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Blockchains in mobility and logistics

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Abstract

In this paper, we analyze the applicability of blockchain in the transport and mobility sector. To begin with, the paper surveys identified and potential application ideas from publicly available information sources. Secondly, we examine an in-depth stakeholder workshop held to analyze selected transportation and mobility applications and ideas. Thirdly, we present a conducted PESTEL analysis to understand the utility and societal impact of blockchains as well as to provide an overall view on this issue for aiding governance.

Identified blockchain application areas are multiple, and include mobility services, such as a peer-to-peer car sharing, carpooling, ride-sharing, smart insurance contracts as well as logistics and supply chains with full transparency, proven authenticity, digitized shipping documents, and automated customs clearance. The current state of blockchain applications for transport is mostly at a proof-of-concept level, with specific cases recently moving towards commercial implementations. A visionary future scenario includes autonomous vehicles that operate as independent service providers earning their own fares, selecting their charging and service stations, paying their costs, obtaining their own auto insurance, and even negotiating liability in collisions. Clearly, the applicability of blockchain is under broad exploration, and the results of this study illustrate the status and directions of exploration. Finally, the paper gives ideas and future recommendations for utilizing and governing blockchain in the European transport sector.

Keywords: blockchain, distributed ledger technology, application, mobility, transport, logistics

1. Introduction

The disruptive nature of blockchain technologies have made them a highly interesting topic. While the disruptive nature has been more or less understood for some years, the research literature is for most part concentrating on very recent years starting from 2015 and onwards (see e.g. Pilkington 2015, Crosby et al. 2016, Mainelli and Smith 2015). The first well-known application of blockchains is the virtual currency Bitcoin (Nakamoto 2008). The essence of blockchain is the decentralisation of event registers, while at the same time these events are part of a defined process linked to each other. This character of blockchains may significantly disrupt how transactions are made and processed in the economy (Iansiti and Lakhani 2017).

Blockchains are more of an information architecture than an actual technology, since blockchains do not require any novel hardware technologies. They have the power to shift control away from centralised transaction and clearing systems typically managed by transaction middlemen such as banks, clearing houses and brokers.

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According to Stenfors (2015) blockchains are a set of protocols that “automatize trust”, handing over the power to build “trust networks” by any actors who decide to do so for the benefit of themselves and their network of trust.

The finance sector has been leading the way in studying and developing blockchain technology, but exploration has expanded rapidly to cover many other sectors, including mobility and logistics. Currently, the very first pioneering companies are presenting commercial blockchain based services in the transport sector. However, there are a large number of potential applications, emphasizing that blockchains are still immature as a marketplace technology. To analyze the overall exploration progress of blockchain applications in the transport sector, this paper adapts the framework of innovation-readiness levels illustrated in Table 1 (Tao et al. 2010).

Table 1. Framework of innovation-readiness levels (IRL) (adapted from Tao et al. 2010)

Innovation-readiness levels	IRL 1 Concept	IRL 2 Components	IRL 3 Completion	IRL 4 Chasm	IRL 5 Competition	IRL 6 Changeover
Key technology and market aspects	Technology feasibility confirmed Market research conducted Working with leading customers	Individual components tested Prototypes demonstrated End-customer identified	Actual system demonstrated External test completed Launch Specific needs and requirements of customers known	General availability to market Positioning in the market Business model established	Lower R&D activities Technological service provided Products differentiated Services and solutions provided	Re-innovate or exit Declining market confirmed

The framework of innovation-readiness levels is originally a management tool for managing the process of innovation (Tao et al. 2010). In this paper, the framework is used to estimate the overall maturity of blockchain applications in transport sector.

2. Blockchain technology

Blockchain is a shared, cryptographically protected database and a distributed ledger technology (Walport 2016). Blockchain facilitates trusted peer-to-peer transactions between unknown parties and an immutable transaction history without requiring an intermediary to guarantee the reliability. Distributed ledgers can be divided into four different types based on their privacy and openness as illustrated in Table 2.

Table 2. Four types of distributed ledgers

Permissionless public ledger • On the internet • All data visible[2]* • Anyone can run a node • Anyone can submit transactions	*Permissionless private ledger* • On a VPN • Data visible on VPN only* • Anyone can run a node • Anyone can submit transactions
Permissioned public ledger • On the internet • All data visible* • Permission required to run a node • Permission required to submit transactions	*Permissioned private ledger* • On a VPN • Data visible on VPN only* • Permission required to run a node • Permission required to submit transactions

Following main characteristics distinguishes blockchain technology from traditional databases, such as MySQL.

- Tamper proof: history cannot be rewritten
- Distributed: data is backed-up automatically and Distributed Denial of Service (DDOS) is mitigated.
- Collaborative: trust is programmed between participants
- Disintermediating: the “middleman” can be removed

The basic principles of blockchain technology are illustrated in Figure 1.

[2] * but can be encrypted

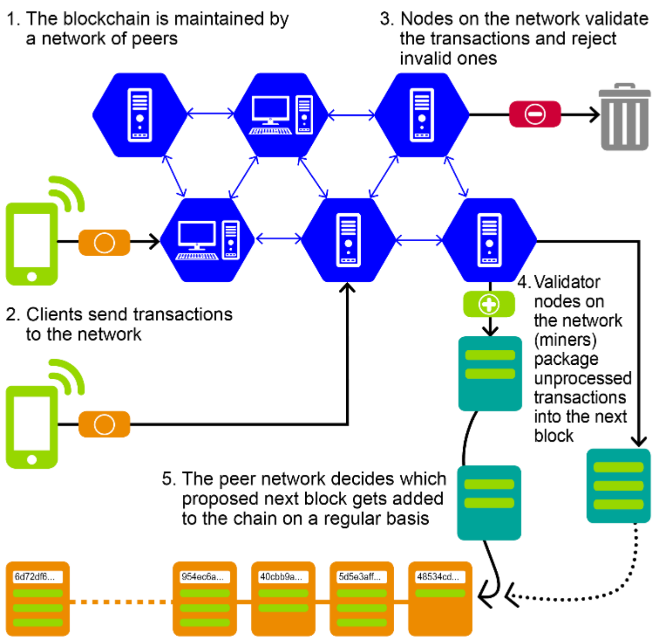

Fig. 1 Principle of blockchain technology

Currently, blockchain is an emerging technology that necessitates years of development before being ready for large-scale operative use in transportation sector.

3. Aim, scope and methodology

This paper analyses the applicability of blockchain in mobility and logistics. At first, identified use cases and application examples are surveyed and listed from publicly available information sources. Next, the examples are studied and their readiness levels are assessed. Finally, potential impacts of blockchain adoption are analyzed using the PESTEL framework, and the results are concluded.

Much of the literature analysis is based on case analyses. The cases gathered for the analysis are those where blockchains were applied, and they cover multiple aspects and sub-sectors of transport and mobility. Hence the research approach can be considered as multiple case analysis (Yin 1989) where typically the research hypotheses are unstructured or do not exist. The cases work as empirical examples (a limited sample not entitling a statistical analysis) in order to gain understanding either of the cases or the nature of state surrounding the cases.

The background for this paper is the assignment that the Finnish Ministry of Transport and Communications gave VTT Technical Research Centre of Finland Ltd. to assess the prospective impacts that blockchains may have on transport and mobility. The research was carried out in 2017. The data was based on literature, expert workshops and a PESTEL (Political – Economic – Societal – Technological – Environmental – Legal) analysis performed by the research team, strengthened by a blockchain specialist company (Chainfrog Ltd.). PESTEL served as a synthesis of the literature findings and the workshop. PESTEL is typically used in strategic problems of greater complexity (Van den Berg et al. 2014).

4. Blockchain applicability in transport and mobility

In the case of mobility (transport of people) services utilizing blockchain technology, the use cases and concepts often, quite naturally, relate directly to the end-user (i.e. the people traveling or their vehicles), whereas in the case of logistics (transport of goods) the benefits are more often realized between business parties involved in the supply chain. Expected benefits of potential blockchain use cases relate to management of identity and connectivity (e.g. authentication and data privacy, and communication with other IoT devices), new business models (e.g. authentication and efficient micro-payments between services and objects), provenance (e.g. tracking a vehicle’s history and transparently sharing it between stakeholders), and tailored services (e.g. sharing of points between services in loyalty programs or usage/history based pricing) (e.g. Deloitte 2017; Licata 2017) Next, more specific example use cases in the contexts of mobility and transport as well as logistics are described.

4.1. Blockchain applications in passenger mobility

Interconnected digital platforms have enabled and made it easier for people to rent out their vehicles and apartments, to share rides with strangers and to purchase used items. While ride-hailing and car-sharing is rapidly continuing to grow (Shaheen & Cohen 2016, Marketsandmarkets 2017 and McKinsey 2017), the sharing economy has challenges to overcome, with trust and with creating real value for both the consumer and service provider being key issues (Malhotra & van Alstyne 2014, Belk 2014 and Tedjasaputra & Sari 2016). The use of blockchain can help address these issues by eliminating intermediaries and thus increasing value by reducing commission costs, and by providing trust between strangers (Sun, Yan & Zhang 2016). Trust issues and risks come in many forms such as damaged property when sharing cars, "stranger danger" when sharing rides, and the condition and authenticity of purchased items. The Table below lists case examples of how blockchain is used in different application areas in the field of mobility. The solutions are very much at conceptual or small scale piloting stages.

Table 3. Identified blockchain application ideas and areas in passenger mobility

Identified application area	Case example[3]	Type of the case
Registration and certification of vehicles and vehicle fleet management.	A: United Nations, Moldova B: HashCoin, Russia	Pilot project Concept
Vehicle mileage verification	C: Bosch and TÜV Rheinland, Germany	Pilot project
Trusted security platform for connected vehicles	D: CyberCar, USA	Pilot
Smart insurance	E: InsurETH, UK F: Capgemini-AIE	Proof of concept Proof of concept
Charging electric vehicles	G: Share&Charge, Germany H: Ethan BIoT Charging Station, Germany	Commercial service Proof of concept
Car rental and leasing	I: DocuSign and Visa, USA	Proof of concept
Autonomous peer to peer ride-hailing	J: Mobotiq	Concept
Ride sharing	K: La`Zooz L: Arcade City	Service/Concept Service/Concept
Electronic tolls	M: Unified Tolling Network, USA	Idea/Concept

The blockchain trait of storing a tamper proof history of items is piloted by, for example, the United Nations and HashCoin, to register and certify vehicles, as well as by Bosch and TÜV Rheinland to verify that reported vehicle mileage is unmodified.

The way AirBnB apartments can be made fully automated with blockchain-powered smart locks (Sun, Yan & Zhang 2016), can be applied to rental cars using similar technologies and solutions. DocuSign and Visa, for example, have designed a proof-of-concept employing blockchain and smart contracts to create a streamlined car leasing process from the signing of agreements and issuing of insurance policies through to secure payment.

Insurance, in general, is a common application area for finding efficiency improvements through blockchain. The insurance types include proof-of-concepts such as car insurance by Capgemini-AIE, which addresses emerging needs such as the sharing economy resulting in vehicles and drivers requiring more specific insurance plans with shorter durations that can be put in place on an on-demand basis. On the other hand, concepts such as InsurETH support passengers and aim to improve processing time (and costs) of insurance claims by automatically triggering flight insurance compensations based on available data when a flight is delayed, thus providing instant compensation for the customer and reducing the cost of processing (simple) claims for the insurance provider.

With smart contracts and secure authentication, blockchain enables vehicles to have unique identities and attached parameters - a "car wallet" - that enables the vehicle instead of the owner to pay or be paid for transactions (Enisa 2017). Concepts for such smart contracts and automatic payment solutions include the Unified Tolling Network of electronic tolls that would allow transactions with any tolling agencies and payments to be sent directly to them without going through an intermediary. The same idea can be applied to parking services or electric vehicle charging stations too.

[3] The information sources are listed in appendix A.

As well as drivers or vehicles using charging stations by authenticating and paying through blockchain, there are also implementations of solutions that allow anyone to enable their own charging station to be used as a peer-to-peer service, by setting prices and handling transactions through blockchain, such as Share&Charge in Germany. Their solution, consisting of a module added to the charging station and a mobile app for controlling and managing the station and its tariffs, has recently rapidly grown to a network of more than 1200 stations.

When it comes to peer-to-peer services in transportation, ride-sharing is an increasingly common topic. Sharma et al. (2017) have proposed a blockchain-based architecture which would allow a more efficient and effective way of developing a large-scale distributed ad-hoc network of vehicles. They suggest their model allows vehicles to discover and share their resources to create a network in which the vehicles can work together to produce added-value services, such as flexibly offering empty seats to people heading the same way, even including switching vehicles during the journey. Blockchain-utilising solutions include Arcade City, which aims to be an "Uber alternative" facilitating user-driver transactions through blockchain, and La'Zooz who aim at cutting out the middlemen and providing a full-on decentralized transportation platform owned by its community and using its own cryptocurrency to pay for the rides.

With automation and sharing being among the main future trends of transportation developments (Franckx & Mayeres 2015), blockchain is envisioned as bringing in the efficiency of vehicles being organizing and optimizing their own behavior to serve passengers, manage payment transactions and fill up the gas tank/recharge the battery when needed (Kumar 2017). Mobotiq have been developing a prototype with the intention of eventually realizing the concept of an autonomous peer-to-peer car sharing and ride-hailing service leveraging blockchain. In order to manage future automation and vehicle-based multi-party services and transactions, connectivity and secure trusted access to data is important. CyberCar is one company addressing this aspect with their blockchain-optimized connected vehicle platform (Secure Telematics Platform).

4.2. Blockchain applications in freight

Below in table 2 the first applications in logistics are list, whereby Blockchain is seen to offer improvements compared to existing methods and operation models. In each of these listed applications, better transparency in particular is highlighted. Transparency is underlined, because it provides logistic operators and their stakeholders better situational awareness about logistical actions and hence offers an opportunity for more accurate and effective management. Enhanced transparency concerns both logistic chain physical information (location of vessels, containers and trucks, for example) and non-material information related to agreements, responsibilities and payments. Some existing case examples, with status information, are also listed in the table.

Table 4. Identified blockchain application ideas and areas in transport and logistics

Identified application area	Case example[4]	
Supply chain management, authenticity and origin tracking	N: Walmart, IBM and Tsinghua University, Beijing, China	Pilot project
	O: Provenance, UK	Commercial service
Container logistics automation	P: T-Mining	Pilot project
Freight tracking, customs clearance and document handling	Q: Maersk and IBM	Pilot project
	R: SmartLog, Baltic states	Proof of concept project
Truck tracking, monitoring cargoes	S: IBM and AOS, Colombia	Prototype
Smart cargo insurances	T: Cargo insurance	Idea

In logistic and freight transport, blockchain is seen to give major advantages for information and data exchange (BIFA 2017 & Del Castillo 2017). With improved information and data transparency, logistics operators and their stakeholders can improve the efficiency of a logistics chain and its distinct logistical actions. The Smart Log project coordinated by Kouvola Innovation Ltd. from Finland, for example, has set logistic efficiency improvements as their main goal. In the project, the aim is to reduce end-to-end transit times via fluent data and information sharing methods enabled by blockchain. (Kinno 2017)

According to Robinson (2016) and Sadouskaya (2017) blockchain can improve stakeholder possibilities to obtain information about logistic chains, and hence improve the efficiency of operations, as with blockchain technology

[4] The information sources are listed in appendix A

information and data can be shared safely among the stakeholders. This transparency in information sharing differs significantly from the traditional operating models, where information sharing has been limited in a linear model. In the traditional model, information and data sharing has been linked to physical cargo flow, and thus sharing has mainly taken place between two or three companies at a time. However, with blockchain technology all stakeholders who are involved can have access to the necessary information regardless of their position in the chain. In Japan, for example, ship owner companies Mitsui OSK Lines, K Line and NYK, together with 12 trade-related companies, have set up a consortium that aims to produce a trade data sharing platform based on blockchain technology. The goal is to develop a platform that enables smooth and efficient data and information sharing (Hand 2017).

At a strategic level, better and increased transparent data and information about logistics can be used for more accurate and real time management (e.g. management of spare parts, fleet, warehouse, labor force, etc.). With a more accurate general picture about operations logistics, operators can enhance their utilization rates by better matching of demand and supply (e.g. vehicle fleet capacity, labor force and cargo handling resources). Maersk for example has shown their interest towards situational awareness by starting a blockchain collaboration project with IBM, whereby companies are focusing on shipment tracking across the seas. The idea of the collaboration is not to only track containers, but the cargo itself inside the containers (Condliffe 2017).

In addition, for accurate and transparent information sharing and monitoring, blockchain is seen to be the key enabler of smart contracts. In transport and logistics smart contracts could intensify the negotiation processes and make them more agile, since in the logistics sector all manner of sizes of companies could cooperate, and typically contracts contain responsibility and payment issues, which are more or less tied to the carriage of the cargo. (Frost & Sullivan 2017 & Sadouskaya 2017) In global business, these transactions might happen almost everywhere, thus a virtual, secure and agile smart contract model is seen as holding a significant potential in logistics. However, negative impacts for logistic sector have also been identified (see e.g. Xirinachs 2017).

In logistics, smart contracts offer operators the freedom to do business that is not as location and time sensitive as traditional models, and also offers a possibility to scale up the geographical business area because of international interoperability. Of course, an important issue in business, and especially in international business, is common trust between companies. This has traditionally been based on negotiations and company reputation. Blockchain and smart contracts provide actors with an opportunity to monitor and check the information behind contracts, and to decentralize responsibilities. Hence, smart contracts might lower the threshold for trust and collaboration with new partners (Cognizant 2016).

4.3. Whether to use blockchain

It is important to consider when it makes sense to utilise blockchains, and when other means are sufficient or more suitable. For example, Li et al. (2016) propose that using a Bitcoin wallet based system in automatic ticket vending machines for public transportation could remove problems of existing payment terminals having to communicate with third-party payment platforms, but this may propose a financial risk if the system is hacked, and the present mobile payment approaches also include commission charges. Their proposed solution adds a Bitcoin wallet to ticket vending machines, solving the inconvenience of using real cash or coins as well as reducing the commission charges.

Bakker (2016), on the other hand analyzed whether public transport ticketing systems would be a relevant and worthwhile case for applying blockchain technology, concluding that it probably would not, as tickets come in various types (e.g. discount groups, monthly passes) and the seller is commonly a trusted public authority. It should also be noted that in the example of public transportation, even if blockchain does bring inherent advantages over traditional means, the interfaces and usage cannot rely on end-users being tech-savvy.

4.4. Analysis of the results

This study identified 20 different blockchain cases in mobility and logistics, of which thirteen are in passenger mobility and seven in freight. We estimated the innovation readiness level of each case based on publicly available information sources listed in Appendix A. The results of this are shown in Table 4.

Table 5. Innovation readiness level estimations of blockchain application case examples

Innovation-readiness levels	IRL 1 Concept	IRL 2 Components	IRL 3 Completion	IRL 4 Chasm	IRL 5 Competition	IRL 6 Changeover
Mobility cases	B,J,M	A,C,D,F,I,K,L	E,H	G	-	-
Freight cases	T	N,P,Q,R,S	-	O	-	-

The results illustrate that early blockchain adopters in the field of mobility and logistics are currently at conceptual or pilot stages, while the very first pioneers have a commercial blockchain application available in the market. At the same time, this indicates that a large majority of actors are only at the early stages of considering blockchain applications. Thus, the empirical evidence is rather weak at this point for generalizing or predicting the applicability of blockchain in the long term. Furthermore, the application areas and use cases in the field of mobility and logistics are mostly identified within couple of years, and they may evolve significantly even in the near future. Clearly, the applicability of blockchain is broadly under exploration, and the results illustrate the status and direction of that exploration.

As regards a case specific analysis, any use case and application share a common challenge in reaching critical a mass of users. Concepts such as the DOVU ecosystem (DOVU 2017) aim to be a blockchain based platform and marketplace for mobility data, with APIs and a common cryptocurrency to be used across different services, thus providing a more widely applicable and stable currency for the end-users. The vision for DOVU is that the sharing of user data anonymously (e.g. movements such as walking, running, cycling and driving, via a smartphone app) would be rewarded by tokens that the user could then use for various transport and mobility services (e.g. buying gas or public transport tickets).

While the DOVU platform is more focused on being a marketplace for data, EY (2017) has announced their blockchain-based Tesseract platform, taking a different approach. It aims to be an integrated mobility platform addressing the needs of shared mobility services, providing multiple stakeholders with the ability to create new value and revenue streams, by making different transport services available on the platform. Transactions are to be logged on the blockchain and settled automatically between owners, operators and third party providers through usage-based payment systems.

One advantage blockchain has, despite being a new technology trying to break through and finding sufficient use cases and users, is that from the end-user customer point of view it can be implemented transparently, as it is merely the underlying technology rather than something the user needs to learn about or see (apart from using service specific tokens). From a service provider's point of view, particularly for small startups or peer-to-peer providers, it can lower the barrier of entry by not having to involve as many third parties in the value chain.

4.5. PESTEL analysis

The outcome synthesis in the form of a PESTEL table is shown in Table 6. It presents the impacts foreseen in the medium to short term (less than 5 years) and long term (ca. 10 years or more), the scale of the impact, as well as the object of the impact. The impacts are assessed as if the scenario where blockchains are more widely utilised will be realised.

Table 6. The results of PESTEL analysis

Aspect of impact	**Short to medium term (< 5 a) impacts**		**Long term impacts**	
	Scale & nature	*Object*	*Scale & nature*	*Object*
Political	Insignificant	-	Significant in terms of regulation	General political pressure
Economical	*Corporate sector:* moderate impacts on B2B transactions	Supply chains, transport agreements	Significant on supply chains, transactions in logistics chains	Corporate sector as a whole, supply chains as a whole (consignors, consignees, logistics operators)
	Public sector: not significant, but new opportunities emerging e.g. related to taxation and use of public registers (e.g. vehicle registers)	Public agencies	Some public sector functions may become redundant due to less need of centralised record and register hosting	Public sector jobs

	Capital markets: new investment opportunities in and for companies making use of blockchains	Investors, entrepreneurs, existing companies outreaching blockchain application	Disruptive effects on banking sector and transaction services	Banking, finance, brokering, clearinghouses (transport)
Societal	Insignificant	-	Uncertain impacts; the digital 'divides' may grow (both for people and industries, as well as between countries)	Social, economic and demographic groups of people; low-tech and high-tech industries
Technological	Interoperability (operational and technological) challenges may intensify; new trust networks are built; digital identity is increasingly important	Throughout the society (and transport and mobility sector)	Uncertain, but disruptive potential exists	All
Environmental	Insignificant	-	Some energy consumption concerns have been raised, but these are uncertain	-
Legal	The regulation environment gets more complex as blockchains create new ways of operation and new types of services	Regulators, industrial bodies responsible for standardisation of procedures and processes	Uncertain	-

5. Conclusions

This paper presents the status and development efforts of blockchains in mobility and logistics by surveying, listing, and analysing twenty examples of blockchain use cases and applications. The results illustrate that early blockchain adopters are currently at the conceptual or pilot stage, while the very first pioneers have introduced commercial services. Clearly, the applicability of blockchain is broadly under exploration and applications in the transport sector are increasing and evolving rapidly.

The risks and problems of blockchain technology are not yet fully known, although it is potentially cost-effective in certain cases, and the economic impacts are foreseeable. Regarding the societal and legal impacts there is a high level of uncertainty: the impacts may be profound and may prompt us to question existing structures and processes, but the immediate impacts may be marginal as well. Many prospective impacts are rather generic and more associated with ICT, and not just about blockchains.

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Appendix A

Table 7. The information sources of case examples.

#	Case example	Source of information [All accessed during September 2017]
A	United Nations, Moldova	https://cointelegraph.com/news/united-nations-will-adopt-emercoin-for-its-car-fleet-management-project
B	HashCoin, Russia	https://cointelegraph.com/news/hashcoin-uses-emercoin-blockchain-for-vehicle-registration-and-tracking
C	Bosch and TÜV Rheinland, Germany	https://www.ethnews.com/bosch-using-blockchain-technology-to-stop-illegal-mileage-manipulation
D	CyberCar, USA	http://www.cybercar.io/
E	InsurETH, UK	http://insureth.mkvd.net/ and https://dailyfintech.com/2016/01/14/what-does-the-future-hold-for-blockchain-and-insurance/
F	Capgemini-AIE	https://github.com/Capgemini-AIE/blockchain-insurance

G	Share&Charge, Germany	https://shareandcharge.com/en/
H	Ethan BIoT Charging Station, Germany	https://medium.com/@blockchainfirst/the-first-multipurpose-blockchain-enabled-ev-charging-station-d8265c1bcb38
I	DocuSign and Visa, USA	https://www.docusign.com/press-releases/docusign-showcases-smart-contracts-payments-prototype-built-for-visas-connected-car
J	Mobotiq	http://mobotiq.com/
K	La`Zooz	http://lazooz.org/
L	Arcade City	https://arcade.city/
M	Unified Tolling Network, USA	https://www.linkedin.com/pulse/unified-tolling-network-matt-milligan
N	Walmart, IBM and Tsinghua University, Beijing, China	https://www-03.ibm.com/press/us/en/pressrelease/50816.wss
O	Provenance, UK	https://www.provenance.org/
P	T-Mining	http://www.portofantwerp.com/en/news/antwerp-start-t-mining-develops-blockchain-solution-safe-efficient-container-release
Q	Maersk and IBM	http://www.maersk.com/en/markets/2017/03/maersk-and-ibm-target-one-of-trades-biggest-barriers
R	SmartLog, Baltic states	https://smartlog.kinno.fi/
S	IBM and AOS, Colombia	http://www-03.ibm.com/press/us/en/pressrelease/52665.wss
T	Smart Cargo Insurance	http://insights.instech.london/post/102e2ub/blockchain-for-cargo-must-lead-to-blockchain-for-the-cargos-insurance

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