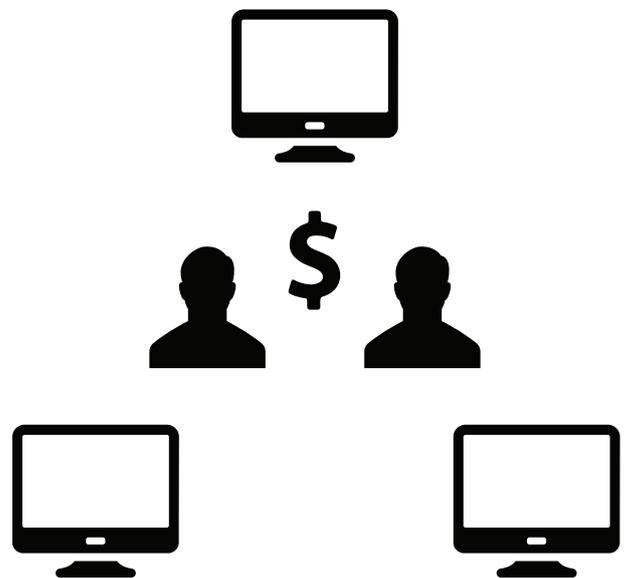
This proof of date is commonly used whenever creating new blockchains to ensure that all blocks must be dated after the genesis. The blocks after the genesis block are all generated by predetermined rules and use computing resources to find suitable hashes for the blocks.

How Blockchain Works

First, an blockchain user initiates a transaction with another party on the blockchain



The transaction is broadcast to a peer-to-peer network that shares the hosting of the blockchain, known as nodes

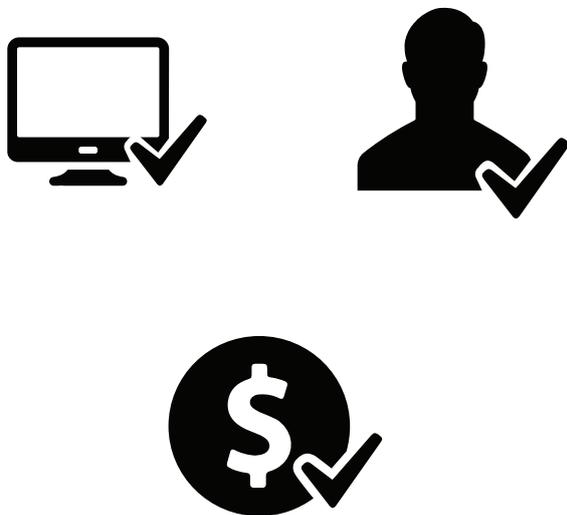


Components

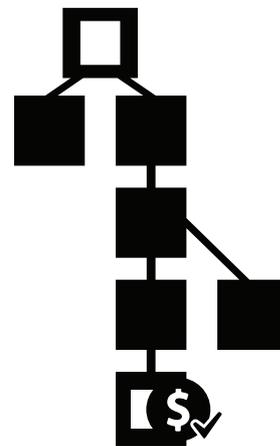
There are four main components to a blockchain.

1. Nodes and their operators or miners, who are responsible for keeping track of the database and making sure it is true.
2. Owners of keys and identifying their owners or keys, the users of the database of various access and privacy levels.
3. Transferring ownership of the tokens, how the database handles a change in ownership of a token from one key to another.
4. Storing this data in blocks of some sort and how these are stored, where compromises have to be made between the costs of transaction, size of blocks and various other common IT-infrastructure concerns.

The network verifies if there are sufficient funds to complete the transaction, the user's status, and access credentials.



Once verified, the transaction is combined with other transactions to create a block on the blockchain.



All information transferred is encrypted: it can be shared across multiple providers without risk of a privacy breach. Blockchain can be used for much more than the transfer of ownership: verified transactions can involve cryptocurrency, contracts, records, or other information. It is decentralized, so there's no need for any central, certifying authority, and established a trustless network with inherent reputation.

Examples of purposed applications include: Digital Currency & Fraud Reduction, Record Keeping, Securities and Smart Contracts.

How Blockchain Works

Distributed Database

As stated previously, blockchain functions as a distributed database: multiple different parties host the database such that no single person or group (of less than half of all participants) can change existing entries in the database. On a public blockchain there is no single person or party responsible for keeping records honest, and all of users benefit from the database being genuine at all times.

A private or consortium controlled blockchain does have some benefits: its governing rules can be changed and mistaken entries corrected more easily, no risk of outside actors colluding to compromise the system, and less computing resources are consumed compared to public blockchains. However, none of these are much of a difference to already existing database solutions, so the benefits remain somewhat questionable (Buterin, 2015).

While possible, there is little benefit from a blockchain that is completely controlled by a single entity or a small pre-selected group of actors, as it would be more cost beneficial, faster and safer to just use a traditional database built on one of many pre-existing database systems.

Mining & Issues

In a global blockchain verified by miners, there are a couple of critical issues: wasted resources, and mining pool control. Bitcoin miners use up approximately the same amount of electricity as the whole of Croatia (Digiconomist, 2017). Additionally, there is physical waste created by the dedicated single purpose computers used for computations, as they need to be replaced very quickly to remain competitive.

The second issue is from mining pools, where miners team up to reduce competition for verification. When these mining pools get too large, they might end up controlling over half of the hashing power of the whole blockchain, at which point they theoretically could alter transactions at will, maybe even double spend tokens or create them out of thin air. This scenario is currently taking place within Bitcoin with mining pools from countries, such as China, where computing components and electricity is relatively cheap (Price, 2017). In smaller instances of local blockchain where there aren't rapidly increasing demands for verification, wasted resources and mining pools are not significant concerns.

Digital Ownership

The common way of operating a blockchain involves the use of miners, who compete to cryptographically validate the latest transactions or transactions that have happened in the last pre-determined amount of time (Antonopoulos, 2017). By chaining blocks to each other using this form of cryptographic validation, one can go through the blockchain to any point in its history to verify what has happened up to that point.

All transactions are open and somewhat anonymous, oftentimes referred to as pseudonymous, which can be compared closely to the workings of a stock exchange: all transactions are openly broadcasted for everyone to see, and the information of the seller and buyer remains a secret. However, as seen with the stock exchange, large transfers can be traced to the largest holders of the token or stock being transferred.

Differences between Private & Public Blockchains

<i>Private</i>	<i>Consortium</i>	<i>Public</i>
<p>In a fully private blockchain all of the major rights - read, write and verification - are kept by chosen actors</p> <p>Pros: automatic backup for validity of older data</p> <p>Cons: next to no benefits above an established database management solution</p>	<p>A group of governing actors vote together on the future or the state of the blockchain. Changes & the addition of a host requires group approval</p> <p>Pros: changes ratified quicker, verification is cheaper</p> <p>Cons: no longer trustless, decentralized nor immutable. Slower than a modern database</p>	<p>Anyone can read the blockchain, mine coins, run a node, and send transactions if they fulfill the necessary criteria & have funds</p> <p>Pros: trustless, open to all participants and immutable</p> <p>Cons: slow processing, expensive, and slow to adapt to much needed changes</p>

History and Challenges

The first large scale blockchain project to take off is Bitcoin, a digital cryptocurrency that isn't backed by a government or physical assets (Gupta, 2017). At the time of writing this report, the market cap of Bitcoin is at around \$40,000,000 while the entire cryptocurrency market cap is at \$101,000,000 (Coinmarketcap.com, 2017). The second wave of innovation has been researching how to utilize the underlying blockchain technology for more than cryptocurrencies: developed nation states and banking institutions seek the benefits brought on by a shared, public ledger such as blockchain.

Smart contracts are at the core of blockchain's current stage of evolution. On top of a shared open blockchain, a simplistic programming language is built for actors to create conditional contracts: when conditions are met, the code executes, and actors cannot manipulate it to do something else. These smart contracts could replace normal signed contracts in applications such as digital wills and transfers of ownership (Etheroll.com, 2017). Physical contracts can be lost, misplaced or tampered, and require a third party to back its safety and reliability. With smart contracts, execution is automatic once conditions are met.

In the same way that cryptocurrencies have replaced the transferring of wealth, smart contracts eliminate the need to trust a third party to keep track of actions.

The next major milestone expected to proceed smart contracts is called Proof-of-Stake (PoS). Currently all blockchains are secured by some form of Proof-of-Work, as described earlier, which consumes increasing large amounts of resources. Proof-of-stake intends to ensure security while minimizing the wasted resources: owners of the blockchain's tokens would "stake" their coins into a smart contract for a predetermined time, and if they act maliciously, their coins could be repossessed or deleted, often times called the burning of coins. If the contract is satisfied, they would get a payment of some sort for their troubles. The proposed yearly rate of return is 1% - 8%.

The last visible hurdle of blockchain is addressing spikes in demand. The largest networks go through extreme congestion every time there is increased market hype. While normal transfer times of an Ether token would be in the tens of seconds to a few minutes, during heavy congestion the same transfer many hours to get verified and transferred. This problem has many proposed solutions, but only a few have been put to live testing.

Blockchain Roadmap

2009

The first Bitcoin
blockchain goes live in
Jan. 2009

Rise in cryptocurrencies
spark increased
interest within financial
institutions

2013

2017

Organizations are
conducting R&D and
pilots, yet there are
limited live applications

Trafi's legacy systems
have been updated
and legislation is being
developed within the EU

2020+

Blockchain vs. Traditional Database

	Blockchain	RDBMS
Infrastructure Requirements	Low	High
Distributed Storage	Default	Optional
Single Point of Failure	None	Possible
Data Unit	Block	Table
Cancel Transaction	Until confirmation	Yes
Modify Old Data	No	Yes
Integrity Control	Every node	Master Server
Centralized access control	No	Yes
Centralized data write	No	Mostly
Concurrent transactions	Possible	No
Update frequency	Set	Real-time
Backup	Private Keys only	All data

Adapted from Ratkov, N. (2015)

General Benefits

Blockchains can have many benefits above databases executed with traditional technologies, depending on their implementation. The most prominent is the increased transparency and trust it offers. Changes made to information stored in blockchain can be viewed by authorized parties (or by everyone in a public blockchain) which ensures data transparency. Blockchains are immutable meaning that the information they contain cannot be altered or deleted. This creates a trusted audit trail for monitoring and compliance (Deloitte, 2017). Blockchain also has the potential to increase efficiency of operations by automating the identification of flaws in a business process (Genovese, 2016).

One of the core benefits of blockchain is that it eliminates the need for a third party to verify the database, which costs a premium. Additionally, these third parties often do not have a stake in the information recorded in the database. Through blockchain, all stakeholders can host nodes to verify the transactions on the blockchain as well as ensure its immutability. To effectively change the information recorded in a historical entry, it would not be enough to edit the information in a historical block, it would require modifying all of the preceding blocks to update their information.

Blockchain technology is built upon databases, whose records are simultaneously held by multiple parties in multiple locations and being kept and verified by all of these parties at all times. If a database needs to be accessed by multiple parties and all parties are interested in the database remaining untampered, a database built on the blockchain might be the optimal solution. Common suggestions for implementations of blockchain based databases are in the realm of land registries and deeds of ownerships. For Trafi, an applicable example would be its database of cars, boats or motorcycles, stored on the blockchain to ensure that the ownership records of any particular vehicle can not be tampered or falsified.

Blockchains are decentralized networks so they do not have a single point of failure. Therefore, a properly implemented blockchain had reduced vulnerability to security threats and frauds (Deloitte, 2017). A permissioned network means that certain members of the network are allowed access to view certain transactions. Use of permissions and cryptography improves the security and the privacy of data. (Genovese, 2016; Gupta, 2017.)

Risks and Problems

The biggest risk with blockchain is its infancy. Blockchain in its current form was written by Satoshi Nakamoto in 2008 and has only been in use since 2009. Complex implementations of the blockchain protocol, such as the Ethereum network, have only risen in the last few years. Currently blockchain's development level is at best equal to an alpha release of commercial software, soon to be released into beta. Such early stage technology should not be used for anything mission critical and building anything larger on the technology poses too high risks for most smaller entities due to likely changes in the near future. The other major problem with building projects on the blockchain is forecasting. As the technology is so new and quickly evolving, forecasting more than 6 months into the future is difficult.

Several problems need to be solved before blockchain can become a commonly used technology. It has been suggested that blockchain is not yet ready for mass usage (Dinh et al., 2017). The most important risks and problems related to blockchain are security issues, scalability, and integration issues. It is relatively difficult to acquire professionals with senior experience working with blockchain technology as it has low maturity. Furthermore, its security is

constantly being tested with increasing numbers of cryptocurrencies and experimental pilots in the industry. Until it has reached a greater critical mass within the world, it will be difficult to tell what is the robustness of blockchain technology against cyberattacks. Integration of blockchain to legacy systems is also a concern. Blockchain applications differ significantly from current technologies and therefore require major changes to be made to existing systems. (Deloitte; Genovese, 2016.)

Due to the emerging nature of the technology, current regulation is not up to date with the technology's recent development. There are no live applications outside the financial industry yet (Dinh et al., 2017), so the direction where blockchain is heading in the near future is still uncertain. For example, possible future drawbacks in reputation of blockchain may significantly slow down the pace of development. This problem with the lack of legislation is absolutely critical for Trafi in their consideration of possibly moving forward with the technology. Should Trafi decide to move onwards with the ever changing blockchain technology, they must be up to the task of complying with the bound to be changing regulation, once it surfaces, most likely from EU sources in the next few years.



Rational Reasoning Prior to Investment

An issue with choosing to invest in blockchain technology is the overload of relatively low value information due to its hype within the marketplace. Venture capitalists are eager to hear of any experiments on the blockchain, which creates ill-placed incentives to build systems on top of the technology. This underlines the importance that organizations should not build on blockchain until there is clear strategic rationale: cost-effectiveness, stakeholder involvement, and distinct benefits above modern database systems. Blockchain is experiencing explosive interest from many parties: they may simply be “jumping on the hype train” even though its popularity will inevitably plateau in future.

EXISTING PILOTS





Overview

Pilot: Sweden

Pilot: Estonia

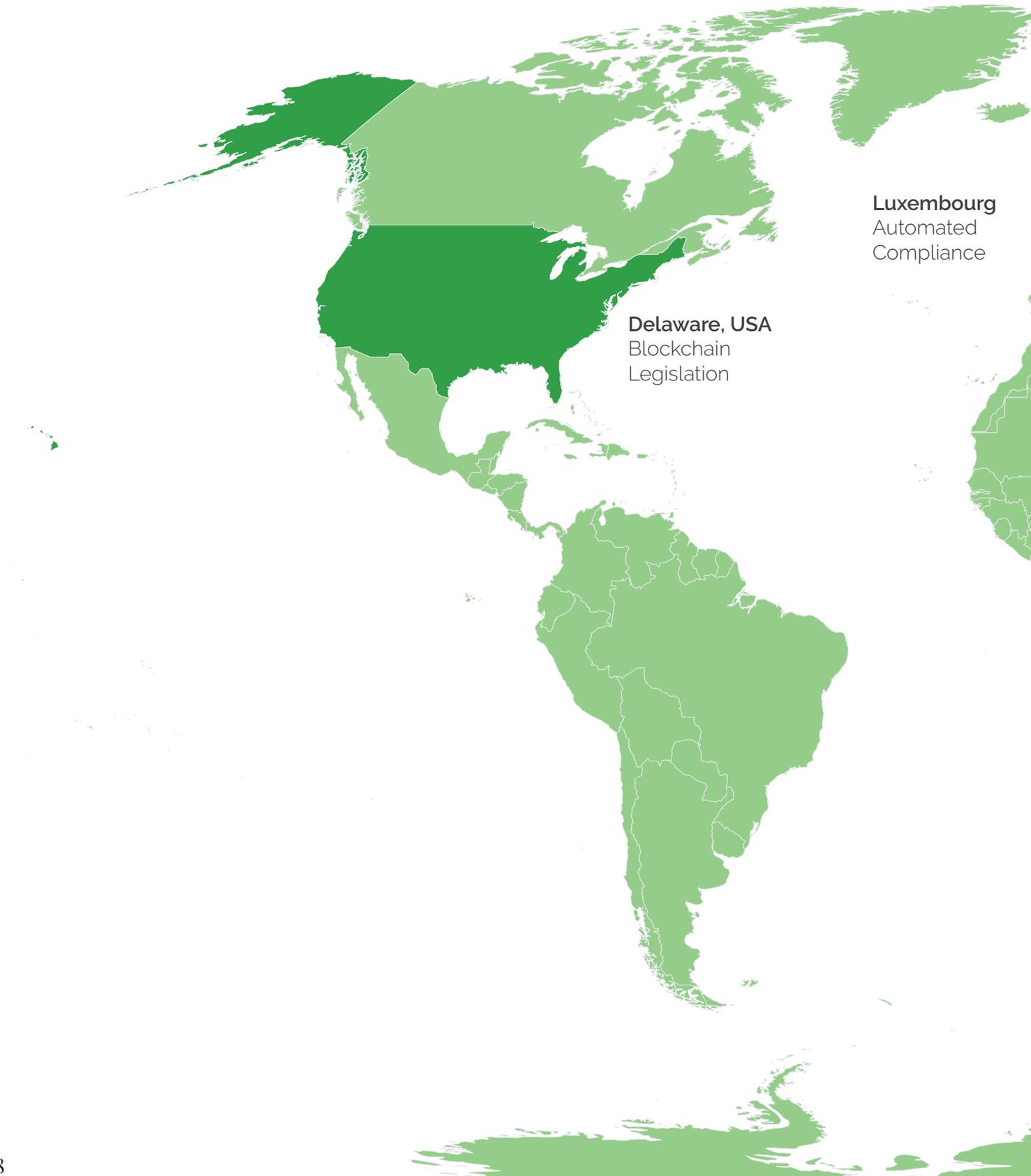
Pilot: Georgia

Pilot: USA

Pilot: Finance

Dropouts

Existing Pilots by Country





Sweden
Land Registry

Estonia
Digital Identification

Georgia
Land Registry

India & UAE
Cross-Border
Payment

Australia
Trade Finance

Overview of Use Cases

The existing use cases of blockchain can be broken down into three core concepts: Assets, Registries, and Smart Contracts (Kempe, 2017). The most well-known example of digital assets enabled by the blockchain is Bitcoin. While digital assets include the use of digital identities for value storage and transfer, blockchain technology does not have to be restricted to trading.

The second use case is a registry where hashes are used to identify an entity. Blockchain enables ledgers to be distributed between partners with varying degrees of permission, while minimizing opportunities for manipulation.

Lastly, the third use case of blockchain are smart contracts: programs/applications that enable the automated verification and enforcement of contracts. Ethereum, a major blockchain player, is a platform focused on enabling the hosting and execution of smart contracts.

The current maturity level of blockchain management is in its infancy: as of June 2017, there are no existing live applications within government. However, there are multiple governments conducting proof-of-concepts and research into possible applications. The progress of government has been split into three phases, as shown on the right:

Phase 2: Pilot Testing

Small-scale process integration

Sweden, Republic of Georgia, Honduras, Estonia

Phase 1: Proof-of-concept

Proof-of-concept and planning

United Kingdom, United States, Singapore, Hong Kong, Dubai, South Korea, Brazil

Phase 0: Research

No actions taken beyond research

Australia, China, Canada, Russia, India, Ukraine

Note: this is not a comprehensive list as stated interest varies frequently.

Pilot: Sweden

Swedish Land Registry

The strategy behind Lantmäteriet's (The Swedish Land Survey) foray into utilizing blockchain management is enabling the utilizing smart contracts to digitize real estate transactions and deed transfers, effectively reducing the time between signing the bill of sale and the property transfer from months down to days.

The pilot project is currently in Phase Two: having completed initial proof-of-concept technology and pilot testing, they are now testing the integration with banks' existing processes with small-scale data transfer (approximately 100 records). Stakeholder currently involved are Lantmäteriet, Telia Company (Digital Identification), SBAB (Bank), Landshypotek Bank, Kairos Future (Consulting) and ChromaWay, whose proprietary blockchain products are being modified for use.

The users of the proposed system would include buyers/sellers of property, real estate agents, banks, and Lantmäteriet itself. At its stage, ChromaWay is aiming to move the existing physical process of real estate transactions onto a common mobile application used by all parties outside of Lantmäteriet. Verification of documentation provided and enforcing contracts will be conducted internally within Lantmäteriet. Future proposals include moving mortgage contracts onto the blockchain.

Key Takeaways

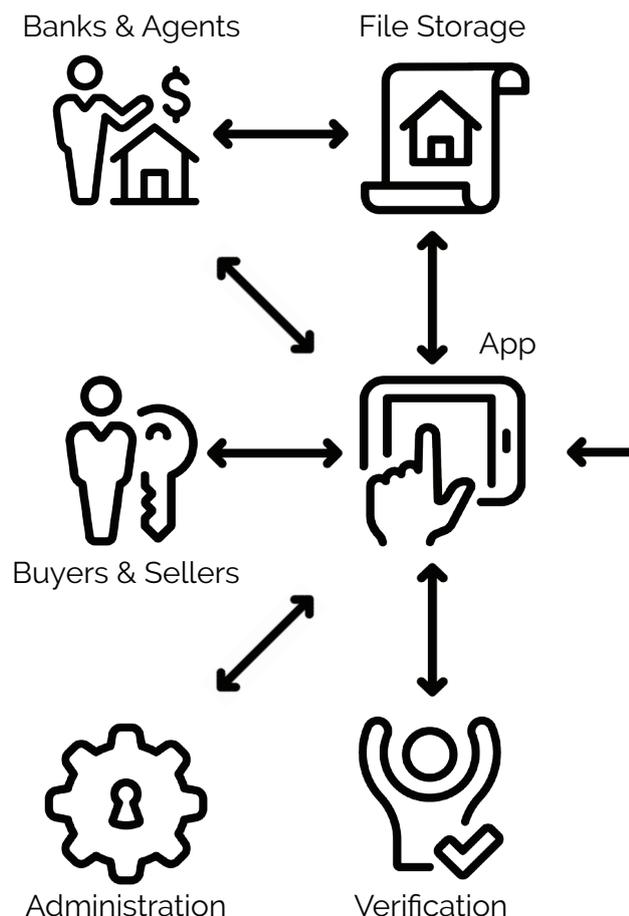
Sweden has pursued this pilot for approximately two years. They focused on creating an appropriate task force and bringing in the necessary stakeholders such that their proposed solution would address their user needs. This pilot is especially important to Trafi given its transferable aspects: shared cultural values, shared goal (blockchain registry), and common intermediaries (identification, banks). This is the only pilot that has shown its proposed IT architecture incorporating blockchain technology. We must stress that the financial benefit behind the Swedish Land Registry is reducing the processing times required for transferring ownership of high-value land, as opposed to vehicles or boats.



Overview of IT Architecture

User Interfaces

In the implementation, there will likely be three main user interfaces: a dedicated mobile application interface for buyers & seller, to facilitate verification and viewing details of their contract; a professional dashboard for banks, agents, employees of Lantmäteriet, integrated with their own systems and processes; and lastly an administrative dashboard for use within Lantmäteriet and the architects of the solution, wherein terms of contract can be revised. The administrative dashboard will enable Lantmäteriet to verify the actions of all actors, view the messages pushed to the blockchain, and properties of contracts: contract dates, ID numbers, public keys (digital IDs) of actors in the contracts, prices, and dates of transfer. With each action, a message (hash) will be included on the blockchain that tracks the progress of the contract: progress is viewable by all actors in the transaction. Any actions conducted will push messages to the blockchain. Identifying information regarding each real estate contract will be stored on the blockchain, while full documentation are kept in offline file storage.

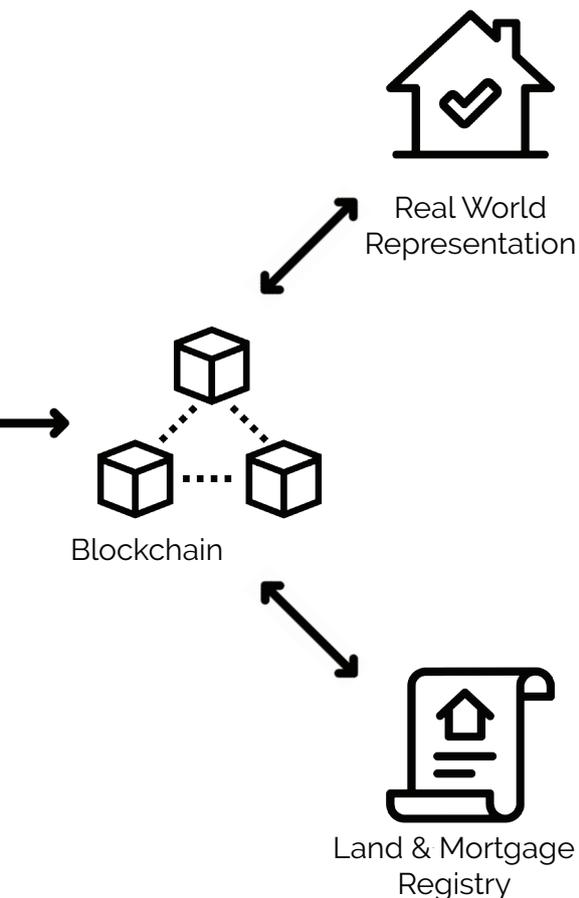


ID: Registry & Application

The major challenge for any digital solution is identification. After the implementation of blockchain in Lantmäteriet, the only method for fraudulent activity would be to enter a contract with false identification. Making a secure ID solution is the main hurdle for widespread implementation. Working off the foundation of digital identification, blockchain enables flexibility in permissioned access.

File Storage

Information kept on the blockchain (as listed previously) is intentionally kept minimal such that the network doesn't become too slow & large to transfer over the internet. The low transaction rate of the land registry, coupled with low cost of storage and network fees ensures that this solution isn't burdensome for the parties involved. File storage will not be handled jointly with the initial implementation. Until then, each party will keep their respective copies of documentation.



Real World Representation

The physical artefacts of the process are the properties transferred between parties. On the blockchain, Lantmäteriet will assign properties with unique IDs. The blockchain will enable a transparent record that authoritatively connects the digital representation with its real-world correspondent. Furthermore, information regarding individual property will be easily accessible with their respective IDs.

Blockchain

The blockchain of Lantmäteriet would be a transparent record of actions taken regarding the property deeds in its registry. In Lantmäteriet's case, nodes of the blockchain will be stored with the partners of this solution, equivalent to a distributed ledger. The blockchain would be highly permissioned with access depending on the identification of the end user, such that only partners are allowed to validate transaction and blocks.

Contract Engine

The contract engine is a key component of the solution, and will be developed based on proprietary IP from ChromaWay. In the initial implementation proposal, the application is not run on the blockchain – it does not utilize smart contracts. Only verifications are stored on the blockchain. The application purposed runs on the end-user's hardware: there is no central point of failure for the system.

Land & Mortgage Registry

The current land registry contains a lot of information beyond contract & transactional details, such as property rights, obligations etc. For the initial implementation, contract details will not be stored on the blockchain. Should partners i.e. banks, real estate agents need to access this data, they will still be required to go through Lantmäteriet with their existing systems.

Pilot: Estonia

e-Residency Program

Estonia introduced an e-Residency program in December 2014 (Running, 2012). E-Residency is a form of digital identification that allows e-residents to log in and use digital Estonian governmental and banking services. The aim is to make it an acceptable online identification in all EU countries in the future. (Running, 2012.) With the e-Residency, it is possible to set up a company in Estonia, run it and use Estonian banking services online from anywhere in the world. However, it is important to notice that e-Residency is not an actual residency or visa, nor it is an Estonian citizenship. E-Residency is simply a government-issued identity that is used for accessing Estonian online services. The authentication of digital identities is built on blockchain. (Running, 2012.)

In 2015, Estonia announced its partnership with Bitnation, a blockchain based jurisdiction that offers same registration services as sovereign nations offer, to build a notary solution where anyone can notarize documents, such as business contracts or marriage certificates, on a blockchain. The digital notary services allow people to digitally sign and verify documents and contracts in a trusted way (Bitnation, 2015.)

Pilot Rationale

Estonia has been developing a solid IT infrastructure for governmental applications for years. Therefore, the Estonian infrastructure supports experimentation with and development of blockchain. Putting both identity authentication and digital notary services on blockchain can cut down bureaucracy significantly. Instead of different authorities, e.g. police and banks, storing the information in their own systems each, blockchain can be used to authenticate the source data directly. This makes the information less vulnerable to attacks compared to data in a single database.

Blockchain allows the individuals to control access to their own identity information by providing access to certain parts of their identity information. (Sullivan & Burger, 2017.) Blockchain also facilitates international interoperability. Many documents, for example birth or marriage certificates, are stored in nations' own databases making it hard to transact with officials in a foreign country. The idea behind e-Residency is "a nation without borders" that makes viewing and verifying foreign documents easy, while still maintaining a high level of data privacy. (Sullivan & Burger, 2017.)

“The Republic of Estonia is the first country to offer **e-Residency, a government issued digital identity** that empowers entrepreneurs around the world to set up and run a location- independent business.”

Republic of Estonia, e-Residency



Benefits for e-Residents

Adapted from the Republic of Georgia's E-Residency website



Establish a Company Online

Start a company 100% online from anywhere in the world
Access business banking & online payment service providers
Be the full owner of your company. No local director needed



Manage Remotely

Sign and authenticate documents anywhere
Encrypt and send documents securely
Easily declare taxes online



Achieve location independence

Continue operating your company online while traveling
No need to re-establish your company after moving abroad
Focus on your passion, not paperwork

Secure Digital Identification

Successes & Challenges

Although many regulation issues regarding blockchain are not tackled yet, e-identity authentication can be integrated within existing standards, such as AML/CTF (Anti-Money Laundering / Counter-Terrorism Financing) (Sullivan & Burger, 2017). These standards require that every bank and financial institution checks and reports the identity of their customers. One of the key successes of the pilot is the idea of changing identity from national concept to transnational (Sullivan & Burger, 2017). If the e-Residency is implemented in other countries in the future, that person can be identified in those countries as well. However, the notary services offered to e-residents may not be legally binding in Estonia's or other nations' jurisdictions, although they are recognized as valid within the blockchain. For example, changing names by getting married in Bitnation using e-Residency for identification creates a false identity as that marriage and thus name change is not legal in the real world.

None of the transactions registered in Bitnation have legal standing unless recognized also by a sovereign nation. Therefore, as Sullivan and Burger (2017) put it, "using blockchain technology in this way raises the potential to create an identity outside traditional national channels".

While blockchain technology makes the unwanted modification of the stored identity information highly difficult, there are challenges related to the application process for e-Residency. The application process can be done completely online by filling in information and sending photos of passport to the granting authority. The unneeded physical presence in the identity checking process increases the risk of creating new, false identities based on inaccurate or made-up information or information from stolen passports. There is a risk that these identities are then used for criminal activities such as money laundering. (Sullivan & Burger, 2017.)

Key Takeaways

Blockchain has the potential to widen international cooperation. This creates a chance for Trafi to increase the data integrity between foreign authorities and to deepen its international cooperation, if Trafi can involve its stakeholders at an early stage of implementation. Application process for e-Residency is not in line with regulations of financial services sector: KYC (Know Your Customer) requires in-person identification. However, this is not a problem of blockchain technology but the application process. Trafi should acknowledge the possible conflicts with regulation as it deals with payment service providers.

Pilot: Georgia

Introduction

In February 2017, Republic of Georgia's National Agency of Public Registry (NAPR) launched a pilot blockchain land-titling project in collaboration with Bitfury Group, one of the best-funded blockchain technology companies in the world, with \$60 million raised as of 2017 (Prisco, 2017). Apart from land ownership, the project is planning to process property transactions, mortgages, demolitions and notary services (Friends of the Fifth Column, 2017).

In this project, the registration of the land titles occurs in a private, permissioned blockchain operated by NAPR. This private blockchain is tied to the Bitcoin blockchain, which is public, in verifying the transactions (Shin, 2017) by posting timestamps on the Bitcoin blockchain, which allows NAPR to verify and sign a document that contains citizen's data about property ownership (Medium, 2016).

Pilot Rationale

According to Prisco (2017), this project is able to make land titles or property rights in general available to citizens "who are currently unable to legally register their property". This is especially the case for Georgia, where property disputes have been a problem for long due to vague record keeping and high

level of corruption (Friends of the Fifth Column, 2017). In addition, when assets aren't properly recorded, they can't be used in creating capital or credit as De Soto, president of Lima-based think tank, estimates this "dead capital" to be 20 trillion\$ in value (Shin, 2016).

Another reason for Georgia's undertaking of this project is due to increased security and transparency. Because land ownership ties in a lot of value, the validation provided by the blockchain increases the needed security (Pisco, 2017). Citizens have greater security that their documents are recognized as legitimate without worrying about information leakage as they will be provided a cryptographic hash to specific data.

Blockchain implementation is easier for Georgia due to its systems being relative modern and the country's solid software infrastructure, which is more open to integration with newer technology, and interoperability with blockchain. In addition to increased security, storing information on the blockchain will smoothen the registration process. Blockchain technology enables time and cost savings in the registration process: records on the blockchain can be audited real time by a public auditor e.g. every ten minutes instead of on annual basis (Betcoin, 2017).

Immutable land registration

Successes & Challenges

The project appears to be going smoothly between Bitfury and NAPR as the Chairman of NAPR, Papuna Ugrekhelidze, also stated in February 2017 that NAPR is satisfied with the technological progress and is willing to continue their collaboration with Bitfury (Prisco, 2017). In 2017 April, the CEO of Bitfury stated that since the launch of the project in February 2017, more than 100,000 documents have been registered on the blockchain (Smerkis, 2017). Due to the low maturity of current blockchain, it might take more time to educate citizens about the technology upon introduction. Thea Tsulukiani, Republic of Georgia's Minister of Justice, also addressed this challenge: "we want to move slowly in terms of explaining to society, and quickly in terms of implementation" (The Economist, 2017). This blockchain implementation also involves risks such as the loss of developer's support, mistakes in the blockchain's code or the possibility of a quantum computer cracking the encryption algorithm (Friends of the Fifth Column, 2017).

Key Takeaways

One of the reasons NAPR could implement blockchain relatively easily is because of the software architecture in Georgia's systems. However, the legacy systems in Trafti don't appear to be as developed. Trafti has described their legacy systems in our conducted interviews as "problematic" and that data needs to be corrected on daily basis. Hence, prior to implementing blockchain, Trafti should focus on updating and improving their ICT architecture, as is currently taking place. Blockchain implementation may be reconsidered in future years, depending on new developments in blockchain implementation and Trafti's updated systems. On another note, there is a higher level of corruption in Georgia and large value is tied in land ownerships. This increases NAPR's need for a secure, immutable decentralized database. Significantly less value is tied in vehicles, making blockchain implementation less attractive in terms of its current high costs and uncertainty for Trafti, until blockchain is more cost-effective.

Pilot: USA (Delaware)

Blockchain Regulation

The state of Delaware is pursuing blockchain enabling legislation and embracing the new technology by launching pilot of a public archive. Jack Markell, the governor of state of Delaware, announced an initiative to adopt the blockchain and smart contract technology industry (Parker, 2016). Markell revealed that the program will provide a legal environment for blockchain development and attract blockchain enterprises to the state of Delaware. Furthermore, Markell announced the need to explore any clarifications regarding allowance of “distributed ledger shares” (Parker, 2016). This is significant as Delaware already is the premier location for many national and international companies. According to Parker (2016), Delaware is the legal location of 66% of Fortune 500 companies, 85% of American IPOs and many start-ups. Markell also outlined four targets to legitimize blockchain in Delaware (PR Newswire, 2016) as seen on the right.

The Delaware Public Archives is working with Symbiont, a distributed ledger and smart securities startup, which specialises in smart contracts and archiving. The project aims to help Delaware to catalogue, store and secure government records that exist in digital form (PR Newswire, 2016).

Create suitable legal infrastructure for distributed legal shares

Ensure that the state regulation environment is supportive

Welcome blockchain enterprises to Delaware

Commit the state of Delaware to using blockchain

Delaware Targets for Blockchain Implementation

Emergent blockchain legislation

Project Rationale

One of Delaware's reasons for blockchain implementation is due to the general benefits of blockchain and smart contracts. Blockchain and smart contracts can help in transactional cost reduction, speeding up and automation of manual processes and fraud reduction (PR Newswire, 2016). In addition, according to Tinianow (2017), there are two other reasons why Delaware has been so keen on making these changes: being the leader in corporate registry services and value-added services.

State of Delaware will maintain its leadership in corporate registry services if it is the first to adopt blockchain technology. According to Prisco (2016), Delaware faced losing its competitive advantage to other jurisdictions in the U.S and outside of U.S, thus they have committed renewed effort in attracting new businesses with an efficient record keeping system. Moreover, if Delaware is to offer registries on blockchain then more value adding registry services could be offered in addition to incorporation services. According to Tinianow (2016), these services include UCCs, land and personal property titles, birth or death registries or professional licenses for example. If companies decide to access the authoritative approval of Delaware on blockchain, then they can also integrate the approval with other technologies to enhance workflows (Tinianow, 2016).

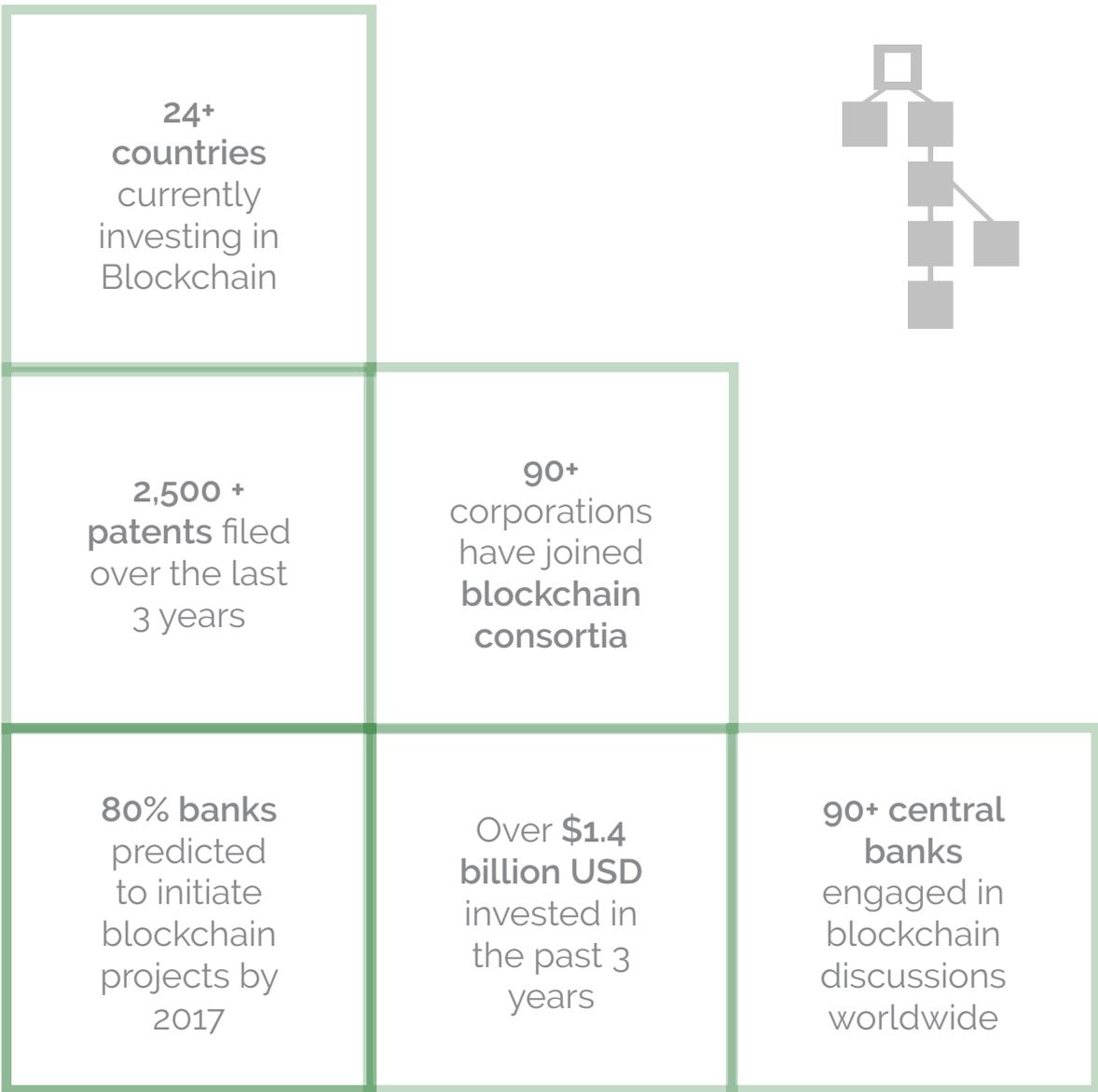
Successes & Challenges

In July 2017, Delaware passed a bill that approves stocks trading using blockchain (Haig, 2017). This is a step towards Delaware's goal of permissive blockchain regulation. However, Delaware still faces challenges regarding the lack of legal definition of blockchain: there is a lack of "clear legal definitions and apparatus pertaining to blockchain technology". Furthermore, since Delaware's law is ahead of federal regulations, it is possible that future federal regulations might not recognize the trading of stocks via blockchain (Haig, 2017). This risk may pose challenges to businesses that operate according to a single state's regulation.

Key Takeaways

Lack of blockchain permissive regulation poses restrictions and challenges as described in Delaware's case. Currently, blockchain enabling regulation isn't developed enough within Finland such that blockchain based services would be legally and widely acceptable. Hence, in order to legally track records on a distributed database and use them for business impact, Trafi might need to wait for the legislation to develop further. Perhaps, Trafi could alternatively make an initiative, such as the state of Delaware, and collaborate with Ministry of Justice regarding permissive blockchain regulation.

Blockchain activity in financial services



Pilot: Financial Sector

Introduction

Interest in the utilization of distributed ledgers grew within the financial services industry with the rapid growth of cryptocurrencies in 2013. Today, nearly 80% of banks are predicted to develop their proof-of-concepts to initiate Distributed Ledger Technology (DLT) projects, synonymous with blockchain, within internal financial operations. (World Economic Forum, 2017) There continues to be significant obstacles to implementation: large-scale projects will require coordinated efforts to build standards, frameworks, and regulations for the financial services ecosystem and its stakeholders prior to moving forward. In the next three examples, we will highlight specific use cases within the financial sector that are applications for Trafi to assess potential feasibility.

Pilot Rationale

Drawing from the general benefits of blockchain listed previously, the following are key value drivers for the financial services (World Economic Forum, 2017). The priority of these benefits differs between use cases, as some parties value certain benefits more than others. In the use cases below, we will describe how the implementation of DLT can overcome current pain points in financial processes, granted blockchain should only be considered as a technology that can assist with business processes.

Operational
Simplification

Regulatory efficiency
improvement

Counter-party Risk
Reduction

Clearing & Settlement
time reduction

Liquidity & Capital
Improvement

Fraud minimization

Value Drivers within
the Financial Sector

Example Use Cases in the Public Financial Sector

Automated Compliance

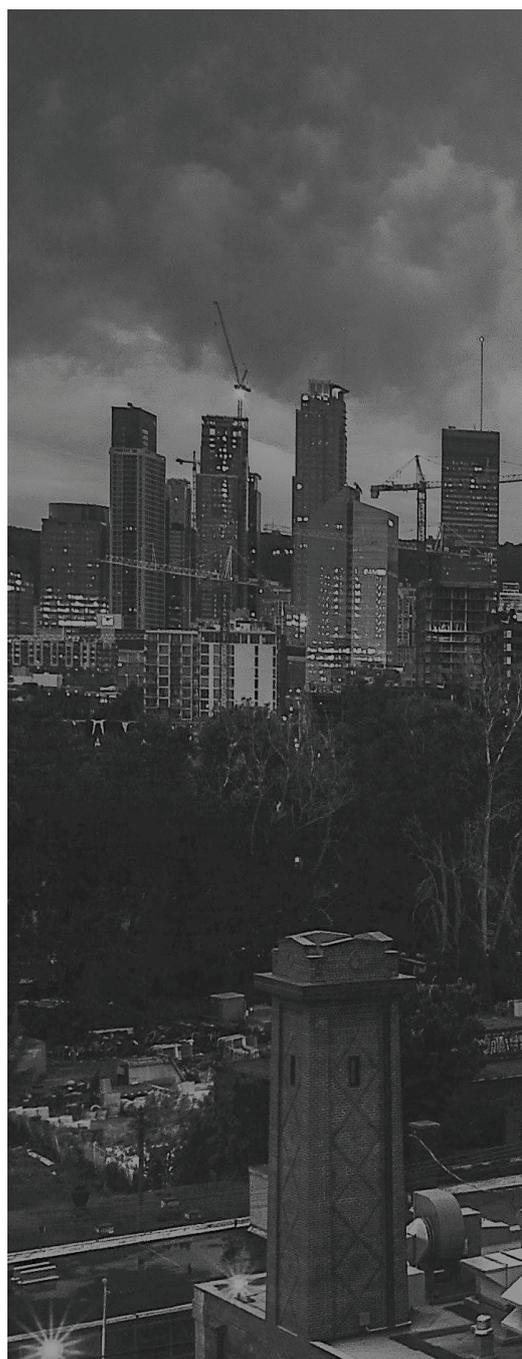
RegTech (regulatory technology) is a relatively new branch of fintech, which includes leveraging DLT to improve reporting and monitoring needs. The focus is on three core areas: regulatory reporting, KYC (Know Your Customer) processes for AML (Anti-Money Laundering) compliance, and the use of smart contracts (Akmeemana, 2017). The integration of DLT could reduce compliance costs within financial institutions up to 50%, according to blockchain startup Coinfirm (Lielacher, 2017), and KYC supporting functions by 50% (Accenture, 2017). While there are relatively few banks spearheading the development of DLT technologies in compliance, consulting firms and blockchain startup are already in motion: as of May 2017, Deloitte Luxembourg has successfully moved beyond its proof-of-concept and developed a new “KYC-as-a-service” solution to facilitate customer onboarding (Lielacher, 2017), with Ulster Bank, AIB and Permanent TSB having taken part in its development and trial process (Higgins, 2017). The main challenges cited for financial institutions in reporting their transaction include data quality, cost of reporting, timing issues and data reconciliation: DLT can support current & future regulatory challenges with regulatory efficiency improvement to “dramatically increase the scope & volume of transaction reported on a daily basis” (Deloitte, 2017).

Trade Finance

In October 2016, the Commonwealth Bank of Australia (Commonwealth Bank), Wells Fargo and Brighann Cotton announced that they had officially executed their pilot in a global trade transaction. While the previous example focused on the payment itself, this pilot’s core focus was the use of smart contracts on the blockchain, used in tandem with Internet of Things (IoT) sensors (Commonwealth Bank of Australia, 2017). The smart contract mirrored a Letter of Credit, with a physical supply chain trigger (IoT sensors giving a preliminary confirmation of geographic location) brought into the contract to allow for the release of payment. The tracking added a new dimension to the security, transparency and reduction of error inherent to the smart contract itself. The key value driver of this pilot is in its operational simplification: “The advancement from paper ledgers and manual processes to electronic trackers on a distributed ledger reduces errors and accomplishes in minutes what used to take days (Commonwealth Bank of Australia, 2017).” Significant regulatory, legal, and financial concerns remain to be addressed in the future.

Cross-Border Payment

Also in October 2016, India's ICICI bank and UAE's Emirates NDB (Bhattacharya, 2017), in partnership with Indian fintech subsidiary Edgeverve (Das, 2017), announced the successful execution of two pilot tests in cross-border payment using blockchain technology. They were among the first few globally to have authenticated transaction messages and documentation in real time. The core benefit of the pilot was settlement time reduction: efficient, near-instant remittance reduced from two days to minutes. Permission parties within the blockchain (the importer in Mumbai, ICICI Bank, the exporter in Dubai, and Emirates NDB) could view the remittance transaction independently through their secure network. The framework was designed to work with the existing systems and processes (ICICI Bank, 2016).



Example Use Cases in the Public Financial Sector

Successes & Challenges

The basis of the successes in DLT pilots thus far have been stakeholder alignment and the rapid development of technology, due in part to the significant investments in blockchain startups and research. While blockchain pilots are moving forward in full steam, there continues to be competition with the technologies and processes it seeks to replace. As such, key players such as Swift (the global interbank payments platform) are continuing to address remittance with more traditional alternative alongside blockchain pilots (Del Castillo, 2017). There are a number of critical conditions for implementation that span across the preceding examples, listed in order of importance:

Enabling interoperability with legacy systems between financial institutions & regulatory agencies

Ensuring compliance with existing and future regulatory & legal frameworks

Providing transparent access to data for enforcement in shared agreements

Providing compartmentalized access with data partitioning

Binding legality of cryptographic hash to exchange value globally

The technological feasibility of DLT heavily rests on the interactions and interfacing with legacy systems, while compliance/enforcement/legality all depend on regulatory precedent (WEForum). Given the progress thus far within DLT development, we predict that the legal environment of blockchain will improve within the next 2 years. Until then, financial institutions and startups will have to continue with small-scale pilots.

Key Takeaways

Blockchain can enable efficiency and operational simplicity through redefined processes. Digital identity can broaden applications to new verticals, however significant collaboration is necessary to address blockchain's critical conditions for impactful DLT implementation due to its complexity. Moving forward, blockchain will drastically change the operating business models within the future of financial services.

Dropouts

Republic of Honduras

In May 2015, Factom, a blockchain record keeping start-up company, partnered with Honduras government to pilot a project of using land title registry on blockchain (Maxim, 2015). The reason for the program was mainly to reduce land title fraud especially when, according to Factom, about 70 percent of Latin America's land is unregistered, exposing to corruption. In addition, the Honduran government and its other federal agencies have historically had many conflicts over property rights and validation of land title ownership (Young, 2015). A transparent and secure decentralized registry system was, hence, needed in order to get rid of these conflicts within the government and the society.



Map of Honduras

Reason for Stall

Despite of the partnership CEO of Factom, Peter Kirby, in December 2015 announced the program being stalled. The reason for the stall appears to be miscommunication and lack of rectification. Based on published documents in 2015, including Reuters article, Factom had agreed on the deal with the Honduran government. However, controversies aroused when suggestions of Honduran government having not committed to the program and not made a deal with Factum (Buntinx, 2015). During the time of the published article by Reuters, Factom team nor Honduran government never rectified the issue (Buntinx, 2015). After the controversies Factum stated that the project is being stalled due to political issues within Honduras and that Factum never suggested that the deal was more than proof-of-concept (Rizzo, 2015). He also stated that the reason why Honduran government has been silent is due to non-disclosure language in the letter of non-binding intent, which Factom received from the Honduran government (Rizzo, 2015). Based on public knowledge and at the time of this report, the Honduran government hasn't responded regarding the controversy. Perhaps, in overall, both parties benefited in the short term from the false claim regarding the program of land registry using blockchain technology. However, the long term negative effects overcome the benefits, making Honduras' readiness for blockchain questionable.

TRAFI & BLOCKCHAIN





Traffic Industry

Scenario Analysis

Current Situation

Requirements

Blockchain in Traffic

Overview

At the time of this report, there are no existing live applications of blockchain in the traffic industry nor in government. However, there are many startups and other enterprises that show interest and are researching in the area of blockchain and traffic industry. The following example use cases give a glimpse on blockchain's current influence on transportation and have been chosen based on greatest relevancy to Trafi. Even though these cases are currently out of Trafi's direct scope, but they are still worth acknowledging and following.

Autonomous Cars

In May 2017, Toyota Research Institute (TRI) announced that it teamed up with MIT Media lab and five other companies to explore how blockchain could be used to speed up the development of autonomous cars (Fermoso, 2017). The project would focus on creating a digital environment where users are able to share data safely on every drive that the autonomous car goes (Francisco, 2017).

In addition to data sharing, users can also manage ride-sharing and car-share transactions more easily and without a third-party intermediary (Shieber, 2017). The rationale behind using blockchain in autonomous vehicle development is the need for

large amount of driving data from different users as also mentioned by Chris Ballinger (2017), director of mobility services and CFO at TRI: "Hundreds of billions of human driving data may be needed to develop safe and reliable autonomous vehicles." He also stated that blockchain allows the pooling of data from vehicle owners, fleet managers and manufacturers to decrease the time to reach safe autonomous vehicles and to increase safety, efficiency and convenience (Shieber, 2017).

Additionally, Toyota Motor Company also believes that blockchain will allow the company to lower costs and increase efficiency (Francisco, 2017). Since vehicle's sensors collect driving data and store it on blockchain, blockchain could also be used to create insurance products with lower rates based in usage (Francisco, 2017). This increases transparency and would enable insurance companies to lower costs to consumers who have safe driving habits.

Overall, blockchain could enable compelling development in self-driving cars, mostly due to its immutability, transparency and efficiency in information sharing. This is significant since autonomous vehicles must be able to process a great amount of data in real-time to make fast decisions about which direction to go.

eWallet in Electric Cars

UBS (United Bank of Switzerland) has teamed up with ZF, an automotive technology company, and Innogy SE, a German energy company, to provide blockchain-backed eWallet for electric cars (Allison, 2017). In this payment system, the end users transfer money from their computers or mobile wallet into vehicle eWallet (Lielacher, 2017). The eWallet then enables end users to pay on-the-go for parking fees, electric charging, highway tolls and receive fees for car sharing.

According to Dr. Carsten Stöcker, Innogy's Machine Economy Lighthouse Innogy Lead, in this project the basis for the decentralized mobility platform has been prototyped and constructed upon convergence blockchain, energy internet and mobility internet to create a new transaction layer.

The new payment system enables many new possibilities. For example, according to Allison (2017), the main challenges for electric car drivers are short driving ranges and charging cycles. Therefore, drivers have the possibility to increase electric car's driving range as they are able to make micropayment transactions.

Micropayment transactions enable inductive charging, for instance, which could occur when the car is resting at a red light or crosswalk (Allison, 2017).

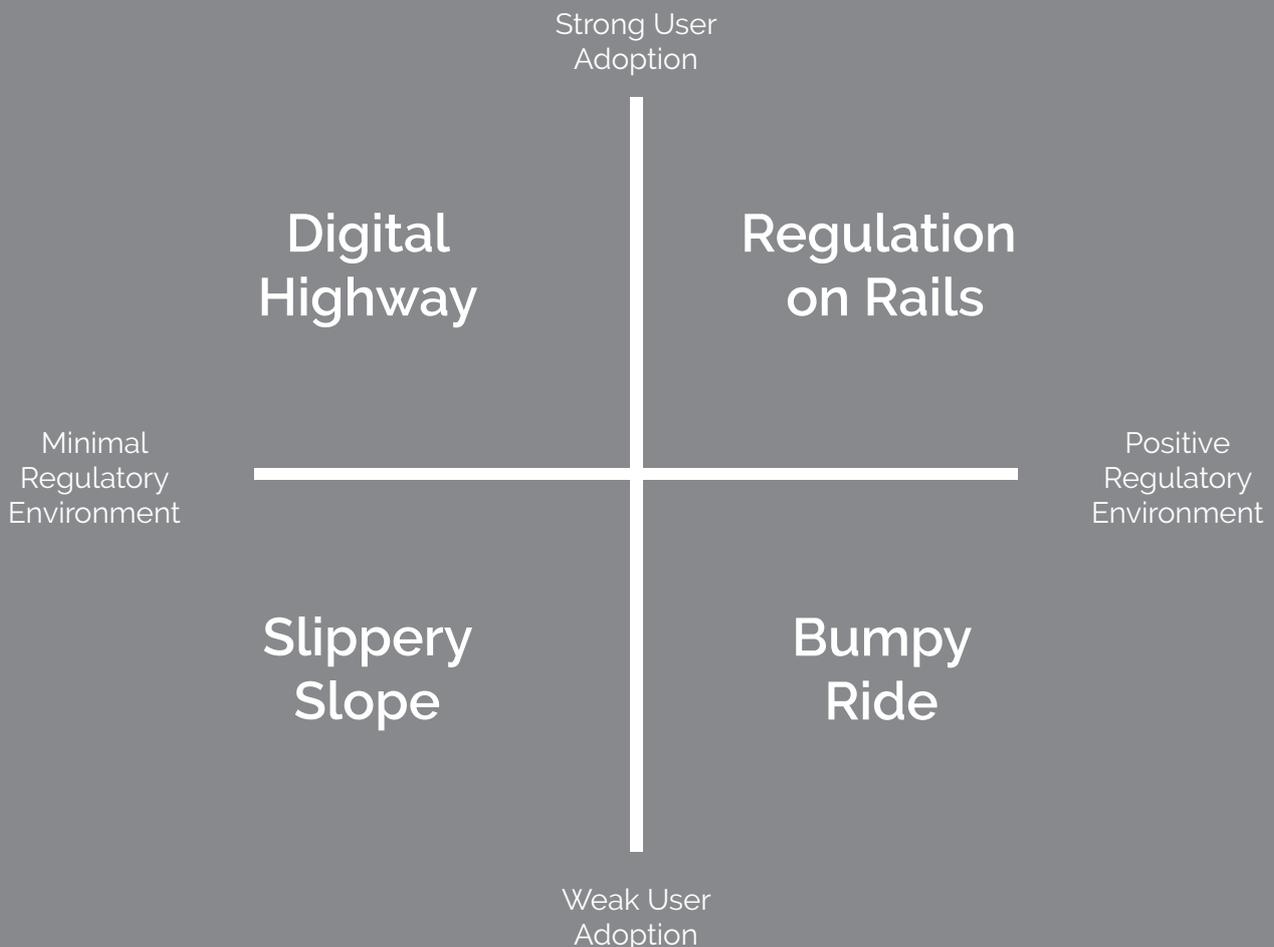
Another planned feature of the eWallet is to receive payments from third parties and grant them authority. Cars can, thus, be integrated into larger sharing economy as users are able to, for instance, access a car's trunk for direct package delivery instead of having full authorized access to the owner's car (Lielacher, 2017). According to Stöcker, blockchain based system could also integrate with intelligent supply systems, allowing the vehicle to control its charging process.

Overall, blockchain based eWallet can facilitate payment efficiency especially when blockchain enables peer-to-peer transactions and eliminates intermediaries. Perhaps, the first features of the system might not be too far away from the future since Innogy, as of May 2017, announced the planned construction of hundreds of electric vehicles charging stations enabled with Ethereum technology (using asset-backed Crypto-Euro payments) in Germany (Quentson, 2017).

Scenario Analysis

Overview

As the scope of this report has largely focused on the current time, it is also beneficial for Trafi to briefly consider plausible disruptive situations regarding blockchain that illustrate adoption, risks and rewards of the technology in the future. We will cover four scenarios of a fictional 2030 that do not seek to predict the future, but allow Trafi to imagine ‘what if’ and be better informed of plausible disruptive situations. Our scenarios are focused on two key critical conditions: the human factors of regulatory support and industry adoption. Given its history, we are certain that distributed ledger technology will continue to develop with or without utilization within public sectors.



Best & Worst Case Scenarios

Aspiration: Regulation on Rails

Government and the public sector have embraced cohesive regulation in technology; As a result of greater trust in the government, there is increased global GDP (www.transparency.org, 2017). In this future, the Finnish government has updated their technology to optimize their operations, governance and service delivery. Auditing and compliance efforts has scaled with the use of blockchain enabled records that deter fraud and corruption. Distributed ledgers are utilized for identity management, fraud control, programmable money/ transaction and regulatory technology.

Transport and infrastructure departments are able to utilize prescriptive analytics to better predict infrastructure failures before they occur with the data from internal and third-party devices (Kim and Kang, 2017).

Within the public economy, automation has led to significant adoption, innovation and development in manufacturing and digital intellectual property. Supply chain management and logistics are now significantly automated with the use of blockchain in internal operations between global partners (Hanson, 2017). Digital identification has grown to include facial recognition and biometric identification. Driverless cars using IoT devices and blockchain-enabled GPS systems have significantly increased the safety standards of modern transportation, such that driving is safer than ever before (Hanson, 2017). Overall, the positive regulatory regime of this future has enabled service delivery with red tape reduction, reduced transaction times and cost, and increased compliance.

Collapse: Slippery Slope

The worst that could have happened, has occurred. The market is held back by obstacles from project setbacks. Criminally minded parties took advantage of the vacuum of regulation to make significant profits. Digital currencies have experienced significant devaluations that quickly crippled and collapsed the technology behind non-

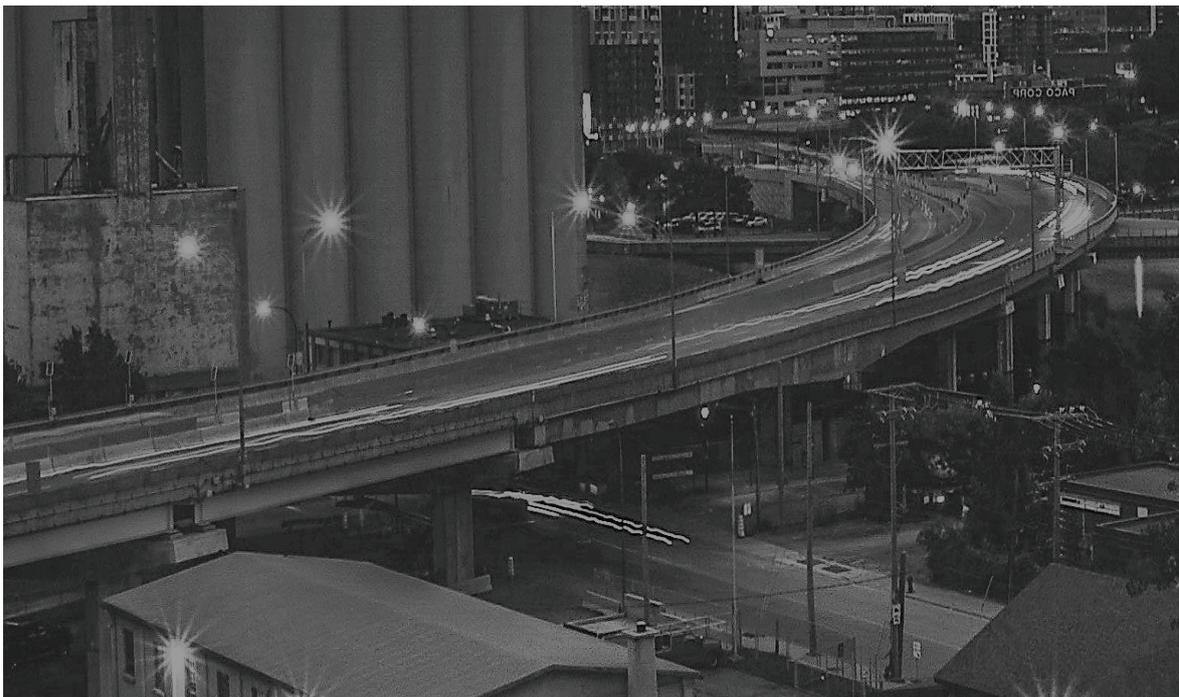
fiat digital currencies. A blockchain voting system, thought to provide voter anonymity, was discovered to be re-identifiable with network analysis. The focus is preventative, with the public and private sector lacking the engagement and interaction of stakeholders, resulting in an abandonment of the blockchain brand.

Minimal Regulation + Strong Adoption

Transformation: Digital Highway

In this future, the private sector took the leadership role in utilizing its resources, networks and connections to collaboratively utilize blockchain technology. However, while IoT and distributed ledgers are quickly becoming global, the requisite laws and regulations are not. The rapidly increasing rate of adoption has outpaced regulators before they could offer an official position on the legitimacy of distributed ledgers. Corporations have established interoperability between their systems & blockchain out of necessity to maintain security and risk management.

An example of blockchain applied to the shared responsibility of drivers utilizing driverless cars is between manufacturers, owners, and insurance parties. Vehicles' movements are recorded in an ongoing distributed ledger that records where it went, how fast it went, road conditions and surrounding traffic. The information is used as a record to ensure the partners adhere to the agreed conditions of the use and in case of accident or emergency. With verified service and repair actions, all stakeholders have data transparency.



Positive Regulation + Weak Adoption

Equilibrium: Bumpy Ride

In this future, governments and regulators have actively avoided stifling innovation and the freedom of the market by leaving the market to its own devices, and only imposing restrictions when the current systems has failed to support “the principles and values of society” (Hanson, 2017).

There continues to be competition between blockchain and the technology it intends to replace: the incumbent (ex. Peer-to-peer payment systems) seek efficiencies and new functionalities to retain its competitiveness with

customers who are hesitant to utilize distributed ledger technology. The technology itself continues to proliferate within startups and disruptive innovators, however the lack of standards leaves the greater industry with uncertainty in credibility and longevity. Many organization are simply waiting to see what develops. Digital currencies have generally lost value over time and have become more regulated. Adoption is slowing down with public interest waning in face of a bewildering array of products and turbulent development in recent years.



Current Situation

Compilation

Based on the interviews conducted with Trafi personnel as well as off-site research, the following is our understanding of Trafi's current internal environment to build upon what has previously been stated:

Security

In 2017, there has been a significant rise in blackmailing, phishing, malware/viruses/worms across organizations. This surge has also impacted Trafi significantly more than previous years which is leading to increased scrutiny regarding access rights & encrypting methods (Ahola, 2017), among other efforts related to availability and backups.

Trafi has been extensively audited for governance, and improving the current breakdown of access levels with stronger multi-factor identification is a major focus. Given the necessity to work across geopolitical borders and multiple systems (internal & external to Trafi), upholding cybersecurity across the greater architecture will require extensive research & auditing.

IT Architecture

Trafi currently operates with many systems spanning from pre-millenia legacy systems to newly adapted support systems. Systems span areas beyond car registration to include airplanes, helicopters, trains, boats, ships and so on. Each separated system is specified to its business needs. (Lauriala and Forsblom, 2017)

Business users outside of Trafi use multiple interfaces that Trafi has provided and developed for data transfer. As a result, data is input through many different portals and Trafi manages data governance within its own data warehouse. On a higher level, new inputs from day-to-day operations that require significant changes often necessitate changing the same information in several different systems for different parties, which requires extensive event handling. (Forsblom, 2017)

There are minor problems within the data warehouse where information is shown to not be found, as well as limited information gathered when changes are made to the stored data.

Trafi's Current Environment

Key intermediaries

Key intermediaries that are part of Trafi's internal operations include Vero (The Finnish Tax Administration), Katsa (Maintenance services) and Rekisteri (REKI, Trafi's Registry Portal). Additionally, as mentioned earlier with regard to standardization, Trafi must adhere to regulations & legislation of the Finnish Government as well as the European Union (ex. EU Data Protection Regulation); however, there is next to none within the EU that specifically relates to the use of blockchain data management.

Expanding beyond a pilot application of blockchain into a integrated solution will require the cooperation of stakeholders including Väestörekisterikeskus (The Population Register Centre) or alternatively, major banks familiar with the citizen registry, for the development of digital identification on the blockchain.

Externally, Trafi's stakeholders may be centralized (Vero) or decentralized, as is the case with repair shops (Pallaspuuro, 2017), which renders collaboration more difficult.

Development Process

Trafi internally uses different programming languages for its front-end, software, and back-end; however, the bulk of its systems are built specifically on Java for its maintenance properties. Trafi is currently focused on moving to newer technology that is more open source, which enables the use of openly developed technology & code to be adapted for internal use. Additionally, there is a call for more prototyping and rapid development to test new ideas. Moving outside of Java for solely improving existing applications can open new opportunities in developing solutions towards data integrity and accountability.

The move towards new technologies is also based on cost-efficiency; the centralized procurement process deters the use of risky emerging technologies prior to extensive auditing of governance & compliance. In the long run, standardization within the EU entails that Trafi will have to adopt the use of common systems in particular sector (ex. in railway & aviation) while others (ex. vehicle) will presently remain to Trafi's discretion. (Lauriala, 2017)

Trafi does not employ in-house programmers: external consultants are employed through service providers. This restricts Trafi's flexibility to incorporate emerging technology.

Trafi's Current Environment

Conclusion

Trafi's current needs could be addressed with the benefits of an extended implementation of blockchains; However, the ongoing IT architecture renewal, the current lack of regulations/legislation within the EU, and limited data transparency within existing systems and business processes entail that blockchain implementation would be an objective too risky and costly to target.

Given blockchain's infancy, the lack of experienced developers/architects or documentation, no roadmaps for expansion within the public sector, and lack of financial analysis for viability, we do not recommend that Trafi consider investing in blockchain data management until its current issues have been resolved.

We acknowledge that blockchain is new technology; as such, based on the projections of other emerging trends such as IoT, we believe the necessary regulations and legislation will be developed over the next 5 years: Trafi should re-examine blockchain in the years following 2020.

Critical Conditions

Based on our research examining the existing R&D and ongoing pilots of blockchain, the following are critical conditions deemed necessary prior to the investment for a pilot of blockchain within Trafi:

- Involve external stakeholders in hosting blockchain nodes & operations
- Establish interoperability between internal, external & regulatory systems
 - System input/output must work with blockchain event handling
- Ensure compliance with existing and future regulatory & legal frameworks
 - Blockchain-specific regulation in Finland & the greater EU
- Facilitate transparent access to data for enforcement in shared agreements
- Provide compartmentalized access with data partitioning & access rights
- Establish binding legality of cryptographic hashes for identification

Cautionary Note

Misuse of Centralized Blockchain

Given the low maturity of blockchain and the current hype of the technology, there is a high risk that blockchain could be implemented for inappropriate reasons. As Greenspan (2016) states: “If trust and robustness aren’t an issue, there’s nothing a blockchain can do that a regular database cannot do.” Using blockchain as a fully centralized database within an organization will not add any value compared to traditional (SQL or NoSQL) databases. Instead centralized blockchain are slower and more expensive as they perform extra tasks on top of what traditional databases do, such as signature verification, consensus mechanism and redundancy (Greenspan. 2016).

According to our understanding of Trafi, if trust is not lacking between Trafi’s internal stakeholders, then a traditional database would be more viable in conducting the data

management tasks as it is also more cost efficient and effective.

Centralized blockchains, intended solely for internal use only, are also unfavorable because they cannot realize the benefits of a decentralized blockchain, such as sharing the hosting of a database across boundaries of trust (between external stakeholders) without the need of intermediation.

Blockchain implementation is only viable if there is a proper reason for it as opposed to getting swept away by the current hype of the technology as mentioned earlier in this report. With this in mind, we cautiously recommend re-examining blockchain technology in future years depending on its technological development, legislation & regulation, and adoption within governments and traffic industries across the EU and beyond.

Current Situation

Lengthy project process in IT development
Legacy systems
Data must comply with government regulations



Blockchain Requirements

Flexibility to adapt rapidly changing technology
Interoperability between systems
Blockchain-specific regulation in Finland

Blockchain Requirements

Collaborate with Stakeholders

Our primary recommendation is that Trafi sets up a task force similar to the format of existing pilot applications within the government sector: partner with local blockchain startup, consulting firm and relevant stakeholders. The blockchain startup may bring relevant technology (often proprietary products), and the specific knowledge regarding governmental and EU changing legislation & regulations. Additionally, many organizations have employed a consulting firm to oversee the

progress of the project itself; this does not have to be external, as consultants can be employed from Trafi's existing contracts. The core benefit of blockchain is utilized when it is decentralized between multiple stakeholders, as such it is crucial that Trafi engages its internal government stakeholders including Vero and ICT Services; as well as external stakeholders such as banks, foreign governments, Katsa, and companies within its transportation sectors, to move forward as partners in expanding Trafi's pilots.



The following are the three main components of our future strategy recommendations, should market development within the next 5 years result in an optimal environment for exploring the implementation of blockchain within Trafi.

Redefine Processes

A comprehensive blockchain solution can introduce redundancies within existing business processes (as detailed in the Swedish Land Registry Report), necessitating a change management plan to address the changes in operations both internally with Trafi personnel, as well as in the processes of external stakeholders.

Blockchain introduces clearer access rights and accountability with regards to data standardization, which will assist with auditing governance and implementation.

Secure Identification

A core component of blockchain is the use of digital identification: parties identify themselves using private/public keys. Depending on the development of identification within Finland in the next few years, Trafi would have to work with its relevant stakeholder: Väestörekisterikeskus (The Population Register Centre) or alternatively, major banks familiar with the citizen registry. While this component is already in development, it is crucial to comply with Finnish and EU legislation & regulations in user privacy and e-identification.

Potential Applications

With our understanding of Trafi's services and scope, there are many areas wherein blockchain could be implemented, including taxation, citizen vehicle registry and vehicle parts registry (digitizing the supply chain). We have previously proposed a mobile application to integrate the existing vehicle registry with maintenance information; however, it would rely heavily on the involvement of external stakeholders.

As such, we must emphasize that the progress of any pilot that aims to integrate blockchain in a decentralized manner must involve extensive stakeholder involvement that focuses on common benefits and shared responsibility: unless co-operation can be slated, pilots will not be able to move beyond alpha stage testing and centralized management.

Furthermore, the current cost-effectiveness of pursuing a pilot is debatable depending on the sector and processes targeted: future improvement in the next years will likely dictate which sectors are most beneficial to target for pilot applications.

NEXT STEPS





Areas for Study

Conclusion

Appendix

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Areas for further study

Projects worth following

There are several pilot projects conducted by early adopters that could be followed for further learning by Trafi. The previously introduced countries – Estonia, Sweden, Georgia and USA (Delaware) – are in the furthest level of all countries in terms of developing governmental blockchain applications. This section discusses the projects worth following and introduces areas for further study. The most promising blockchain projects and the aspects to specifically focus on are listed below. Estonia's and its partnering organization Bitnation's projects are discussed in more detail in the following chapter along with EU regulation related to these projects.

Project	What to look for
Estonia	International cooperation Blockchain based services on a platform EU regulation during presidency of EU Council
Sweden	IT architecture for blockchain Collaboration with stakeholders Digital ID authentication
Financial Sector	Development of smart contracts First-to-market initiatives from heavy investments
Bitnation	Bitnation's legal status Governmental services on a blockchain

Estonian Blockchain adoption

Estonia is a leader in governmental sector blockchain adoption with their e-Residency project. The storage of citizens' healthcare records is a bold move as the data is confidential by nature. However, as mentioned before, Estonia's architecture supports experimentation with new technologies. Therefore, Estonia's project provides an interesting insight into blockchain's future potential if the project goes smoothly. The healthcare records are planned to be available for several public and private sector stakeholders, such as clinics and insurance companies. Organizing this collaboration between the government and private companies is worth following.

As Estonia has opened the e-Residency to everyone in the world regardless of their nationality, the development of blockchain applications for e-Residents truly benefit from international cooperation. For example, the global recognition of digital notary services would greatly benefit businesses that operate without a physical location. It is in Estonia's best interest to push for international cooperation.

EU & Bitnation

Estonia has the presidency of the Council of the EU from July 1st to December 31st 2017. The presidency will focus on four key areas, which are

- 1) Open & Innovative economy
- 2) Safe & Secure Europe
- 3) Digital Europe
- 4) Sustainable Europe

As the main task of the presidency is to drive forward the Council's work on legislation, Estonia is likely to forward the regulation of blockchain. It has stated that it will focus on "development of cross-border e-commerce and e-services" and that free movement of data inside EU is one of the key aspects of the digital Europe theme. (EU2017.EE)

As stated before, Estonian government's partner Bitnation has a revolutionary idea of a digital nation. There are still many regulatory issues (see "Existing Applications: Estonia"), but if they are solved, Bitnation as one of the earliest adopters, will be a significant player in international blockchain related operations and a potential partner of governmental organizations in smart contracts.

Thus far, the majority of research had been focused on revealing and improving the limitations blockchain from privacy and security perspectives, but many of the proposed solutions lack concrete evaluation on their effectiveness. Many other blockchain scalability related challenges including throughput and latency have been left unstudied. (Yli-Huumo et al., 2016)

In regards to security, there are several startups such as Bitnation and uPort (a system for self-sovereign identity built on Ethereum), that offer global identities and their authentication in blockchain. (Lundkvist et al., 2017.)

We recommend that in the following years, Trafi looks into the continuously evolving research regarding blockchain's latency, throughput, usability, fork/multiple chains, and bandwidth.

Conclusion

In conclusion, Trafi's current needs could be addressed with the benefits of an extended implementation of blockchains; However, the ongoing IT architecture renewal, the current lack of regulations/legislation within the EU, and limited data transparency within existing systems and business processes entails that successful blockchain implementation would be a moving target too risky and costly to aim towards.

Major changes would need to be made to current systems before blockchain could be used. Even though Trafi is renewing its systems, many of its stakeholders are not. This would bring integration issues between organizations if blockchain is used for services that involve multiple organizations. Furthermore, blockchain's infancy, the lack of experienced developers/architects or documentation, no roadmaps for expansion within the public sector, and lack of financial analysis for viability, we do not recommend that Trafi consider investing in blockchain data management until its current issues have been resolved.

However, the potential is there and it has been predicted that blockchain will have a big impact on how IT systems are used. Therefore, Trafi should follow ongoing initiatives to be up to date with the technological development and benefits that can be achieved with blockchain.

We acknowledge that blockchain is a new technology; as such, based on the projections of other emerging trends such as IoT (Internet of Things), we believe the necessary regulations and legislation will be developed over the next 5 years and there will be more evidence on the technology's robustness against cyber-attacks. We suggest that Trafi should re-examine blockchain in the years following 2020.



Appendix: Interviews

Interview 1: ICT Architecture

Interviewee: Markus Lauriala

Interviewers: Kai-Ling Yim, Margaret Kapitany, Viivi Nuorti

Date and place: 27.6 at Trafi's premise

Kai-Ling: What kind of IT architecture and systems Trafi currently has?

Markus: We have many systems. We have different systems for each business area. The main users are from the stakeholders and a few users from Trafi. But our stakeholders are doing our business, we are as supervisors. We have a couple of legacy systems and we are renewing those systems. We have some new systems but we have also designed support systems. Every business systems use those support systems. Our stakeholders use our systems via interfaces, web service, user interfaces. We are offering all those opportunities. Can you be more specific what you want to hear about our systems? About technology?

Viivi: Yes, and what do you have exactly currently in use and for how long? And do you have any challenges regarding them?

Markus: We have this technology IBM WAS 9, Database 2. Those are for the legacy systems. And in railway business we have Oracle. Our newest systems are based on Maria database, Mongo database, Jetty, Tomcat. Our all new interfaces are RESTful based interfaces. Our old one is AJP 3.0, so they are old and expensive to develop and expensive to keep on. We are planning to make those legacy systems again with new technology which are based on Mongo, Maria or Postgres and Jetty, Tomcat and things like that. We are more and more taking open source to our technology. Cloud service not so much we have 1-2 projects on our way which are getting some of service on cloud but we don't have any in operation at this moment.

Kai-Ling: You mentioned about renewing legacy systems. What is your timetable and goal?

Markus: We are renewing one of our legacy system right now. We have one very big project for that going on. And second big project is starting next year. The timetable for our legacy systems is 2019. We are getting rid of those systems.

Viivi: About tendering out. How do you tender out your technologies? Is the only factor price or is it something else, because Oracle seems really expensive? About the new technology, is it already been integrated and are they more cost efficient compared to old ones?

Markus: Costs are very important when you're working in the public sector. The use of Oracle is limited and we don't want to use that anymore. That's why we use those new technology as techs. Our procurement in public area is centralised so we have to use what our public sector has tendered.

Viivi: When it comes to scalability, spikes and demand, is that a problem currently?

Markus: In legacy systems, it's a little bit hard and it's a problem. But in the new systems not so much. In the interface layer we have external integration service which blocks the peaks.

Kai-Ling: Is the existing It architecture in a single platform or in many shared ledgers?

Markus: Yes. We have database layer, system software layer, interface layer and user interface layer. So, we have back ends and front ends separately. We are going for that design for all our projects that we have separated those layers.

Kai-Ling: How does that affect integration of data? Do you, for example, need to input data from different systems and many times?

Markus: Yes. We have support systems for example customers' data. We have to all the time search and read for that information. We don't want to put that data into the operating systems. So we are using those interfaces to search different customers' data. Second example for codes: we have our own codes system to search for codes and not saving data in the operating systems. So, it's a bit like master data thinking. We have different systems for different data. And data is available via interfaces.

Kai-Ling: Do you think that having several databases would affect efficiency? Have you considered alternative methods to integrate the databases?

Markus: Not so much, because we have our data warehouse. We offer our data to different kinds of stakeholders via the data warehouse and from the operating system. Our main focus is the interface that is the same without thinking where the data is coming from. It looks like same even though the source is different.

Kai-Ling: Are there any key intermediaries in your system? (Looking at the picture from your IT architecture about car taxation for example.) How much do you rely on the kind of system?

Markus: Very much. Our taxes are coming from Vero, and our registry is coming from REKI and our inspections from KATSA system. We are centralizing our one business to one system, so that various roles make taxes and make payments for customers. And there are a lot of transactions before you can have your taxes paid.

Viivi: Are the processes automated? Or do you always have to go to the interfaces? Or how does this specifically work for you?

Markus: It's pretty much automated. VERO system does the checking.

Kai-Ling: You mentioned about the renewal of the existing IT architecture. What would be the progress in 5 years?

Margaret: Or at least after you have finished what would be the next steps?

Markus: It's a tough question, because we are planning all our architecture for the business. We don't know what the business team want. They have some visions of some business. There are some systems coming that all the EU countries have to use. For example, in the railway business area there is a system called ERA coming, and we are planning to get that system and get rid of our own. In the aviation business, there is same kind of system coming and we are planning to get that. For our largest business area, vehicle, there are some plans that we are moving to regulator model that we don't have anything: we have no data, no systems, nothing. Our stakeholders are taking all and we are just supervising them. But that's just thinking and maybe in 2030.

Kai-Ling: I would like to ask about the data accuracy of your database. How sensitive is your system to errors?

Markus: Our legacy systems are very much problems. We have to correct those data every day.

Viivi: From the compliance regarding IT security, there is a new IT regulation data protection and privacy loss in the EU. Has that been a huge problem for you?

Markus: We got a lot demands from that. We have to renew our technology and architect for that. We have plenty of good solutions, but there's plenty of job to do.

Kai-Ling: About the practicalities, how long does it take to process a transaction?

Markus: It depends on the transactions.

Kai-Ling: Let's say in the most essential databases.

Markus: From example the register?

Kai-Ling, Margaraet, Viivi: Yes.

Markus: I actually don't know, because the business knows these things. Pretty fast, if the systems ae doing it. But if you have to check something manually then it takes time. I would say some milliseconds.

Kai-Ling: We looked at some customer reviews about Trafi on the internet. And some mentioned that Trafi's system isn't open during the weekend?

Markus: Yes, we are trying to improve it. I don't know exactly the SLA of our systems, not 24/7, but during working hours it should be on.

There are lots of problems in our data warehouse, where the information comes. Sometimes it shows data not found. But we use data governance in data fetching.

Margaret: What are the levels of interest regarding blockchain within Trafi?

Markus: The most interest is from the business side.

Kai-Ling: How do you think blockchain could be used in Trafi's systems?

Markus: Support systems could be on blockchain. Blockchain could be used to keep track of change information in e.g. registry.

Kai-Ling: How resistance to change are Trafi's employees?

Markus: ICT people would have their thumbs up for internal use of blockchain.

Kai-Ling: How much internet traffic does Trafi have on their website registry at a time? (how many users?)

Markus: Few thousands, not ten thousands or hundred thousands. Can be 40 thousand users altogether but not at the same time.

Kai-Ling: How much are current database maintenance costs?

Markus: Few millions just to keep up.

Appendix: Interviews

Interview 2: Software Architect

Interviewee: Oskari Forsblom

Interviewers: Kai-Ling Yim, Margaret Kapitany, Viivi Nuorti

Date and place: 27.6 at Trafi's premise

Viivi: What's your background and what kinds of things are you interested in?

Oskari: My name is Oskari Forsblom and I'm a software architect here in Trafi. My responsibility is to manage the whole software architecture. We have 6-10 teams and they all develop in different technologies and I'm trying to manage and make standard technology stack and so on. It's a huge work to do that. I like to go by myself during free time but here in Trafi I don't do difficult things, I just manage the situation. I don't have any experience in blockchain but I have read about that a lot and it's a pretty interesting field.

Margaret: Based on what you know about blockchain, how do you see blockchain in Trafi?

Oskari: I think that when we change the registry data, there has to be change information that we collect and I think that blockchain could bring something new to that, so we know exactly what data we have changed and when we have changed it. So it's like a check. Maybe some taxation or that kind of field, it could be implemented.

Viivi: During the previous interview, Markus drew us a graph about vehicle registry in which information went through REKI for example. Is that a nightmare for you?

Oskari: It's kind of a nightmare, because every system has a copy of the data and it's not centralized. That's the problem.

Viivi: How much manpower Trafi needs to run daily operations in ICT work?

Oskari: We have big teams. I don't remember exactly how many teams, but 6-10 teams and 5 persons per team, so that's big. That system that Markus told you was only for one system and only in car registration. We also register airplanes, helicopters, trains, boats, ships and son on. We have a lot different kinds of systems and domain.

Margaret: Are they all separate systems?

Oskari: Yes, they are separate systems. And those systems have different timelines so the car registration system is kind of old, and the maritime system is newer. They are done with different technologies and frameworks but all the systems are based on Java. That's the only common thing between them.

Kai-Ling: What kind software architecture Trafi has currently?

Oskari: I'm the only one that in Trafi whose responsibilities are in software architecture but every team has named software architect and they come from outside, so they are not in Trafi. And every team designed their software architecture but I look after it and approve it.

Viivi: I heard about Oracle and IBM in the previous interview with Markus. What kind of technologies would you like to see in future?

Oskari: I like open source technologies so in database maybe Postgre, MariaDB. Java is Oracle's, but I think you can't go wrong with Java since it's so maintained. But I like to see more Spring Boot kind of technologies more than Java EE. Also, in the front end I would like to see more JavaScript based frameworks like Handler and React and that kind of improvement. And also it's nice to proof of concept more of these technologies like blockchain. There are a lot of different kinds of technologies that would bring something new to our domain and maybe we could learn about those.

Kai-Ling: Are there any other challenges you're currently facing right now?

Oskari: There is a lot of. I think the biggest problem is the difference in technologies right now. Also, it's not about software architect but more in coding: there is a lot of variation in the quality of coding.

Margaret: So is it specifically in the code or in the data?

Oskari: Yes, in the code. But also in the data, but I'm more worried about the code.

Viivi: You do a lot of work with Tieto. How is tendering out from your seat?

Oskari: A year ago when we haven't tendered out. We had a lot of teams from a lot of different organizations like Solita, Tieto. Now that we have done the tendering, Tieto wants that tendering so we have to buy everything from Tieto. I think that's a big problem, because we can't compare and we are intertwined with Tieto. We can't compare other organization's ideas.

Viivi: If you had free hands how would you improve this institution?

Oskari: We need to have a flatter organization so that we can prototype more and benefit from prototyping.

Kai-Ling: Are you trying to renew software architecture and what are your goals, for example, within 5 years timeline?

Oskari: I'm trying to make some standards about our software architecture from technical point of view and I would like to see that Trafi is in 5 years in line with those principles and design patterns. But we will see because I'm just one guy and I don't have the power. The leaders are doing the approvals.

Kai-Ling: What kind of renewals are you making exactly?

Oskari: I have done the technology stack that the teams would follow, when they are doing something new. Also, the software architecture pattern that the front end is done with Angular 2 and application layer is done with Spring Boot. The databases are done with the PostgreSQL. So that is the newest standard how we develop and also there are some patterns which kind of clashes with code implementation and how do they implement those. There's going to be some standard of implementation as to how you would do the basic authentication and those kinds of things in the code.

Margaret: If you were to implement blockchain, would you outsource the expertise?

Oskari: Yes.

Margaret: Is the software that you develop is a lot of it for the public or mostly for the internal stakeholders?

Oskari: Both, but it depends on what services we are doing. We have mainly three different kinds of systems. A system for the public use and then we do software for ourselves that we could maintain the register data, and then we have services that we sell our data to the customers. The technologies are different in these kinds of systems. Our sell of data is based on Oracle's data warehouse technologies and the register data is Java applications and the public interface for those services is based on REportal. Also, we are doing some new kinds of things like applications for the phones and mobile apps.

Kai-Ling: Can you estimate how much would the software architecture management cost currently?

Oskari: I don't know, since I don't do budgeting. But the average cost for the new the system is one to 1-2 million euros, but that is from scratch to end.

Margaret: Are there any aspects or areas that need to be thought of when moving to a new technology like blockchain?

Oskari: We are doing a lot of development and improvement in old fashion. We have Java application and when we do improve it, we do another Java application. We don't think outside of the box. I would like to see that we could learn these kinds of new technologies and maybe implement those in our systems. Like you said about data integrity, this blockchain could address that.

Viivi: What do you think of centralized data integration so you don't need to go 6-7 different places? And what would integrating data require from you?

Oskari: I actually don't know whether we would like to move to a single big information pool. I would personally see it as more difficult to maintain compared to having multiple smaller ones.

(Oskari draws on a whiteboard and further explains the figure.)

Oskari: This system that Oskari was talking about consists of REKI, ASIAK, KATSA and all of these have currently their own databases. The problem is we have a copy of the car registry data here, here, here and here. That is the problem. If we change that data, for example regarding tire features, then we need to change it from all of the systems.

Now we have started to design the model in a way that we would now record basic microservice like here are the cars, and here events and here for instance registrations. Basically in one place there is one set of data, but as to how we know the connection between these is robust, there is a change information in everywhere. And the use of blockchain is here. The data itself can still be in the database, but the event handling can be in blockchain.

On the other hand, when we make changes regarding the cars and update technical information, the update of cars would also be based on blockchain. The advantage is that you can't really mess in between the data when it's in blockchain. We also have some quite sensitive data, for example deviation data e.g in our computer and we need to do a deviation report and they are really sensitive data. That data can't be published or be changed. In this kind of situation blockchain would be an ideal situation to ensure that the blockchain is intact.

As I've been here in Trafi for a while, I've realized that if we find even a small test/prototype from a sub-area, it would be easier to do compared to changing the whole car thing. It would be such a big change, so a small narrow sub-set would be an ideal situation. One area that would be interesting is that how do we approach blockchain: do we take it as it is or do we take a product alongside with the blockchain or do we start approaching blockchain as a concept.

Kai-Ling: How long do you think this would take?

Oskari: If we do that then it would be a bigger project, but it's difficult to say how many years as so many sub-areas are on board. But if we do a small project then it would be a project under a year. If we do the whole thing then it would at least take 5 years. It's interesting how we can extract data out from the blockchain as we sell data to outsiders. We are not only interested in the data of one block, instead we are interested in the data of the whole chain.

Appendix: Interviews

Interview 3: ICT Security

Interviewee: Petri Ahola

Interviewers: Joonas Leimola, Toni Kokkonen

Date and place: 3.7 at Trafi's premise

Joona: What projects or challenges you have with the cybersecurity stuff at the moment?

Petri: I just came back from vacation... [laughs] What projects we have? Well, right now we have a cybersecurity project going on. We try to think what digital security is for us and to create a program. So that we could improve the things that need to be improved through projects in the future. And now the EU's data privacy, GDPR, is a big thing. I work with that. And then there are some other directive renewals but they don't actually apply to us yet.

Joona: What challenges you have in the cybersecurity? Or what challenges have you worked with during the last couple of years? Have you some bigger threats?

Petri: Recently there have been quite many attacks related to phishing, blackmailing and malware. There have been a lot of them during the last month. And I understood that more will come. They predicted that some attacks are coming this week. But yeah, we have already mapped out the biggest ones this year. I can check. [Looks at the laptop] There. The highest risks we have malware and viruses and worms and... then we have denial-of-service attacks. Managing access rights, we have a separate project going on for that, we try to improve that. And then different kind of encrypting methods, backups and recovery, and cybersecurity management in general. We have thought of SOC, Service Operation Center service, that would be open 24 hours. That type of solution. And then we have the quality of system implementation and availability issues related to that.

Joona: Some blackmailing programs have attacked hard to some organisations. Have you had any problems with these?

Petri: Yeah, there have been a lot of DoS attacks this year. I must say that before this year, none of them were targeted to us and now almost ten have targeted to us so far. Although, they have been quite small so they haven't been the size of several gigabytes that are used for taking down banks. The downtimes have been a few minutes. But still they have interrupted our services. And like I said, these blackmailing programs and malware exist. Last year there were a few of them, and this year, too. Nearly every time

someone in our organization click those links. We have 700 employees. There is always someone who reads email carelessly. But we have tried to train the people who deal with emails the most and to harden up their workstations to decrease the risk.

Joona: You mentioned managing the access rights. After a few years it could be possible to use blockchain for that. What do you do in that field?

Petri: What comes to cybersecurity, we have been trying to ensure that we've reached the basic level. Data privacy regulation came in 2010 and we set the basic level. We got that audited as far as governance is concerned, but the implementation of the system is not audited. We try to bring the access rights to the basic level. And then we have one-time log ins in several systems...

Toni: Basic multifactor or 2fa?

Petri: When you log in to your workstation, it is attached to our AD and then the same log in is used for accessing all our systems. You don't have to type your password to every system.

And the challenge is that you can access all information using just one password even though we have different confidentiality levels. We don't have any strong identification at the moment. This confidential information would be good to...

Toni: Do you use multisig or something?

Petri: We don't have anything like that. We are conducting a data classification project at the moment. There shouldn't be any level 2 information in our systems because the systems can be used over internet. But we haven't gone through all the information yet.

Joona: Will the development of new systems affect cybersecurity?

Petri: We have a system called ATI at land vehicle department and a new system at aviation department. Systems at railroad traffic will be renewed. I don't know how it will affect cybersecurity as it is a bit of a mystery to me, too. I understood that the cybersecurity center of Communications Regulatory Authority (FCRA) would be left as it is now.

Joona: What are the roles between you and FCRA?

Petri: FCRA gives advice, information and recommendation. We implement things.

Joona: How will GDPR affect Trafi's operations?

Petri: I update cybersecurity appendices for contracts between Trafi and its partner companies. For example Ajovarman, which handles the driving licenses.

My role in general is to translate the legal text to IT context and to make sure that everything is done according to the requirements.

Toni: What is your opinion on using blockchain?

Petri: It would be good for data integrity. I can't say how it would affect confidentiality and availability. If personal information is put in blockchain then the geopolitical borders must be considered. We operate within EU and ETA countries. There are more benefits than downsides.

Toni: What kind of data would be good to put in blockchain?

Petri: Maybe the personal information and information related to vehicles. We have European-wide and even global cooperation. Let's imagine that a British ship comes here and the information related to that ship changes during the trip and that information has to be updated. It must be confirmed that it is that exact ship or something. In these kind of cross border actions, it could be good.

Information about a ship is usually needed in many places. In multiple harbours, for example. If we change that data, like what it has done here in Finland, that information would be false. Blockchain could be used for confirming that data. That could be done with personal information as well.

We have address, name, phone number and email recorded in our systems. And driver's licenses.

Toni: Is there something that shouldn't be put in blockchain?

Petri: We have different levels of information.

4: social security number

3: religion, criminal charges. If someone's life is under a threat and that person's address has to be hidden. These kind of things could be level 3. But it depends on who interprets the regulation.

2: documents related to harbour or airport security

1: could be information related to national security or European security

We have at least level 2 information in our systems.

Appendix: Interviews

Interview 4: Business

Interviewee: Toni Pallaspuro, department chief of vehicles

Interviewers: Joonas Leimola, Kai-Ling Yim

Date and place: 31.7 at Trafi's premise

Joonas: How much do you know about this project we are currently working on?

Toni: I have some experience with ITP as students from there have been here at Trafi in previous years, so that concept is clear. I have read some stuff about blockchain and have gone over some use cases.

Joonas: What is your job?

Toni: I lead the vehicle department here at Trafi. Our department is in charge of all things regarding vehicles that Trafi handles: from the beginning of a vehicle's lifecycle to its end. We handle permits, inspection, permissions for special cases, standard registrations, data regarding owners and what data is being collected from a vehicle. We secure ownerships for the needs of the society. A small section of vehicle taxation.

Joonas: In what kinds of projects are you currently participating in?

Toni: Road traffic and ground vehicle is a big part of Trafi's business, which also reflects the larger number in projects. We are doing a huge architecture project, in which the ground vehicle information system is being renewed. We are talking about refactorization or recoding everything. We are creating a new foundation for our business. System base is being renewed and architecture along with strategy. We are also improving our mobile and e-services. We are integrating our services in order to improve customer experience. The standard is that if we can give up on things then we will give up on them completely. If that's not possible, then we will automate them. And if that's not possible then we will provide services as self-service for the customers. And the last option is to provide e-service.

Joonas: What is the business model of Trafi from your perspective?

Toni: The business model of an authority differs from those of traditional companies. We don't have a self-made vision. We are given certain tasks by other authorities and we try to complete those tasks in a customer friendly and efficient manner. There are also so called extra services that we provide as we can always complete tasks on a bare minimum level. We try to balance productivity, such as cost efficiency, and customer service.

Joona: What kind of trends are there in the traffic industry currently?

Toni: Traffic is one of those industries that are going through major breakthroughs. If we are talking about road traffic then automation and robotization are major trends and the questions regarding these such as how are they possible and secure. Alternative forms of moving are also in trend such as natural gas vehicles and electric cars. And this leads to environmental issues, emissions such as Co2 emissions globally and locally. Taxation ties these together and it also relates to political considerations.

Joona: If we take Trafi into consideration, what challenges does Trafi have regarding these trends?

Toni: The greatest challenge is how to forecast where the world is heading to and how to focus on existing service production, for instance how to recruit new talent into the company, and keeping up with these changes. New tasks are just coming and we just need to know how to complete them in this organization and react to changes.

Joona: Are there any new opportunities in which Trafi could utilize these changes? Do you have any examples?

Toni: Even though I spoke of regulation, regulation can also be a tool to validate changes. Regulation might restrict but it also need to be flexible. We can improve our operation in a flexible manner when the regulation is flexible. There are new regulation and old regulation and we need to improve our operations something between those regulations.

Regarding to examples related to previous trends, we don't manufacture or develop robotic vehicles, but we make things possible for them to move on roads. We try to utilize new technology and new ways of working, for example piloting automation and actively following up on what can be done on the customer and stakeholder interfaces.

Kai-Ling: Regarding the architecture renewal, Markus and Oskari mentioned in previous interviews that the renewals will take 2-3 years. What is your estimation on that?

Toni: It depends on from which perspective we are looking. If we take the business side and the (customer) services into the picture then 2 years will not be enough. It will take 4-5 years to get everything in place.

Joona: Do you have any idea how Trafi could use blockchain? This is a question we are also trying to answer during this project, but we would like to hear your opinion as well.

Toni: No, I don't, but I have tried to think of this matter. I have pondered in which areas blockchain could bring added value. I am certain that there are uses of blockchain within Trafi, but we need to make decisions as to where it is used. We collaborate with the finance industry and maybe there we could find a common project and foundation for blockchain piloting.

Kai-Ling: In one of our course projects, we created a potential use case of blockchain within Trafi. Our idea was that car maintenance history could be digitized and recorded using blockchain so that it is transparent and secure between e.g. vehicle sellers and buyers. What do you think of this?

Toni: Digitizing maintenance history is not really possible, because the stakeholders are so scattered in Finland. And because cars can be repaired in different repair shops. If we take certain stakeholders on board, such as brand repair shops, only then there will always be some other parties that are left out. The problem has existed for a very long time but currently there just isn't enough drive to change this.

We were thinking whether blockchain could bring better ways of data collection and data utilization and whether blockchain could be used in (public) data releases.

Joona: Do you have any international collaboration regarding road traffic?

Toni: Yes, we do. We do a lot of collaboration within EU, since our main operations are in Europe and also a little bit on global scale.

Kai-Ling: Let's say that blockchain would be implemented on a very large scale. How difficult is it for Trafi to get other stakeholders, such as Vero and banks from the finance sector, on board?

Toni: It would be extremely difficult. For example, in the finance sector it is very expensive to obtain expertise in this field and it is difficult to get banks and insurance companies to change their systems suitable to blockchain even though Trafi asked. However, if it was about a common project between Trafi and banks or a group of other parties then it could be possible as we would need to face common factors etc.

Kai-Ling: On a smaller scale, according to Markus and Oskari in previous interviews, blockchain could be used in capturing the change information between the different databases, for example in terms of car registration, within Trafi. What do you think of this application?

Toni: I don't know the details of blockchain technology implementation, but the idea sounds logical. If we make a pilot program then other questions such as when do we do it (does it affect our other schedule) and how much does it cost would need to be considered.

References

Aalto University. (2017). Information Technology Program (ITP) minor. Retrieved from: <https://into.aalto.fi/display/eninformation/Information+Technology+Program+%28ITP%29+minor>

Accenture (2017). Blockchain Technology Could Reduce Investment Banks' Infrastructure Costs by 30 Percent, According to Accenture Report. [online] Retrieved from: <https://newsroom.accenture.com/news/blockchain-technology-could-reduce-investment-banks-infrastructure-costs-by-30-percent-according-to-accenture-report.htm>

Ahola, P. (2017). Informational Interview at Trafi Corporate Office.

Akmeemana, C. (2017). Using Blockchain to Solve Regulatory and Compliance Requirements. [Blog] Medium. Available at: https://medium.com/@akme_c/using-blockchain-to-solve-regulatory-and-compliance-requirements-1629of4b4ac1

Allison, I. (2017). UBS, innogy and ZF collaborate on blockchain wallets for cars. Retrieved from: <http://www.ibtimes.co.uk/ubs-collaborates-blockchain-wallets-cars-1599055>

Allmann, E. (2017). Blockchain technology in real estate. [online] Chicago Agent Magazine. Retrieved from: <https://chicagoagentmagazine.com/2017/06/06/blockchain-technology-real-estate/>

Betcoin. (2017). Republic of Georgia First Government to Store Data on the Blockchain!. Retrieved from: <https://www.betcoin.ag/republic-georgia-first-government-store-data-blockchain>

Bhattacharya, A. (2017). For Infosys, blockchain and AI are opening new doors in India's digital payments market. [online] Quartz. Available at: <https://qz.com/1020325/for-infosys-blockchain-and-artificial-intelligence-are-opening-new-doors-in-indias-digital-payments-business/>

Blockexplorer.com. (2017). Bitcoin Block Explorer [online] Available at: <https://blockexplorer.com/block/00000000019d6689c085ae165831e934ff63ae46a2a6c172b3f1b60a8ce26f> [Accessed 20 Aug. 2017].

Buntinx, JP. (2015). Factom Purposefully Twisted The Truth Regarding Deal With Honduran Gov't. Retrieved from: <http://bitcoinist.com/factom-purposefully-twisted-the-truth-regarding-deal-with-honduran-government/>

Coinmarketcap.com. (2017). CryptoCurrency Market Capitalizations. [online] Retrieved from: <http://www.coinmarketcap.com>.

Commonwealth Bank of Australia (2017). Landmark Blockchain Trade Transaction. [online] Available at: <https://www.commbank.com.au/guidance/newsroom/CBA-Wells-Fargo-blockchain-experiment-201610.html>

Das, S. (2017). Indian IT Giant Infosys is Working on 50 Blockchain Pilot Projects. [online]

CryptoCoinsNews. Available at: <https://www.cryptocoinsnews.com/indian-giant-infosys-working-50-blockchain-pilot-projects/>

Data61.csiro.au. (2017). Blockchain: what does the future hold for blockchain in Australia? - Data61. [online] Retrieved from: <http://www.data61.csiro.au/en/Our-Work/Safety-and-Security/Secure-Systems-and-Platforms/Blockchain?featured=6EDF11D88EED4B6794F2FBDFD65766B2>

Del Castillo, M. (2017). Swift Reveals Future Global Payment Tech – Blockchain Not Included – CoinDesk. [online] CoinDesk. Available at: <http://www.coindesk.com/swift-reveals-its-future-global-payment-tech-blockchain-not-included/>

Deloitte (2017). Deloitte paves the way for smart transaction reporting using blockchain. [online] Available at: <https://www2.deloitte.com/lu/en/pages/technology/articles/smart-transaction-reporting-using-blockchain.html#>

Deloitte. (2017) Blockchain Technology: 9 benefits and 7 challenges. Retrieved from: <https://www2.deloitte.com/nl/nl/pages/innovatie/artikelen/blockchain-technology-9-benefits-and-7-challenges.html>

Digiconomist. (2017). Bitcoin Energy Consumption Index – Digiconomist. [online] Available at: <https://digiconomist.net/bitcoin-energy-consumption> [Accessed 20 Aug. 2017].

Dinh, Chen, Liu, Ooi, Tan. (2017) Blockbench: a framework for analysing private blockchains. Retrieved from: <https://arxiv.org/pdf/1703.04057.pdf>

Etheroll.com. (2017). Etheroll :: Ethereum casino :: Ether gambling. [online] Retrieved from: <http://www.etheroll.com> [Accessed 30 Jun. 2017].

EU2017.EE. Programme of the European Presidency of the Council of the European Union. Retrieved from: https://www.eu2017.ee/sites/default/files/2017-06/EU2017EE%20Programme_o.pdf

Fermoso, J. (2017). Why Toyota thinks blockchain could enable self-driving cars. Retrieved from: <https://www.greenbiz.com/article/why-toyota-thinks-blockchain-could-enable-self-driving-cars>

Francisco, M. (2017). Toyota Taps Blockchain Tech for Self-Driving Cars. Retrieved from: <https://www.cryptocoinsnews.com/toyota-taps-blockchain-tech-self-driving-cars/>

Friends of the Fifth Column. (2017). Georgia: Authorities Use Blockchain Technology for Developing Land Registry. Retrieved from: <http://thefifthcolumnnews.com/2017/04/georgia-authorities-use-blockchain-technology-for-developing-land-registry/>

Genovese, B. (2016) Blockchain Technology: Hype or Reality? CIO. Retrieved from: <http://www.cio.com/article/3058266/security/blockchain-technology-hype-or-reality.html>

Greenspan, G. (2016) Blockchains vs centralized databases. Retrieved from: <https://www.linkedin.com/pulse/blockchain-vs-centralized-trade-off-gideon-greenspan>

Gupta, M. (2017) Blockchain for Dummies. IBM Limited Edition. John Wiley & Sons, Inc.

Gupta, V. (2015). Dangerous Old Men: Cypherpunk's Failure, Ethereum's Success.

Gupta, V. (2017). A Brief History of Blockchain. [online] Harvard Business Review. Retrieved from: <https://hbr.org/2017/02/a-brief-history-of-blockchain> [Accessed 30 Jun. 2017].

Haig, S. (2017). Delaware Passes Bill Recognizing Stock Trading via Blockchain Technology. Retrieved from: <https://news.bitcoin.com/delaware-passes-bill-recognizing-stock-trading-via-blockchain-technology/>.

Hanson, R. (2017). Distributed Ledgers: Scenarios for the Australian economy over the coming decades. [online] Data61, pp.27-49. Available at: <https://www.data61.csiro.au/media/2579B61A69FD4CoBA985AE8B823557DE.ashx> [Accessed 18 Aug. 2017].

Hernando De Soto, BitFury. Retrieved from: <https://www.forbes.com/sites/laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/#fe5f22744da3>

Higgins, S. (2017). 'Big Four' Irish Banks Join Blockchain Payments Pilot - CoinDesk. [online] CoinDesk. Available at: <http://www.coindesk.com/big-four-irish-banks-join-blockchain-payments-pilot/>

Higgins, S. (2017). UK Land Registry Plans to Test Blockchain in Digital Push - CoinDesk. [online] CoinDesk. Retrieved from: <http://www.coindesk.com/uk-land-registry-plans-test-blockchain-digital-push/>

ICICI Bank (2016). ICICI Bank executes India's first banking transactions on blockchain in partnership with Emirates NBD. [online] Available at: <https://www.icicibank.com/aboutus/article.page?identifier=news-icici-bank-executes-indias-first-banking-transactions-on-blockchain-in-partnership-with-emirates-nbd-20161210162515562>

Kastelein, R. (2017). Blockchain to Play Role in Future of Transportation? UBS Teams up with ZF and innology SE to Make it Happen. Retrieved from: <http://www.the-blockchain.com/2017/01/05/blockchain-to-play-role-in-future-of-transportation-ubs-teams-up-with-zf-and-innology-se-to-make-it-happen/>

Keane, J. (2017). Sweden Moves to Next Stage With Blockchain Land Registry - CoinDesk. [online] CoinDesk. Retrieved from: <http://www.coindesk.com/sweden-moves-next-stage-blockchain-land-registry/>

Kempe, M. (2017). The Land Registry in the blockchain - testbed. [ebook] Stockholm: ChromaWay, pp.3-71. Retrieved from: https://chromaway.com/papers/Blockchain_Landregistry_Report_2017.pdf

Kim, K. and Kang, T. (2017). Does Technology Against Corruption Always Lead to Benefit? The Potential Risks and Challenges of the Blockchain Technology. 2017 OECD Global Anti-Corruption & Integrity Forum. [online] Available at: <https://www.oecd.org/cleangovbiz/Integrity-Forum-2017-Kim-Kang-blockchain-technology.pdf> [Accessed 18 Aug. 2017].

Lauriala, M. and Forsblom, O. (2017). Informational Interview at Trafi Corporate Office.

Lielacher, A. (2017). Deloitte's RegTech Offering: Blockchain-Powered KYC-as-a-Service Solution — Bitcoin Magazine. [online] Bitcoin Magazine. Available at: <https://bitcoinmagazine.com/articles/deloittes-regtech-offering-blockchain-powered-kyc-service-solution/>

Lielacher, A. (2017). How the Blockchain will Help to Shape the Future of Private Transport. Retrieved from: <https://btcmanager.com/how-the-blockchain-will-help-to-shape-the-future-of-private-transport/>

Lundkvist, C; Heck, R; Torstensson, J; Mitton, Z; Sena, M. (2017.) UPort: a Platform for Self-Sovereign Identity. Whitepaper. Draft version. Retrieved from: https://whitepaper.uport.me/uPort_whitepaper_DRAFT20170221.pdf

Marshall, J. (2017). Estonia prescribes blockchain for healthcare data security - Health Matters. [online] Pwc.blogs.com .Retrieved from: http://pwc.blogs.com/health_matters/2017/03/estonia-prescribes-blockchain-for-healthcare-data-security.html

Maxim, J. (2015). Factom Partners with Honduras Government to Build Blockchain-backed Land Registry. Retrieved from: <https://bitcoinmagazine.com/articles/factom-partners-honduras-government-build-blockchain-backed-land-registry-1432065422/>

Medium Corporation. (2017). The Bitfury Group and Government of Republic of Georgia Expand Historic Blockchain Land-Titling Project. Retrieved from: <https://medium.com/@BitFuryGroup/the-bitfury-group-and-government-of-republic-of-georgia-expand-historic-blockchain-land-titling-4c507a073f6b>

Pallaspuro, T. (2017). Informational Interview at Trafi Corporate Office.

Parker, L. (2016). Delaware to 'embrace the emerging blockchain and smart contract technology industry,' with distributed ledger shares. Retrieved from: <https://bravenewcoin.com/news/delaware-to-embrace-the-emerging-blockchain-and-smart-contract-technology-industry-with-distributed-ledger-shares/>.

PR Newswire. (2016). Governor Markell Launches Delaware Blockchain Initiative. Retrieved from: <http://www.prnewswire.com/news-releases/governor-markell-launches-delaware-blockchain-initiative-300260672.html>.

Press release. (2015). Estonia e-Residency Program and Bitnation DAO Public Notary Partnership. [online] Retrieved from: <https://bitnation.co/blog/pressrelease-estonia-bitnation-public-notary-partnership/>

Price, R. (2017). The 21 companies that control bitcoin. [online] Business Insider. Available at: <http://www.businessinsider.com/bitcoin-pools-miners-ranked-2015-7?r=UK&IR=T&IR=T/#21-unknown-entity--01-1> [Accessed 20 Aug. 2017].

Prisco, G. (2016). Delaware Blockchain Initiative to Streamline Record-Keeping for Private Companies. Retrieved from: <https://bitcoinmagazine.com/articles/delaware-blockchain-initiative-to-streamline-record-keeping-for-private-companies-1462812187/>.

Prisco, G. (2017). Bitfury, Republic of Georgia Push Ahead with Blockchain Land-titling Project. Retrieved from: <https://bitcoinmagazine.com/articles/bitfury-republic-georgia-push-ahead-blockchain-land-titling-project/>

Quentson, A. (2017). Hundreds of Charging Stations for Electric Cars Blockchenezed with Ethereum in Germany. Retrieved from: <https://www.cryptocoinsnews.com/hundreds-charging-stations-electric-cars-blockchenezed-ethereum-germany/>

Ratkov, N. (2015). Blockchain: New Frontiers. Retrieved from: <https://www.slideshare.net/IosifItkin/extent2015-blockchain-new-frontiers>

Rizzo, P. (2015). Blockchain Land Title Project 'Stalls' in Honduras. [online] CoinDesk. Available at: <http://www.coindesk.com/debate-factom-land-title-honduras/>

Running, T. (2012). The Ultimate Guide to Estonian e-Residency, Banking and Taxes. [online] Nomad Gate. Retrieved from: <https://medium.com/nomad-gate/estonian-e-residency-ultimate-guide-banking-taxes-cc27fe39c368>

Shieber, J. (2017). Toyota pushes into blockchain tech to enable the next generation of cars. Retrieved from: <https://techcrunch.com/2017/05/22/toyota-pushes-into-blockchain-tech-to-enable-the-next-generation-of-cars/>

Shin, L. (2016). Republic Of Georgia To Pilot Land Titling On Blockchain With Economist Hernando De Soto, Bitfury. Retrieved from: <https://www.forbes.com/sites/>

laurashin/2016/04/21/republic-of-georgia-to-pilot-land-titling-on-blockchain-with-economist-hernando-de-soto-bitfury/#6ce2b81744da

Shin, L. (2017). The First Government to Secure Land Titles on the Bitcoin Blockchain Expands Project. Retrieved from: <https://www.forbes.com/sites/laurashin/2017/02/07/the-first-government-to-secure-land-titles-on-the-bitcoin-blockchain-expands-project/#3db348054dcd>

Smerkis, V. (2017). Georgia Records 100,000 Land Titles on Bitcoin Blockchain: BitFury. Retrieved from: <https://cointelegraph.com/news/georgia-records-100000-land-titles-on-bitcoin-blockchain-bitfury>

Sullivan, C & Burger, E. (2017) Computer Law and Security Review. Volume 33, Issue 3. Szabo, N. (2015). History of the Blockchain.

The Economist. (2017). Governments may be big backers of the blockchain. Retrieved from: <https://www.economist.com/news/business/21722869-anti-establishment-technology-faces-ironic-turn-fortune-governments-may-be-big-backers>

Tinianow, A. (2017). Delaware Blockchain Initiative: Transforming the Foundational Infrastructure of Corporate Finance. Retrieved from: <https://corpgov.law.harvard.edu/2017/03/16/delaware-blockchain-initiative-transforming-the-foundational-infrastructure-of-corporate-finance/>.

Trafi. (2017). Liikenteen turvallisuusvirasto Trafin kokonaisarkkitehtuuri: Nykytila ja lähtökohdat. Retrieved from: https://www.trafi.fi/filebank/a/1491221683/d83b89798f8b37be811f3d1ebd230a66/24733-Trafin_julkaisuja_06_2017_Liikenteen_turvallisuusvirasto_Trafin_kokonaisarkkitehtuuri.pdf

Transparency International. (2017). Corruption Perceptions Index 2016. [online] Available at: https://www.transparency.org/news/feature/corruption_perceptions_index_2016 [Accessed 18 Aug. 2017].

World Economic Forum (2017). The future of financial infrastructure: An ambitious look at how blockchain can reshape financial services. Future of Financial Services. [online] New York: World Economic Forum LLC, pp.14, 18-31, 39-100. Available at: <https://www.weforum.org/reports/the-future-of-financial-infrastructure-an-ambitious-look-at-how-blockchain-can-reshape-financial-services>

Yli-Huumo, J., Ko, D., Choi, S., Park, S. and Smolander, K. (2016). Where Is Current Research on Blockchain Technology?—A Systematic Review. PLOS ONE, [online] 11(10), p.e0163477. Available at: <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0163477> [Accessed 20 Aug. 2017].

Young, J. (2015). Factom Stalls Honduras Land Title Registry Initiative. Retrieved from: <http://www.newsbtc.com/2015/12/26/factom-stalls-honduras-land-title-registry-initiative/>

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