Chapter 5
Blockchain Applications in the Public Sector: Investigating Seven Real-Life Blockchain Deployments and Their Benefits

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Highlights

- The study uses an empirical approach to analyze the deployment characteristics and benefits of real-life blockchain deployments in the public sector
- A horizontal comparison of case studies is conducted based on a novel structured framework
- The analysis shows that the benefits are currently mainly in the domain of automating the enforcement of transactions
- The study shows that key inhibitors like a lack of standards and trusted hosting infrastructure are to be addressed to fully realize the benefits of this technology

1 Introduction

Blockchain (BC) technology was initially recognized as a typical business sector innovation offering a new, lower-cost solution for transaction settlement (Casino, Dasaklis, & Patsakis, 2019; Konstantinidis et al., 2018). Eruption of use cases across nearly all sectors of the economy, particularly in finance, logistics and energy, created high expectations towards distributed ledgers (DL) technology becoming new information and business infrastructure. Recently, in economic and political

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debates, the attention is shifted to the more fundamental implications of decentralisation and transformative role of blockchain in the public sector. Decentralisation is a core property of distributed ledgers that enables fundamentally different way of establishing trusted relationships between various actors in the ecosystem. Blockchain technology, is a ‘trust machine’, that has a potential to transform organizations, enterprises and governmental institutions, undermining the role of intermediaries and giving rise to new business models and forms of cooperation (Boucher, 2017). To what extent blockchain technology will reach technical maturity and a practical capability to generate these benefits is still an open question that can be answered only by referring to empirical evidence.

Existing literature on the use of blockchain by governments provides mainly conceptual insights. Recent systematic literature reviews adopt technology perspective, focusing on design, development and evaluation of system architecture (Batubara, Ubacht, & Janssen, 2018; Hughes et al., 2019). Due to the scarcity of development efforts, research papers speculate about 'promised' or 'potential' benefits of blockchains for government. Consequently, after 10 years from its advent, little is known about practical applicability of blockchain technology and real-value it may bring to the public sector. In order to move forward, the discussion on potential benefits of blockchain needs to be supported by empirical argumentation (Ølnes, Ubacht, & Janssen, 2017). There is a growing consensus in the in the research community, that a shift towards empirical research is needed to inform about actual advantages and disadvantages of distributed ledger technology (Batubara et al., 2018).

Present paper aims to take a first minor step in moving the research agenda in the new direction. Growing experimentation with blockchain by governments and the emergence of first operational implementations provide an opportunity to understand better, how blockchain technology may practically affect public sector. The study analyses seven projects, active in 2018, with a participation of governments. The projects are in different stages of the life cycle, ranging from early-stage experimentation pilots to production deployments. We developed a custom case-study assessment framework to provide a comparative analysis of information collected from project teams via structured interviews. The study asks two research questions:

1. What patterns emerge from the current experimentation of governments with blockchain?
2. What benefits blockchain may bring to the public sector?

The added value of the present study is twofold. First, this is one of the first attempts undertaking a rigorous and comparative analysis of ongoing blockchain projects in the public sector. The sample represents a diverse range of services, functionalities and blockchain architectures. Moreover, projects differ in life-cycle maturity. To cope with these challenges and compare different projects in a meaningful a structured analytical framework is needed. To gain clearer insights, our framework distinguishes institutional, functional, technical and economic aspects and compares project across these dimensions. Our results might be of interest to public administrations that consider implementation of blockchain-based services and for the policy makers who are responsible for policy agenda supporting adoption of blockchain technology in the public sector. Moreover, practical observations and generalizations from the study can serve as a reference point for future assessment of blockchain implementations by governments.

The rest of the paper is organized as follows. Section 2 elaborates on the innovative features of distributed ledgers and provides literature on blockchain the public sector. In Sect. 3, analytical framework is introduced, followed by the horizontal analysis of seven case studies. Section 4 presents main findings and answers both research questions. Section 5 concludes.

2 Background

2.1 Understanding Blockchain Driven Innovation

A distributed ledger is a database technology that facilitates an expanding, chronologically ordered list of irrevocable transactional records, shared by all participants in a network. For convenience, transactions are often grouped in blocks prior to recording on a ledger. In such case, a ledger takes the form of a chain of blocks, in which each new block is linked via a cryptographic signature referring to the exact content of the previous block. The ledger is stored in multiple nodes and validated by some form of consensus in the network, which makes it resistant to unilateral change or tweaking. The ledger must also be tamper-resistant to attack of a coalition of malicious nodes.

In the so-called, permissionless blockchains, that are anonymous and open to everyone, this is ensured by using computationally heavy consensus or consensus participation mechanism that selects nodes in the network that have the greatest stake and thus greatest incentive to behave honestly. In permissioned blockchains, tamper-resistance is not an issue and is ensured by transparency and gatekeeping—entry is restricted, and all nodes have identity. Within these limits, distributed ledgers safeguard transactions and eliminate the risk of double spending just as traditional third-party intermediation does. The main difference, according to enthusiasts of blockchain technology, is that decentralised intermediation is cheaper, more effective and does not lead to concentration of power in hands of one institution that may than start to push for its own agenda (rent seeking).

Practical use cases leverage two innovative enablers of distributed ledgers. First, because of resistance to tweaking, a ledger can serve well for notarization purposes, providing solid proof of existence, ownership and originality of any digital or physical asset or a statement. Smart contract functionality is the second enabler of blockchains, coming on top of notarization. Smart contract is a piece of computer code that formalizes governance rules for transaction and executes it. A workflow might be conditional on statements signed by various human or machine agents, including sensors and connected things. Programmability of smart contracts makes them very flexible and adjustable to much wider range of arrangements than could be handled in traditional paper-based contracts. Smart contract functionality enables enforcement of commitments and automation of complex arrangements among multiple parties that otherwise would be too risky and too costly to execute (Szabo, 1997). Hence, it potentially generates huge efficiency gains.

The emergence of algorithmic trust has far-reaching implications from the broader economic and political perspective. If the technology itself can eliminate uncertainty related to intentions and identity of the transacting parties, then the role of institutional intermediaries is seriously undermined. Decentralized intermediation holds a promise to reduce transaction costs and shift the balance of control and power from economic and political institutions towards the ecosystem. For example, blockchain supports creation of decentralized autonomous organizations (DAO). These systems can effectively self-organize, create own sustainable business models and enforce own governance rules. DAO might challenge the current role of firms and governments as providers of private and public goods. The distributed nature of the blockchain technology may be highly disruptive for a large number of industries. At the same time, it evokes strong resistance from private and public institutions that have built their economic position on the provision of central intermediation.

The first application of blockchain, Bitcoin, illustrate both issues very well. The concept of Bitcoin, "A Peer-to-Peer Electronic Cash System" proposed by an anonymous (group of) author(s) called Satoshi Nakamoto (Nakamoto, 2008) proved to be robust in practice and essentially created a global and independent payment system.[1] The idea of a peer-to-peer cash system and accompanying cryptocurrency is still leading to resistance from regulators, legislators and the media, given the border-less nature of the financial system, its' pseudonymous properties and the fact that traditional financial institutions like banks are not part of the system. The success of Bitcoin inspired recent revolutionary concepts of private stable coins or central banks crypto currencies, which may seriously hit the business of private retail banking sector.

Currently, the majority of blockchain applications and explorations focus on financial and business sectors. The interest in this technology is also increasing in the public sector, as can be seen from the growing scientific literature. Emerging experimentation that involves governments is fueled by the expectations that blockchain technology may bring efficiency improvements to the informative and administrative functions of governments and perhaps also transform relations between citizens and administration (Berryhill, Bourgery, & Hanson, 2018; Swan, 2017).

[1] Bitcoin application demonstrates also very well the general property of public, permissionless blockchains, namely that they need to have a built-in cryptocurrency to provide incentives to run the ledger. We thank one of the reviewers for pointing this observation to us.

2.2 Related Literature

Technology-driven innovation has been a topic of research since the early 1990s. Public administrations have experienced organizational and institutional transformations, caused by developments of information technology. As Gasco concluded in 2003 that technology will change public administrations in their technological managerial, and political structures (Gascó, 2003). Over the years, the public sector has seen an increasing amount of IT embedded in public services, initially merely digitizing the manual paper-based processes and later fundamentally changing the way public services are delivered (Janssen & Van Veenstra, 2005). Many researchers have created or analysed maturity models in the domain of e-government. Recently, public sector modernisation strategies have shifted towards digital government paradigm (OECD, 2016). Contrary to e-government that focused on the use of digital technologies by governments, the new approach adopts citizen-centric and problem-focused perspective. Over the last 5 years, an increase in variety of potentially disruptive technologies is observed in the public sector, included the Internet of Things, Big Data, Robotic Process Automation and Blockchain (Leitner & Stiefmueller, 2019). Our study fits into the new digital government approach by taking a closer look at how blockchain technology can transform administrative processes as well as end-user service design and delivery.

The interest of scientific community in the research on blockchain and government has originated in 2015. Early studies presented blockchain as a disruptive, holistic governance system that will redefine the role of governments (Atzori, 2017; Davidson, De Filippi, & Potts, 2016). Initially, the disintermediation argument was taken to the extreme. Blockchain was naïvely claimed to compete away contemporary political and economic institutions due to their chronical inefficiency. These claims ignored the subtle difference between rule enforcement and rule making (Lehdonvirta & Robleh, 2016). In the public sector context, permissioned blockchains seem to resolve this centralization paradox reasonably well. This particular type of distributed ledgers introduces efficient enforcement but setting the governance rules remains under control of a single organization or a consortium. Soon researchers started to focus on more operational issues looking at how governments could modernize administrative processes by substituting human-based bureaucratic procedures with machine-based automated enforcement (Ølnes et al., 2017). Specific attention has been dedicated to healthcare (McGhin, Choo, Liu, & He, 2019) and education (Alammary, Alhazmi, Almasri, & Gillani, 2019; Grech & Camilleri, 2017). This literature concentrates on theoretical use cases and therefore only speculates about potential or promised effects of blockchain technology applied to public services. So far there are no empirical papers that link this conceptual perspective with real implementations (Batubara et al., 2018).

There is a strong conviction that blockchain-enabled automation and information sharing could support several administrative functions of governments. The list of main applications, based on existing literature, includes provision of identity, facilitation of voting, management of benefits and pensions, management of tax liabilities, combating frauds, management of citizen records and state registries and facilitation of regulatory oversight. Several positive effects from adoption of blockchain are expected across public administration: increased process efficiency and flexibility, reduced bureaucracy and corruption and broken siloes between agencies (Berryhill et al., 2018; Ølnes, 2016).

The list of specific public sector use cases continuously expands and it is impossible to provide an actual overview off all ideas. Use cases can be found in almost sections of broadly defined public sector, including healthcare, education and public administration (Casino et al., 2019). Functional typology is more informative and recognizes few broad groups of potential use cases: provision of identity, facilitation of voting, management of benefits and pensions, management of tax liabilities, combating corruption and frauds, management of citizen records and state registries, facilitation of regulatory oversight and introducing central bank cryptocurrencies (Berryhill et al., 2018).

In the context of public administration blockchain-enabled automation and information sharing is expected to bring several operational benefits: increase process efficiency, reduce bureaucracy, break siloes between agencies and eliminate corruption (Ølnes & Jansen, 2017). Blockchain technologies can also potentially be used as an information infrastructure to provide the exchange of information by public administrations, for example the exchange of criminality information, the distribution of grants and the exchange of information regarding academic degrees (Davidson et al., 2016). Potential impact of blockchain technology in the public sector goes far beyond efficiency gains enabled by database innovation in recordkeeping and information exchanges. Blockchain technology could have more transformative impact, taking over a large part of the administrative roles that governments fulfil in society nowadays. Smart contracts are likely to trigger a new wave of public sector innovation in governance generating new service delivery models and disruptive business architectures of governments (Reijers, O'Brolcháin, & Haynes, 2016). Full traceability and transparency of transactions on the ledger creates an additional layer of algorithmic trust and algorithmic control over governmental organizations, which may shift the balance of power between administration and citizens (Meijer & Ubacht, 2018). To what extent these more ambitious impacts will be realized is still to be seen.

Some critiques argue that in reality, these projected effects are unlikely because of genetic incompatibility between public administrations and blockchains, but this claim mostly holds only for public permissionless blockchains. From the governmental point of view, public permissionless blockchains have several undesirable properties. They allow for unrestricted participation and anonymous identities and do not provide any level of transaction secrecy (Mik, 2018). Moreover, transaction intensive public services based on existing public permissionless blockchains would not only be expensive, due to involvement of cryptocurrencies, but also difficult to scale-up because of technical constraints (Hughes et al., 2019).

On the other hand, private blockchains are compatible with centralized governance as they mandate known identities and approval of users by the system administrator. Much smaller number of writing nodes, lack of untrusted participants and lower latency in the network favor a combination of high throughput and light consensus that are required to deliver cheap mass-scale services. Nevertheless, the list of potential technical and organizational issues that make integration of private blockchains with the legacy systems questionable is long. Distributed nature of blockchain systems creates concerns regarding stability in the network and lack of one point of control. Certain public services, such as pension management or vat tax collection not only involve extremely high transaction volumes but are particularly challenging for maintaining privacy and security of data (Allessie, Sobolewski, Vaccari, & Pignatelli, 2019; Batubara et al., 2018). Governments should consider that blockchain implementations have fundamental differences in comparison with traditional, centrally managed information infrastructures. Most importantly, blockchain rely on the network of nodes that require some form of consensus to agree on the state of the system. This introduces latency and other implementation challenges related to integration of storage on mobile devices or the need for interoperability to generate cross-border network effects.

3 Empirical Analysis

3.1 Methodology

The analysis of blockchain projects is based on data collected from structured interviews with the representatives of the project development teams. During interviews, we have explored both technical and institutional part of the project. Given qualitative nature of primary data sources, large diversity of developed services and a limited number of projects in the sample, our methodological choice is the case study analysis (Eisenhardt, 1989). The protocol to study multiple case studies requires that data on each individual case is systematic and comparable to ensure external validity and enable discovery of patterns via cross-case comparison. Drawing on the insights from literature, we have elaborated a case study assessment framework. The assessment framework was derived based on the two strands of literature: (1) technology acceptance models adapted for governmental organizations and (2) digital government paradigm. From the first strand, we took classical factors that affect adoption and usage intensions: technology and organizational dimensions, and perceived benefits (Davis, 1989). Technology adoption models provide however an incomplete analytical framework A digital government project is a multidimensional phenomenon that extends beyond pure technology adoption (Sandoval-Almazán et al., 2017) to a set of contextual, application-specific impacts, such as external relations between stakeholders, project governance, openness and transparency (Janowski, 2015). Given these guidelines, in our analysis we have accounted for governance, openness, efficiency and ecosystem perspective. Our analytical framework has six ‘bins’. They cover institutional, functional, technical and economic aspects of individual projects (see Fig. 5.1). Institutional aspect.

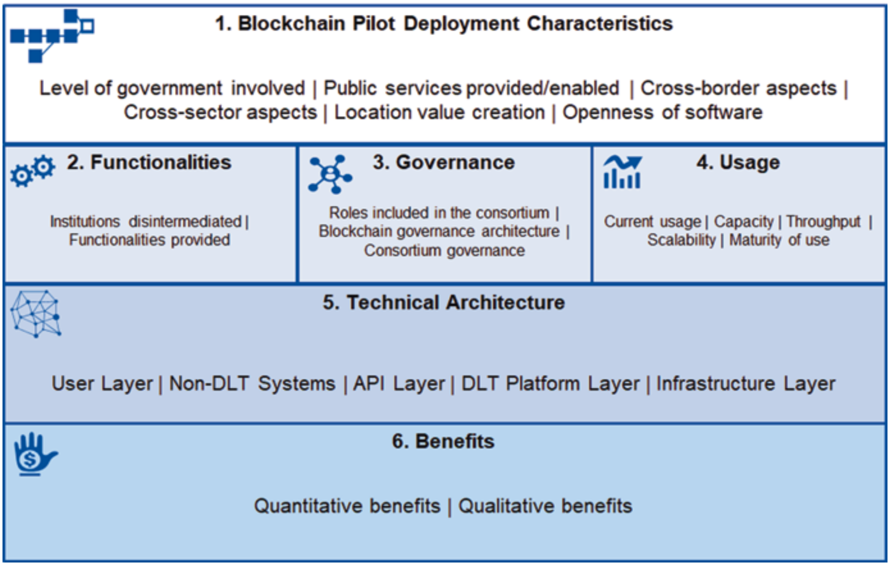

Fig. 5.1 Analytical framework

This aspect focuses on project and technology governance. Project governance refers to the way it is controlled and directed. Decentralized governance means that all consortium stakeholders have an equal say in the decision-making and centralized governance means that a central party has the ability to take decisions on the direction and implementation of the service deployment. The rules of consortium governance directly affect the speed of development and the future evolution of the service. By looking at these issues, we wanted to check if there is any relation between governance model and the complexity of the service developed. Another objective was to see if the way public institutions position themselves within consortium has any impact on the maturity of the developed service. Regarding blockchain governance, the openness of transaction validation (validate/commit) and openness of participation (read/write) in the transactions is analyzed. These principles determine how the distributed database is maintained and directly affect service performance, scalability and the level of trust (Casino et al., 2019). Public permissionless blockchains are largely incompatible with the requirements set out in real-life applications which require an oversight from governmental organizations (Mik, 2018). The main limitations here are pseudo-anonymity, non-compliance with privacy and impractical security model based on public-private key cryptography (Hughes et al., 2019). We therefore expect to observe some form of restrictions concerning who can access the ledger and participate in consensus mechanism.

3.1.1 Functional Aspect

We begin with identification of core blockchain functionalities that are leveraged to provide a public service. Based on the literature, the three main groups of innovative enablers of blockchain are differentiated: notarization of transactions (proof of existence), automatic execution of transactions (smart contracts) and identity verification (proof of identity). These enablers are then mapped onto specific functionalities developed by the projects. In this way, one can see which blockchain innovations are being leveraged in practice and if any of existing institutions are at risk of disintermediation.

3.1.2 Technical Aspect

Digital architectures are usually analyzed with hierarchical approach, focusing on different layers of a service. We follow this approach, building on existing models of blockchain architectures (Tasca & Tessone, 2019). Given the practical objectives of the study, our model is much simpler and differentiates only five main layers. User and API layers refer to how the service interfaces with the end users and the ecosystem. Usually blockchain technology facilitates selected functions provided within a service, while for example storage of data or authentication use external, possibly centralized non-DLT systems. The DLT part of the service design is examined in detail by separately looking at the type blockchain platform blockchain and underlying infrastructure. We also consider project choice regarding the openness of software developed within a project. This choice is important because it affects the speed of development and adoption of the service. The openness of the software can range between fully open source to completely proprietary software. In reality, mixed situation can be expected as well. For example, parts of the system, such as user interfaces or application protocol interfaces (API) can be proprietary, while the core elements of the system may adapt existing open source solutions. Technical aspect explores also current usage parameters, such number of users and number of transactions per second. The teams provided also information on the system capacity, understood as a number of users that the blockchain system can comfortably facilitate. Capacity and usage parameters will be informative mostly for services in production stage, because pilot projects use non-scalable test environments.

3.1.3 Economic Aspect

Economic aspect will be explored by looking at benefits involved in the development and operation of blockchain service. We did not include the costs involved in this analysis, as for projects in experimentation phase it was impossible to collect quantitative information on costs and development risks.

The catalogue of potential benefits from deployment of blockchain technology is well elaborated in the literature (Hughes et al., 2019). We have introduced a distinction between quantitative and qualitative benefits. Quantitative benefits include cost savings (reduced costs of processing transactions without intermediary as compared to the traditional system) and efficiency gains (reduced time of completing a transaction compared the traditional system). Qualitative benefits include reliability gains (decreased risk of cyber-attack, system breakdown or data leakage), transparency and accountability gains (an increased oversight of the current state of the system and transaction history).

3.2 Sample Selection

The initial list of candidate projects was created from several publicly available sources. Only those projects qualified, in which governmental agency was listed among consortium partners and the kick-start date was at least 6 months prior to data collection. The list was restricted to projects implemented in Europe, but consortia could be composed of technological or scientific partners from outside Europe. Selection was carried in such a way as to ensure sufficient variability across three dimensions:

- Field of implementation;
- Country of implementation;
- Level of government involved in the project (local vs national).

The final sample contained seven projects, listed in Table 5.1. The fieldwork took place in February-April 2018.

The sample contains projects implementing services from three broad groups: (1) public aid and social transfers, (2) citizen's records and public registries and (3) foundational components related to user identity and regulatory compliance. Short characterizations of individual projects can be found in the Annex. For a detailed overview a reader is referred to (Allessie et al., 2019). Projects in the sample were implemented in six different European countries. Five projects involved national governments while the remaining two had local authorities in the consortia. In the next section, we present the results of horizontal analysis of case studies based on structured in-depth interviews. The questionnaire explored all elements of the analytical framework from Fig. 5.1.

3.3 Horizontal Analysis of Case Studies

Horizontal comparison of case studies is an established method for the analysis of qualitative data. It enables to explore diversities and similarities among individual projects and to uncover patterns. In what follows we compare projects along six dimensions set out in the case study assessment framework.

Table 5.1 Final sample composition and general features of blockchain projects

Project name	Country of implementation	Field of implementation	Level of government involved	Openness of software
1. Exonum land title registry	Georgia	Land title registry; property transactions	National	Open source
2. Blockcerts academic credentials	Malta	Academic certificates verification; personal documents storage and sharing	National	Open source
3. Chromaway property transactions	Sweden	Property transactions; transfer of land titles	National	Proprietary
4. uPort decentralized identity	Switzerland	Digital identity for proof of residency, eVoting, payments for bike rental and parking	Local (municipality of Zug)	Open source
5. Infrachain governance framework	Luxemburg	Blockchain governance	National	Open source
6. Pension infrastructure	The Netherlands	Pension system management	National	Hybrid: open standards, proprietary software
7. Stadjerspas smart vouchers	The Netherlands	Benefit management for low-income residents	Local (municipality of Groningen)	Hybrid: open blockchain protocol, proprietary smart contract layer

3.3.1 Project Characteristics

Currently public governments experiment with a number of specific services like registration, verification and transfer of land titles, verification of personal certificates and attestation of identity or allocation of benefits, as indicated in Table 5.1. These concrete services support the three main functions of governments: (1) management of governmental and citizen registries (2) management of social transfers / benefits and (3) provision of verified information for facilitation of economic transactions and regulation. Majority of services are targeted at citizens as end-users. A few projects develop foundational building blocks of blockchain: government-attested decentralized identity and governance framework. The decentralized identity solution developed locally in Zug, can serve for authentication to a wide range of services including electronic voting, access to public infrastructure or rentals. The level of government involved varies across case studies, yet dominantly the national government is involved. Two projects where local governments participate in the consortia are relatively advanced in the lifecycle, despite leveraging advanced blockchain functionalities on top of notarization. Most likely, their higher maturity is related with smaller scale. The majority of projects use open source software at the blockchain protocol level, but not necessarily at the application level. Only one implementation, the Postchain system in Chromaway property transactions, is fully proprietary. Few projects combine open source blockchain protocols and proprietary software. Proprietary parts include specific implementations of smart contracts or user wallets, which are not available on-shelve.

3.3.2 Functionalities

Most services will take over particular tasks from public organization, but none of them assumes full intermediation of the institution. In Chromaway system for property transactions, a private institution will be redundant. The notary will not be involved in registration and attestation of documents as this will be done directly provided by the smart contract. The humane tasks that can be handed over from public administration to blockchain protocol include attestation of identity, verification of documents or eligibility check-up. These transfers will likely reduce paper work and speed up administrative workflows by removing existing bottlenecks.

Analyzed projects differ with respect to the scope of implemented blockchain functionalities (Table 5.2). Blockchain-based notarization allows for attestation and verification of the originality and ownership of a document by storing its hash. A hash is a fixed-length cryptographic extract of a document, which can be conveniently stored on blockchain without disclosing its content or personal details.

Table 5.2 Functionalities overview

Project	Institutions disintermediated: full/ partial	Blockchain functionalities leveraged: notarization/smart contract shared database/automation
1. Exonum land title registry	None/none	Notarization
2. Blockcerts academic credentials	None/yes: reduced tasks for admin office at university	Notarization
3. Chromaway property transactions	Yes: notaries/yes: reduced tasks for banks and land registry back offices	Smart contract automation/shared database
4. uPort decentralised identity	None:/yes: reduced tasks for municipality	Notarization/smart contract shared database
5. Infrachain governance framework	None	Notarization/shared database/smart contract automation
6. Pension infrastructure	None/yes: reduced tasks for pension funds back offices	Notarization/shared database/smart contract automation
7. Stadjerspas smart vouchers	None/yes: reduced tasks for municipality	Notarization/smart contract automation

Exonum system records hashes of land titles on public blockchain to create an independent verification layer. Distributed notarization alone generates rather limited gains compared to traditional services. Other projects, like Blockcerts or uport, combine notarization with non-DLT functionalities, such as local mobile wallets. These wallets create additional value, because users may store and share personal certificates. Five projects in the sample implement DLT functionalities, based on programmable smart contracts. Smart contracts introduce automated workflows on running on a shared database between different actors such as (1) employees, employers and pension funds (Pension Infrastructure); (2) citizens using decentralized identity and service providers (uPort); (3) property agents, sellers, buyers, banks and title registry (Chromaway); (4) voucher holders, municipality and providers of subsidized services (Stadjerspas). Projects, which utilize smart contracts for shared databases and automated workflows, are less advanced in their life cycle. These implementations have to reconcile different needs in the ecosystem, integrate legacy systems of various actors through APIs and deliver mobile interfaces.

3.3.3 Governance

The governance of the project consortia are mostly centralized or hybrid as shown in Table 5.3. In the centralized model, usually government has a vast amount of decision-making power. In the hybrid model, few large players can steer the consortium in certain directions, often with a strong influence of the technology provider. In around half of the case studies, an open source software community contributes

Table 5.3 Governance overview

Governance	Roles in the consortium	Blockchain governance	Consortium governance
1. Exonum land title registry	Government; open source community; tech provider	Private permissioned and public permissionless	Centralized (NAPR)
2. Blockcerts academic credentials	Government; open source community; tech provider	Private permissionless	Hybrid—various consortium partners
3. Chromaway property transactions	Government; tech provider; banks	Private permissioned	Hybrid—various consortium partners
4. uPort decentralized identity	Government; open source community, tech provider	Private permissionless	Hybrid
5. Infrachain governance framework	Government; businesses, tech provider	Private and public permissioned	Decentralized
6. Pension infrastructure	Government; open source community; pension funds; tech provider	Private permissioned	Hybrid
7. Stadjerspas smart vouchers	Government; businesses, tech provider	Private permissionless	Centralized (City of Groningen)

technically to the solution, which requires stronger coordination from the technological partner. Once services enter to production, governments naturally start to play a dominant role in the consortium acting also in a capacity of the client. The choices of blockchain governance architectures are not clear-cut. No single project uses solely a public permissionless archetype. There is always some type of restriction: either on who can transact in the system or on who can validate transactions. Four projects display elements of a private permissioned design, with limited number of known nodes participating in the validation. Permissioned blockchains are by definition closer to centralized systems. They do not reproduce trust and hence do not run heavy consensus. Permissioned blockchains are a default choice in case of services targeted at increasing operational capacities of governments, like introducing automated enforcement of voluminous transactions (pension system, property transfers). Projects, which use permissionless design, either operate in a small (municipal) scale or experiment with test environments.

3.3.4 Usage Overview

The current usage differs greatly per project and is logically largely dependent on the lifecycle phase. At the time of writing, the majority of projects were in a conceptual or pilot phase. Only two services were already operational. Usually pools of test users do not exceed few hundreds, but for operational services they reach several thousands. Georgian authorities have registered over 100 thousand land titles hashed on the Exonum blockchain. Voucher system of the Municipality of Groningen already has over 20 thousand users. As can be seen from Table 5.4, pilot projects have very limited account of the current throughput parameter of their blockchain systems. This is not surprising in early stage, when the objective is to develop a functional service in a test environment. Stability and scalability of the system are considered at later stages of experimentation. Although impossible to verify, the declared scalability in current environments (understood as a maximal number of transactions in a given time interval) ranges from 7 transactions to 5 thousand transactions per second. Generally, projects, which utilize permissioned blockchains, do not report scalability constraints. Transaction speed, latency and maintenance costs are often considered to be impediments for scalability of permissionless blockchain (Casino et al., 2019), but in case of analyzed implementations they do not seem to be the major obstacles. All projects with permissionless design have developed ways to overcome throughput bottleneck. For example, Blockcerts records transactions in batches and Exonum hashes the whole state of the system, instead of individual land titles.

3.3.5 Technical Architecture

An overview of the architecture layers is displayed in Table 5.5. User layer provides mobile wallets or web portals. Mobile applications are a dominant form of interface because they greatly enhance user experience. Looking at the non-DLT systems, a

Table 5.4 Usage overview

Project	Current usage	Current throughput	Scalability (per April 2018)	Maturity
1. Exonum land title registry	Over 100,000 titles	Unknown	5000 tps (private permissioned part)	Production
2. Blockcerts academic credentials	Hundreds of users	7 tps (Bitcoin)	7 tps (Bitcoin)	Early stage pilot
3. Chromaway property transactions	Unknown	Unknown	160 tps	Proof-of-concept
4. uPort decentralized identity	300 users	Unknown	7 tps	Early stage pilot
5. Infrachain governance framework	Unknown	Depending on blockchain	Depending on blockchain	Early stage pilot
6. Pension infrastructure	5000 users	Unknown	Unknown	Proof-of-concept
7. Stadjerspas smart vouchers	20,000 users, 4000 transactions monthly	7 tps	7 tps	Production

separate registry or database is always found to which blockchain system connects, like credential database or state registry. Blockchain pilots dominantly use APIs to connect the blockchain layer to the existing systems of project participants. The most complex blockchain pilots display a range of different APIs with varying exchange, authentication and admin functions. The physical storage of the transaction data heavily depends on the architecture. Private blockchain infrastructures often allow participants to host blockchain nodes and participate in the consensus. In public blockchain architectures, the physical location of transaction data is usually unknown.

Varying consensus mechanisms currently occur in the pilot deployments. In permissionless blockchain deployments, Proof-Of-Work and Proof-Of-Stake are mostly available. This will however change with transition of service from infancy towards production phase. Services in production establish consensus among known nodes that are owned by consortium participants including government institutions. In such cases a more efficient consensus model will be deployed, such as PBFT or Proof-Of-Authority. The organization of infrastructure layer on which the consensus mechanism is running is largely determined by blockchain design. In permissioned blockchains, consortium participants often own the nodes. In permissionless deployments, anyone can theoretically establish a node. If a service anchors hashes in the Bitcoin blockchain, these would be stored in all full Bitcoin nodes spread all over the globe.

Table 5.5 Architecture overview

Project	User layer	Non-DLT systems	API layer	DLT platform layer	Infrastructure layer
1. Exonum land title registry	Admin NAPR application	NAPR land title registry system	Admin API to land title registry	Private consensus (private blockchain) and Proof-Of-Work (Bitcoin)	Known nodes and Bitcoin blockchain
2. Blockcerts academic credentials	Wallet (mobile app) and issuer software	Certification database of institutions	Blockchain APIs for confirmation and searching	Proof-Of-Work consensus	Bitcoin blockchain
3. Chromaway property transactions	Smart contract interface (mobile app)	Swedish Land Registry	Internode API, client API and legacy API	Proof-Of-Authority with PBFT (private) consensus	Storage is in PostgreSQL or another RDBMS with known nodes
4. uPort decentralized identity	uPort (mobile app)	Front-end portal (municipal webpage)	uPort Connect API	Proof-Of-Stake consensus	Hash is stored in Ethereum (test net) blockchain, user data stored locally
5. Infrachain governance framework	Not applicable	Not applicable	Not applicable	Private consensus (currently Proof-Of-Work)	Nodes based on Ethereum protocol
6. Pension infrastructure	User group specific application	Exiting salary and pension databases	Currently unknown	Private consensus (currently Proof-Of-Work)	Hash stored in Ethereum blockchain with known nodes, storage of transaction unknown
7. Stadjerspas smart vouchers	QR code, browser (mobile app)	Municipal registries	Admin API	Proof-Of-Authority consensus	Nodes using the Zcash protocol

3.3.6 Benefits

Experimentation projects focus mainly on the functional development. Economic and technical efficiency is not considered at this stage. While data from pilot projects may not serve as a proxy for the deployment costs of production services, experimental projects already have reflected about the expected benefits. In Table 5.6, we have collected insights about the types of benefits foreseen by the project teams from implementation of their services.

Table 5.6 Benefits overview

Project	Quantitative benefits	Qualitative benefits
1. Exonum land title registry	400 times faster registration of extract; reduction of operational costs (over 90%)	Improved transparency; higher fault-tolerance; increased reliability of data
2. Blockcerts academic credentials	Lower operation cost; efficiency gains; lower integration cost	Citizens' ownership of data, convenient storage; quick and selective sharing; identity and privacy protected; no hard copies; elimination of fake certificates; self-management
3. Chromaway property transactions	Est. €100M/annum; reduced transaction time (over 95%); reduced transaction cost (90%); faster registration and transfer of land title	Increased trust; higher liquidity of assets; improved market operation; improved resilience to record modification and fraud
4. uPort decentralized identity	Lower administration cost; lower storage cost; lower infrastructure cost; efficiency gains for administration; efficiency gains for citizens	Citizens' ownership of data; reduced risk of cyberattacks; self-management
5. Infrachain governance framework	Not applicable	Increased reliability and resilience; increased transparency and flexibility
6. Pension infrastructure	Est. €500M/annum; lower storage cost; efficiency gains for pension funds; efficiency gains for administration; lower transaction costs for citizens	Increased transparency; increased security of data; improved regulatory oversight
7. Stadjerspas smart vouchers	Lower administration cost; efficiency gains for administration; lower transaction costs for citizens	Effective redistribution; improved auditability of public funds

Process efficiency is the most frequently declared benefit from introducing blockchain. Elimination of human-based registration and verification of documents and reduction of hard copies will reduce operational cost of administration. This is particularly expected from projects that establish shared databases, like Chromaway or Pension Infrastructure avoid endless copying of the same data between different IT systems. Smart contracts enable to streamline various business processes and hence create efficiency by reducing the uncertainty and automating transactions. Quicker and more reliable settlement of transactions reduces transaction costs also for citizens. According to Chromaway estimates, reduction of end-to-end property transaction time from weeks to hours will result in 100M EUR savings on insurance for safeguarding mortgage deed. The blockchain-based pension administration system in the Netherlands is expected to bring €500 million annually of savings on pension system administration. This corresponds to 50% decrease in costs from the actual level. These gains are attributable to all types of participating actors: public and private institutions and the citizens. In case of the Stadjerspas project, specific benefits such as improved redistribution and targeting of public funds are in fact attributable not only to the users but to the society as a whole.

Blockchain technology is expected to bring also a number of qualitative benefits. Storing transaction records in a shared ledger increases security and resistance to malicious behavior. The append-only way of updating blocks ensures irrevocability of records and increases integrity and auditability of data. All these benefits are provided directly by the technology itself, adding to the reliability and trustworthiness of governmental record keeping. Moreover, the analyzed services improve citizen experience from interacting with the public authorities. For example, Exonum system allows transferring a land title from home, without visits to the town hall or state registry. In the front end, the service has an attractive user interface, but in the back end, there is a private permissioned blockchain system operating. Users may not be aware about it, but it is a backbone of the entire service. Similarly, in the uPort project, users gain an ownership and control over their personal data. They may selectively disclose it to any third party via their mobile phone, without actually being aware that a distributed ledger ensures the reliability of exchanged data. These examples demonstrate the potential from integrating blockchain with other state-of-art technologies to provide new generation of highly reliable and trustworthy public services operated via personal devices.

4 Results and Discussion

In the current section, we elaborate on the two research questions posted in the introduction.

1. What patterns emerge from the current experimentation of governments with blockchain?

Pattern 1: Ongoing projects experiment with the full spectrum of blockchain functionalities.

Blockchain notarization enables verification of originality of a document and confirmation of the date of its creation and the owner. Decentralized notarization represents only incremental innovation and hence it brings only incremental value to centralized governmental services. The remaining two blockchain functionalities relay on programmable smart contracts. Smart contracts are implemented either as a shared database to facilitate exchange of information (in Pension Infrastructure or Stadjerspas) or as automated workflows to facilitate multiparty transactions (in Chromaway). Both functionalities offer higher stand-alone value and can facilitate or enhance wider range of governmental functions: internal data management, provision of information for ecosystem partners, redistribution of public funds or enforcement of regulations. Services leveraging smart contracts bring also concrete benefits to citizens such as reduced uncertainty and quicker settlement times.

Pattern 2: Type of implemented functionality affects the maturity of projects.

Services based mainly on plain blockchain notarization are relatively more mature, while services with the more advanced functionalities face challenges. Projects that rely solely on the proof of existence via verification of hash have quicker implementation times. They require less integration effort and may use existing software components. Projects which utilize smart contracts are less advanced in their lifecycle. This is expected, as these implementations have to reconcile possibly different needs in the ecosystem, integrate legacy systems of various actors through APIs and deliver mobile interfaces. In some cases, like in Chromaway project, blockchain functionalities already work well technically, but are not compliant with legal frameworks. The most common problem is legal non-equivalence of blockchain and traditional notarization as well as smart contracts and traditional contracts. Smart contracts do not have reconciliation and appeal mechanisms, which are required for legally binding contracts. These problems currently hinder the advancement of more advanced services beyond early pilot phase.

Pattern 3: Projects with a higher level of maturity tend to have less stakeholder complexity and more centralized governance.

The Pension Infrastructure project, which is in proof-of-concept stage, is the most complex in the sample. It has several types of stakeholders involved with varying business objectives and different legacy databases. On the other hand, Stadjerspas voucher system, Exonum land title registry or Blockcerts academic credentials have fewer stakeholder types. In addition, projects with more centralized governance structure are more advanced. More hierarchical decision-making processes in consortia that have a strong governmental leader is likely the cause.

Pattern 4: Services in production respond to clear business needs.

Two projects in our sample already deliver operational services. In both cases there is a strong technological partner, providing required integration with the legacy systems. Both projects also fit within the current technological limits. Exonum utilizes basic blockchain functionality, essentially time-stamped proof of existence. Stadjerspas utilizes an advanced programmable layer that allows for setting eligibility criteria and managing the use of subsidized services. Importantly, both projects have started from clearly defined ownership roles and business needs of the administration: registration and verification of land titles on a blockchain layer and more targeted allocation of vouchers according to specific criteria of beneficiaries.

Pattern 5. Blockchain is always just one layer of the developed service, dependent on non-DLT layers, which run legacy systems.

Blockchain is always one of several layers in the technical architecture. In all projects a centralized database is found that either stores user data or that feeds transaction data into the distributed system. In Exonum and Stadjerspas projects a centralized database is used to store transaction data. Blockchain protocol is used only to anchor hashes yet all the transaction details are stored in the databases of NAPR or DutchChain. The Uport project is an example of implementation where a centralized database is used to feed into the distributed system. Municipality checks the validity of the citizen's request and links own records with the Uport address, referred to as the blockchain identity.

Pattern 6. Blockchain technology does not pose a threat of disintermediation of existing public institutions.

In no case, blockchain substitutes any public institution. Chromaway is the only project that explicitly assumes disintermediation of traditional notary function. Blockerts project assumes elimination of one of the functions of national agency for academic credentials but this is unlikely to make the entire institution obsolete. The remaining blockchain-based solutions are either complementary to the existing administrative processes or partially substitutable. Complementary solutions build on top of existing processes, like in the Exonum project, which simply adds and independent content verification layer to centrally stored land titles. Partially substitute solutions propose new or changed way of providing an administrative function within institution. In the latter case, blockchain technology may take over some tasks, such as for example attestation of identity or eligibility check-up. These changes reduce paper work and generate time savings for administration, but does not threaten public institution's role as intermediary.

Pattern 7. Personal data is always stored off-chain.

The storage of personal data is carefully designed in all services. When permissionless or public blockchains are leveraged, user data is stored off-chain, either in centralized repositories, like in the Exonum project or locally by the users, like in the Blockcerts or uPort projects. When a private permissioned blockchain is used, private data in principle could be stored on-chain in an encrypted form. However sending large portions of data in the network is usually inefficient due to bandwidth restrictions. In the Chromaway project for example, a smart contract platform is used to connect centralized databases of participants and records statements about the new states in the workflow.

Pattern 8. Transaction throughput does not appear to be a major bottleneck.

A clear difference between permissioned and permissionless blockchains is observed with respect to the number of transactions that can be validated in a time interval. The throughput in permissionless blockchain protocols is significantly less than the permissioned blockchain protocols (up to 7 tps compared to 160–5000 tps). Projects that anchor transaction on public permissionless blockchains are in minority but they have designed ways to mitigate throughput constraints. For example, transactions are batched or the hash of total state of the system is recorded. Projects that use permissioned blockchains usually do not report any problems with a throughput however the most transaction-intensive projects, such as Pension Infrastructure, expect some scalability problems related to processing a large number of smart contracts.

2. What benefits blockchain may bring to the public sector?

Ongoing experimentation is still on a relatively early stage with only few operational implementations. The analyzed projects demonstrate however that blockchain technology offers potential benefits that may be allocated to administration, citizens and society as a whole. Services utilizing blockchain-based notarization increase the auditability of data and the transparency of administrative processes. Immutability of records on the ledger can possibly enlarge trust of citizens and companies in the governmental record-keeping. Blockchain can also increase reliability of markets on which governmental institutions participate as providers of information and facilitators of transactions. Besides trust and reliability, blockchain generates efficiency gains measurable in monetary terms. For example, streamlining mortgage handling and transfer of land titles in a smart contract workflow, shortens property transaction times from weeks to hours. Quicker settlement reduces property transaction costs and improves liquidity on the market, providing possibilities for more economic activity. Given the high value of traded properties, these savings may account for hundreds of millions of Euro annually. Blockchain based pension management system is another example of potentially high gains induced by smart contract workflow. Smart contracts allow for high level of process automation, which translates to lower administration costs, elimination of paper work and storage costs.

Shared ledger offers also new opportunities for governmental institutions in policy design and funding management. For example, an immediate access to information on the state of the pension transfers or taxed transactions among businesses will enhance ways, in which governments can counteract fraud and evasion from public liabilities. The smart voucher program for promoting social inclusion is another example of how management of transactions via smart contracts enhances effectiveness of administration. Besides elimination of human errors and cost savings on personnel due to automation of management process, smart contracts improve the allocative efficiency of public funds and their targeting to beneficiaries. From the citizen's perspective blockchain in combination with other digital decentralized technologies can eliminate excessive bureaucracy, hard copies or visits in the town hall. Most of the projects develop mobile app to serve as remote interfaces to interact with public administration. An important part of this new user experience links to citizen self-sovereignty. Thanks to blockchain-attested identity and local storage of personal records, citizens will become largely independent from central repositories.

Public permissionless blockchains seems to have a limited use for governments for their numerous economic and technical limitations, such as the use of built-in cryptocurrencies, network latency and possibility of untrusted writers. Nevertheless ongoing experimentation uses this design to some extent mainly to build an additional layer of trust on top of existing central registries. By recording extracts of documents on a public distributed ledger, which is opened to everyone, governments can increase reliability of the record keeping of their own centralized registries. Independently run and publicly accessible ledger is useful for verification of originality and integrity of the kept by citizens or governmental agencies. However even this rudimentary functionality requires additional non-DLT systems that actually store the records and authenticate users with government-attested identity.

Going beyond notarization via distributed consensus, the majority of analyzed services utilize blockchain to establish a shared database technology. This is a domain of private permissioned blockchains. Such database is a single source of truth that enables new service delivery and interactions within an ecosystem of organizations and actors. Sharing a ledger among certified and known nodes enables provision of new types of 'smart' services that are located outside traditional organizational boundaries. In some cases, the role of governments may be quite limited although critical for the whole value chain, like for example in property transactions where public institution simply submits a land title. In other cases, the role of governmental institutions is more profound, like for example in pension system where public institutions obtain powerful tools for regulatory oversight.

Our analysis confirms that important part of efficiency gains is attributable to smart contracts. There is however a second side of the coin. Smart contracts have to be carefully designed and properly coded to evoke an exact behavior at exact conditions. In real life implementations reconciliation mechanisms must be in place to correct for instances of improper outcomes or simply errors in code. Some applications, which use smart contracts for a simple task, such as eligibility check or store of personal identifiers, are already operable. Complex workflow-based applications have a longer way to the market. They require severe integration effort with different legacy systems and encounter non-compliance issues.

5 Summary and Conclusions

In this paper, we investigated a number of ongoing blockchain developments in the public sector in Europe in order to assess how blockchain technology could in practical terms change the operation of governments and what potential benefits it may bring. Analyzed projects experiment with three main groups of services: (1) social transfers and pensions, (2) citizen's records and public registries and (3) foundational components related to user identity and regulatory compliance. The data for the study was collected between February and April 2018 via structured interviews with the representatives of each project. Horizontal analysis of projects across different institutional, functional, technical and economic aspects was carried out in order to reveal current patterns of adoption of blockchain technology in the public sector.

We have found that all governments experiment with the three main blockchain functionalities: notarization, shared database and workflow automation. There are however some notable differences. Services leveraging blockchain notarization are relatively more mature, while more disruptive solutions face challenges in implementation, mainly related to incompatibility with the current administrative processes and regulatory noncompliance. Blockchain-based services that are already in operation respond to clear business needs. They also have an active public sector actor and a strong technological partner. Besides, projects with a higher level of maturity tend to have less stakeholder complexity and more centralized governance.

Blockchain implementations are predominantly based on open source software at the protocol level, but not necessarily at the application level. Some governments are pushing towards the publication of platform-agnostic open standards to minimize the risk of lock-in and to incentivize the adoption of the service by third parties. The majority of implementations use, at least partially, private permissioned blockchain. This design is best tailored to handle voluminous transactions between known nodes owned by government institutions and ecosystem partners. The distributed ledger is however always just one layer in the architecture and interconnects with non-DLT layers. Blockchain is dependent on inputs from centralized governmental databases or user wallets that provide storage of private data. Distributed ledger allow overcoming critical bottlenecks in the administrative process where attestation and verification of data is traditionally done by human work. Blockchain-based solutions do not threaten public institutions role as intermediaries. They are either complementary or partially substitutable for existing public services. Transaction throughput does not appear to be a major bottleneck for any of the analyzed projects. Those projects that anchor transactions on public permissionless blockchains have designed ways to mitigate throughput constraints.

Literature on new technology implementation within the public sector argues that institutional changes will follow with the introduction of new technologies. In our empirical research, we have yet to see these institutional changes proliferate with the implementation of blockchain. So far, blockchain implementations in the public sector seek mainly for efficiency enhancements in record-keeping and financial management. Existing projects experiment with automated enforcement of transactions and new service delivery models, which utilize mobile interfaces and shared databases. The outcomes are promising and demonstrate capability of blockchains to reduce bureaucracy and costs of administrative processes and break silos between governmental agencies. These efficiency enablers are available mainly in permissioned environments. These systems do not need to reproduce trust, but rather automate exchange of information between known nodes belonging to different ecosystem partners.

Some implementations demonstrate a capability to enhance experience from interactions with public authorities. For example, personal certificates and land titles issuance can be provided to the citizen automatically via mobile app, without a need to visit a town hall. Self-sovereign identity can also represent a real value for citizens, if it will serve as authentication gateway to large pool of digital services. These benefits for citizens or businesses would not be possible without other innovative digital technologies, pointing to the role of technological convergence as a general paradigm for citizen-focused services.

These potential impacts of blockchain technology look quite promising. Whether blockchain will disrupt the status quo with inefficient governmental processes is however uncertain at this point. The set of production implementations is very limited, which is an indication that technology has yet to mature. The technological landscape suffers from lack of standards and trusted hosting infrastructure as well as gaps in essential functionality (e.g., smart contracts). Challenges recognized by the project teams are scalability, governance, flexibility and interoperability. Without addressing these issues, blockchain will not become a transformative technology for governments.

6 Future Research

This research shows that current blockchain-driven innovation in the public sector mainly consists of automating the enforcement of transactions and that main benefit drivers are reducing bureaucracy and costs of administrative processes, like record-keeping or financial management. Some projects, such as identity management or academic credentials, highlight also a path for digital transformation of public services through self-management by citizens. However, a lack of standards and trusted hosting infrastructure as well as gaps in essential functionality are currently key inhibitors for blockchain to become a transformative technology for governments. We therefore suggest practical research into a trusted hosting infrastructure for public services using blockchain. In addition, we suggest research in technical standards and interoperability structures enhance the effectivity of this technology in the public domain.

Moreover, we acknowledge the fast-moving pace of this technology. The cases were analyzed mid-2018 and we suggest continued empirical research in this domain to revisit the current benefits and inhibitors of blockchain within the public sector.[2]

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Annex: Characteristics of Individual Projects

Exonum Land Title Registry: Georgia

The National Agency of Public Registry (NAPR) of the Republic of Georgia partnered-up with Bitfuri Group in April 2016 to build a blockchain-based service for issuing digital certificates of land titles. The rationale for using blockchain was to increase public confidence in the property-related record-keeping, fight corruption and resolve disputes over contested property deeds. Solution based on Bitcoin protocol allows citizens and notaries to validate property-related certificates and make new registrations. The service allows for the registration of purchases and sales of existing land titles and a registration of new land titles. In the future, the system will

[2] For example, in 2019 the European Blockchain Partnership involving all EU Member States MS plus Norway and Liechtenstein started to build European Blockchain Services Infrastructure. EBSI will deliver EU-wide cross-border public services using blockchain technology. Three out of the four initial EBSI deployments that are underway: notarisation, diplomas and European self-sovereign identity represent clear scale-up attempts of the concepts analysed in this study. Deployment of these cross-border services will offer a unique opportunity to revisit some of the case studies presented here.

be extended to a registration of property demolitions, mortgages and rentals. The actual transaction validation occurs by a group of known servers or nodes. The transaction data is then hashed and recorded on the public Bitcoin blockchain. The hash is a cryptographic proof that transaction details match with the data recorded in the NAPR registry, without actually seeing it.

Blockcerts Academic Credentials: Malta

The Maltese government has launched a project that develops academic credentials verification using blockchain technology in October 2017. The Ministry for Education and Employment (MEDE) of Malta decided to use the Blockcerts open standard, developed in 2015 by Massachusetts Institute of Technology (MIT), for management of academic records. Blockcerts provides all aspects of the value chain: creation, issuing, viewing, and verification of the certificates, and uses blockchain technology as the infrastructure. The functionalities provided in the project include the issuance of academic credentials, the verification of certificates, and the storage of personal credentials in the user app. The Blockcerts app provides a wallet where the citizen has a full ownership of his records. System allows a citizen to control which third parties can see his academic records and verify their originality. By providing the URL of the certificate, one can verify the validity of the certificate, the owner of credentials, the issuing date, the issuing institution and the transaction ID. The system uses private permissionless design. The private blockchain network is composed solely of the certified institutions that participate in registering academic certificates using Blockcerts solution. The verification of the certificates is done on the Bitcoin network via the Blockcerts universal verifier. Anyone that has credentials of one of the consortia partners can apply for certificate and share it with any third party.

Chromaway Property Transactions: Sweden

The project was initiated in September 2016 by the Swedish Mapping, Cadaster and Land Registration Authority, Landshypotek Bank, SBAB, Telia, Chromaway and Kairos Future. The project was set-up to redefine real estate transactions and mortgage deeds. It aimed to address the main weaknesses of the current transacting system: lack of transparency, slow registration and transfer of land title and resulting high transaction costs. The underlying technology in this project consists of two main components: the blockchain platform (Postchain) and the smart contract workflow (Esplix). The smart contract workflow enables an automatic processing of transaction by the participants. The blockchain system uses private permissioned design. It combines the capabilities of centralized, relational databases with private blockchains. The shared database has capacity to store all transaction data, however in order to meet laws and regulations, the identifying (personal) data is stored off-chain and is represented on the blockchain by a hash. The solution introduces a completely new blockchain-based workflow that streamlines and secures the process of transferring a property title. Five types of actors are involved in the workflow: the buyer, the seller, the real estate agent, the banks and the land registry. The system interfaces to the Swedish Land Registry that is responsible for storing land titles. The blockchain updates state of the system after execution of each step in the workflow. In this way, synchronization among participants involved in the transaction is ensured.

uPort Decentralized Identity: Zug, Switzerland

In November 2017, City of Zug has launched a government-issued identity on the Ethereum blockchain, called uPort. The aim of the project is to provide a trusted and self-reliant blockchain-based identity to authenticate for e-government services and share personal data with third parties. uPort introduces a decentralized model of ownership, management and attestation of the identity of a person. It allows for a selective disclosure of specific information to particular companies or governmental institutions, giving citizens a full control over their personal data. Personal data is stored locally on the user's device in uPort application and anonymized before sending via network. Upon installation, the uPort application creates a unique private key, stored on a mobile device and two smart contracts running on Ethereum. The self-sovereignty property means that only the identity smart contract can make statements about a person's identity when interacting with other smart contracts or uPort users. These statements do not require confirmation from centralized certification providers. The identity contract is monitored by a controller contract. The controller contract grants or withdraws an authorization to sign statements. It also allows a citizen to recover identity access if a phone with the private key is lost. The city registration office has admin rights in the uPort application. After the verification, which has to be done in person in the town hall, the municipality issues an attestation signed with its private key. This implies that uPort is recognized as government-issued identity.

Infrachain Governance Framework: Luxemburg

The project started in November 2016 in Luxembourg. It aims to create pan-European host operator of blockchain network with certified nodes that comply with SLA-enforced governance. The certification will be based on the ISO27001 standard on the information security. Infrachain supports the creation of independent and incorruptible nodes involved in the operation of blockchain instances.

Infrachain develops a governance layer placed ‘on top’ of existing and future permissioned blockchains. The governance framework gives attention to privacy protection, cyber-security, law enforcement and business continuity to the same degree as centralized systems. The framework postulates a separation of service and network layers and the establishment of a reference blockchain infrastructure, composed of independent nodes, hosting different public and private services. Currently, individual private blockchain infrastructures comply with some security and confidentiality requirements, but there is no comprehensive set of shared rules followed by different implementations. This could be achieved via a virtual layer that serves as a host network operator with participating nodes operating under common service-level agreement (SLA). Because physical nodes are owned by different organizations, the host network would have a federated structure with a common governance framework. The host operator will offer high network stability and security, typical for public blockchains, and high performance required to host numerous private blockchain instances.

Pension Infrastructure: The Netherlands

The Pension Infrastructure project started in 2017 in collaboration with the two largest pension providers in the Netherlands. The Dutch National Government is involved in the project through the Dutch Authority for the Financial Markets (AFM) and the Dutch National Tax Office. The aim of the project is to build blockchain back-office for community-based pension administration. The system will allow for flexible and transparent pension administration for citizens, while reducing significantly pension management costs. The project has a variety of stakeholders, including employers, the national identity service, the tax authority, payroll providers, pension funds, technology providers and citizens. The system provides different functionalities based on the role of the actor. For the tax authority, for example, it provides an integral image of the contributions collected by a specific individual across many pension funds. For a citizen, it provides real-time insights into the evolution of their pension scheme and pension balance. Employers can directly introduce a salary change. Regulators do not have an active role, yet they can see part of the data. The project will create private blockchain architecture with a permissioned instance of the Ethereum protocol. The nodes in the network will have known identity and represent the stakeholders involved in the development of the infrastructure. Smart contracts are used to determine the rules for building up a pension balance for a citizen. They will also prescribe rules of who can view, change, and use the data. The project requires a combination of several blockchain functionalities: distributed registration, membership management, information exchange, automatic execution and digital fingerprints (hashing). The system is developed by setting up connections between the back-end systems of all the involved parties.

Stadjerspas Smart Vouchers: Groningen, The Netherlands

Stadjerspas is a fully operable service, developed by DutchChain. It uses blockchain infrastructure to distribute discounted services to low-income citizens of the Municipality of Groningen. The voucher system in Groningen was moved to a blockchain in 2016. The benefit of the blockchain-based system is the enhanced targeting of public money thanks to programmable money flows. Detailed spending conditions and eligibility criteria are set in the smart contract. Smart vouchers can be used, for example, in sport clubs, cinemas or for allocating subsidies to solar panels for homeowners. Stadjerspas ensures that public money reserved for a specified purpose is spent exclusively on that purpose and targeted at a desired group of beneficiaries. The municipality can provide eligibility criteria for users of smart vouchers, for example based on their residence, income, and number of children or any data linked to the resident number. Users of the system can see the vouchers they are eligible for in the mobile app or in the web portal, upon providing a QR code. The provider of the discounted service records each instance of a voucher use in the system. This blockchain implementation uses smart contract functionality and automatic payments. The blockchain system allows for transparency and programmability of public funding, specifically by adding functionalities of distributed registration, membership management, information exchange and automatic execution. The system uses public permissioned blockchain type. Initially the Bitcoin protocol was used, but the system has transferred to Zcash, which has significantly lower transaction costs. Every transaction is recorded in form of a hash, but the details of the transaction are not stored on blockchain.

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