IV. INTERNATIONAL

APPLIED SOCIAL SCIENCES CONGRESS (C-IASOS)

PROCEEDING BOOK

22nd-24th October 2020

“Applicable Knowledge for a Sustaniable Future”

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Address: OĞUZLAR MAH. 1251/2 SOK. NO:8 35230 KONAK / İZMİR / TURKEY

ISBN: 978-625-44354-0-9

25.10.2020

CONGRESS ID
Name of Congress
International Applied Social Sciences Congress
Type of Participation
Davetli ve Çağrılı / Keynote and Invited
Date and Place
22-24 October 2020 Turkey

Towards a Better Understanding of Blockchain Based Government and Public Services

***Busra Ozdenizci Kose*[1]**

Abstract

As a distributed ledger technology, Blockchain technology has started to show its potential and opportunities in various service domains over the world. Blockchain is considered not only in cryptocurrency and finance, but also in a wide spectrum of applications ranging from energy, healthcare, supply chain, real estate to public and government services. Government agencies around the world are exploring the benefits and constraints of incorporating Blockchain into the public services. The use of Blockchain in government and public sector services has the potential to provide great advantages such as data integrity, transparency, accountability, trust, corruption and fraud avoidance, high security and privacy, and efficiency of services with optimized cost. Governments from all over the world have started to realize valuable pilots of Blockchain based services in a wide array of government and public sector applications such as identity management, supply chain traceability, judicial decisions storage, land registration, healthcare data management, business licenses management, corporate registration, tax registration, and even e-voting. This study aims to provide an overview of the Blockchain in government and public services agencies and sheds light on the benefits of Blockchain technology with a classification of recent worldwide implementations depending on their purpose. Blockchain technology ensures valuable services and benefits particularly in domains of digital identity management, secure data storage, and asset tracking and auditing. This study will provide significant insights for researchers and practitioners that are investigating the effectiveness and efficiency of Blockchain in government.

Key Words: *Blockchain, Government, Public, Services, Classification, Benefits*

Jel Codes*:* *O32, O33, Q55*

INTRODUCTION

Governments have been seeking for promising technologies to extend their digital transformation and to realize their strategic objectives such as efficiency of processes, high quality services with optimized cost, better relationships with citizens, businesses and other stakeholders. Electronic governments (e-governments) process and store a massive amount of sensitive data about citizens, employees, businesses, products, services particularly in a single centralized environment as central server and database. With the adoption of new technologies, the centralized management of such confidential data is likely to remain vulnerable to privacy and security breaches; cyberattacks such as DoS (Denial of Service), DDoS (Distributed Denial of Service). In e-government systems, the compromise of this sensitive data leads to the loss of users' trust and confidence, opportunities, and other financial advantages (Elisa et al., 2018). Ensuring the security, privacy, integrity, availability and confidentiality is an inevitable issue within context of digital governments.

As an important Distributed Ledger Technology (DLT) trend of today, Blockchain has started to show its opportunities in various domains over the world. It was created and first introduced by Satoshi

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Nakamoto as an enabler of digital cash currency Bitcoin in 2008; was published in the white paper of "Bitcoin: A peer to peer electronic cash system" (Nakamoto, 2008). Beyond the foundation of cryptocurrencies, Blockchain "facilitates an expanding, chronologically ordered list of cryptographically signed, irrevocable transactional records shared by all participants in a network" (Allessie et. al., 2019). Blockchain as a revolutionary DLT provides decentralized and transparent data management in an auditable, immutable and irreversible manner based on consensus among different parties. The capabilities of anonymity, transparency, decentralization and auditability provided by Blockchain technology has attracted great attention from researchers and practitioners (Zheng et al. 2016; Yuan et al., 2018; Conti et al. 2018).

Currently, the technology is considered not only in cryptocurrency and finance, but also in a wide spectrum of applications ranging from energy, healthcare, supply chain, real estate to public and government services. Regarding the recent developments, it is obvious that, in near future Blockchain will influence and change the processes in government; and enhance information exchange on e-government platforms and digital assets transactions of public sector services that require high levels of authentication and trust. (Olnes et al., 2017a; Olnes et al., 2017b).

This study aims to examine the recent status of the Blockchain development in government and public services. In this regard, a systematic classification of recent worldwide Blockchain implementations in government and public services is performed depending on their purpose. The remainder of the paper is organized as follows. Section 2 explains the Blockchain technology with its features briefly, and then the potential of Blockchain in government services is reviewed. Section 3 presents the classification of Blockchain services depending on their purpose with recent examples and examines the underlying values provided. Section 4 concludes the study by contributing to the research agenda on Blockchain implementations in government.

BACKGROUND

In this section, the related research on Blockchain technology, its technical infrastructure and benefits of Blockchain technology in government and public services are presented.

Blockchain Technology

Blockchain as a distribute network of peers presents a continuous sequence of blocks including list of transactions (Zheng et al., 2017). Blockchain is a chain of timestamped blocks including valid transactions. With the aim of security, blocks are linked by cryptographic hashes which is used to identify the information and to ensure the integrity of data (Zheng et al., 2018). As shown in general structure of Blockchain by Figure 1, each block is directly chained to the previous timestamped block by a reference. This reference is a hash value of previous parent block. The first generated block - which has no parent- of a Blockchain network is called as genesis block. The linked blocks build the chain structure; namely Blockchain. Blocks can be defined as timestamped batches of approved and validated transactions (Ølness et al., 2017a). A block includes a block header and a block body (Fernández-Caramés et al., 2018). The block header includes general characteristics regarding the block; block version, parent block hash value, hash value of all transactions in the block -namely Merkle tree root hash-, current timestamp and nonce value. The block body contains transactions and a transaction counter. The maximum number of transaction that a block can have depends on the size of transactions and block size.

Blockchain technology integrates several core technologies such as cryptographic hash, digital signature and distributed consensus mechanism (Zheng et al., 2017). Asymmetric cryptography and digital signature -generally elliptic curve digital signature algorithm (ECDSA)- technologies are used in order to validate authentication of transactions and administer the untrustworthy environment. In order to develop a Blockchain, a peer-to-peer (P2P) network is first created among all nodes; each have key pairs of public and private keys which will be used for encrypting an decrypting in asymmetric cryptography operations. As illustrated in Figure 2, when a node performs a transaction, it signs and broadcasts it to its peers on the Blockchain network. As the peers of regarding node receive the signed transaction, they verify that it is valid transaction before retransmitting it to other peers; by this way the validated transactions spread through the network and packed into timestamped block by special nodes as miners (Fernández-Caramés et al., 2018; Zheng et al., 2017; Zheng et al., 2018). By the way, creating new blocks is defined as mining.

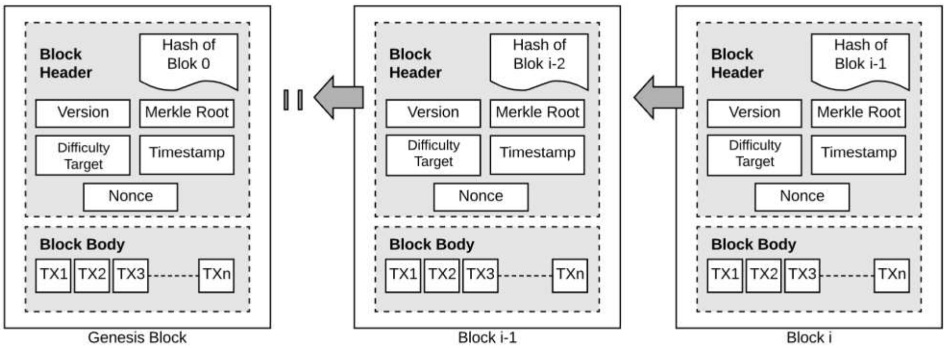

Figure 1. Blockchain Structure

Consensus algorithms -such as Proof of work (PoW), Proof of stake (PoS), Ripple, Delegated Proof of Stake (DPoS)- are the most significant component of Blockchains in order to reach a consensus between untrustworthy nodes which is considered as the transformation of Byzantine Generals (BG) Problem (Zheng et al., 2017). The algorithm used over the network ensure that shared ledger in different nodes are consistent with each other.

Blockchain systems are generally classified into three categories: public blockchain, private blockchain and consortium blockchain (Buterin, 2014; Xie et al., 2019). Public blockchain systems are decentralized and permissionless blockchain; while consortium blockchains are partially centralized and private blockchain is fully centralized which means that it is controlled by an entity. Both consortium and private blockchains are permissioned systems; whereas a public blockchain system allows any entity to join the network and participate in consensus process easily; read and send transaction and provide shared ledger (Buterin, 2014; Xie et al., 2019). Most blockchain platforms are permissionless systems; Bitcoin and Ethereum are two public blockchain examples. Currently, Hyperledger as a popular platform is developing business consortium blockchain frameworks. Ethereum also has provided tools for building consortium Blockchains. In case of private blockchain systems, there are also various companies implementing private networks for efficiency and auditability.

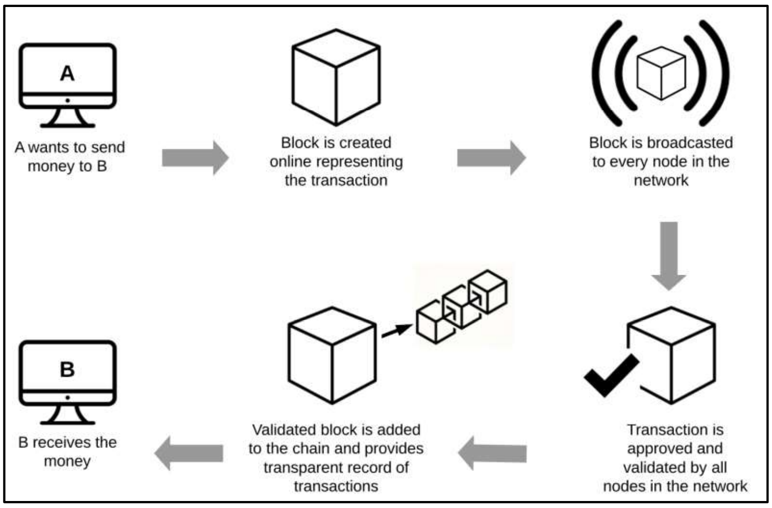

Figure 2: How Blockchain Works

One of the important implementations of Blockchain technology is Smart Contract which is defined as a crypto economically secured execution of code, a code fragment is executed by the miners automatically or a self-operating computer program (Zheng et al., 2017; Zheng et al., 2018; Kshetri, 2017). Without intervention of any third parties, smart contract self-executes the contractual statements and defined rules as codes independently on every node in the Blockchain network. Several projects such as Ethereum and Bitcoin implemented smart contract. Since all actions are recorded and verified in the decentralized ledger of Blockchain, smart contract provides real-time auditing services and also undeniable transactions (Zheng et al., 2017; Kshetri, 2017). It helps to translate various and assets into virtual identities in Blockchain, and allows them to interact with other assets automatically with defined rules in trackable and undeniable manner.

Potential of Blockchain in Government

The study of Zheng et al. (2017) highlights general key characteristics of Blockchain as decentralization, persistency, auditability and anonymity. A traditional transaction mechanism requires validation of the transaction by a trusted central authority; however with Blockchain technologies, every node needs to validate transactions and store an identical copy of the ledger which provide advantages in - as stated by Batubara et al. (2018)- fault tolerance, more user control, data consistency and integrity, attack avoidance, transparency and elimination of third-party intermediaries such as notary.

The consensus mechanism, timestamp and cryptographic schemes are fundamentals of persistency; these core technologies allows to store just only valid transactions as an immutable record; no one can edit, delete or copy the already recorded transactions. The link between all blocks including transactions via hash mechanism also provides easy verification, traceability and auditability of all transaction. Instead of electronic transactions, user privacy and anonymity is ensured by Blockchains systems; since identities of individuals performing interactions on Blockchain is covered by pseudonyms.

As emphasized by Batubara et al. (2018), the significant features of Blockchain technology ensure valuable benefits to be used in the government and public sectors to improve public services. Various governments around the world are exploring the potential benefits and constraints of incorporating Blockchain into the public services. According to the study of Alkebti et al. (2018), UK Government published a report about the significance of Distributed Ledger Technology for government and public services which recommends exploring and testing Blockchain in government services; in this regard, UK government approved Fintech startup Credits as supplier of Blockchain technology in government services (Alkebti et al., 2018).

The adoption of Blockchain technology by Estonian government is the most significant and advanced example in government and public services (Alexopoulos et. al., 2019). Estonian government can be highlighted as the first country that integrate Blockchain technology into several digitized services after the country's experience of cyberattacks in 2007. Today, a scalable Blockchain network on a national level is developed to maintain data integrity in government repositories and to protect sensitive citizen and government data against threats (E-Estonia, 2020).

As an enabler of digital government, Carter and Ubacth (2018) emphasizes that Blockchain based government and public sector services advances data integrity, data quality, transparency, avoidance of fraud and manipulation, decreasing corruption, and establishing trust, improving security and privacy. As one of leading global Blockchain company, ConsenSys (2020) indicates advantages of Blockchain technology for digital government as secure storage of sensitive - government, citizen, and business-data; reduction of labor-intensive processes and excessive costs of accountability; decreased potential for corruption and abuse; increased trust in government and online civil systems. It is clear that the decentralized network structure of Blockchain provide significant opportunities in government and public services to advance transparency, to prevent fraud and protect data, streamline processes, reduce corruption, and increase trust and accountability in the public sector.

Individuals, businesses and even governments share valuable assets and sensitive resources regarding government and public services. With the capabilities of Blockchain technology, all these assets and resources can be shared over a distributed ledger and can be secured using strong cryptographic mechanisms. The infrastructure of Blockchain removes a single point of failure which protects sensitive data in a decentralized manner (Allessie et. al., 2019; ConsenSys, 2020).

Ølness et al. (2017a) emphasizes that realizing the advantages of Blockchain technology highly requires understanding of all government processes and requirements of services; and existing structures need to be changed to enable distributed transaction management in government processes. Ølness et al. (2017a) provides a systematic review of benefits and promises of Blockchain systems in terms of five categories for government and public sector services: strategic, organizational, economical, informational and technological. In terms of strategic advantages, Blockchain systems provides high levels of transparency and auditability which is a primary focus of government services. It is defined as democratizing access to data. Shared ledger including valid transactions are visible for every node; transactions or information cannot be changed by unauthorized entities which supports data integrity; reduces the likelihood of any fraud, manipulation of transactions and also reduce corruptions since data is stored in decentralized, distributed ledgers. Organizational benefits of Blockchain are highlighted as increased trust and control in addition to transparency and auditability. Immutable record of transactions, reaching a consensus over the network and validation by all nodes in the network increases the levels of trust and control in an untrustworthy environment. In terms of economic benefits, Blockchain allows to streamline processes and operations with digital transformation of business. Automated creation and control of transactions reduces human errors and increases the security and trust in processes (Ølness et al., 2017a).

Besides enabling high levels of security in processes and operations, it reduces costs of conducting and validating a transaction -through reducing human involvement and replacing paper based systems- as well as costs of preventing attacks like DDoS on systems. Benefits from informational perspective can be directly highlighted as data integrity, more data quality with decreased human errors, authorized and high speed access to data stored on distributed ledger; secure storage of data by powerful cryptographic and encryption mechanisms; more privacy and reliability. Consensus mechanisms in Blockchain provides that only data or transaction is modified with the agreement of all nodes. In terms of technological benefits, Blockchain provides irreversible and immutable records, and promises integrity of transactions. Since data is stored in multiple databases as ledgers in an encrypted structure, it becomes impossible to change or hack them at the same time without noticing; which makes it resilient to malicious behavior. Another highlighted benefit is reduced energy consumption by increased efficiency and transaction mechanisms (Ølness et al., 2017a).

Governments from all over the world have started to deploy valuable pilots of Blockchain based services. It is seen that Blockchain presents critical opportunities in a wide array of government and public sector applications such as digital currency and payments, identity management, passports, supply chain traceability, judicial decisions storage, land registration, health care, business licenses, corporate registration, tax registration, and even e-voting (Manski, 2017; Ølness et al., 2017a; Alkebti et al., 2018; Allessie et. al., 2019).

CLASSIFICATION OF BLOCKCHAIN SERVICES IN GOVERNMENT

This section performs a classification of Blockchain services in the government depending on their purpose including recent pioneering implementation examples over the world. The defined service domains are identity management; data storage; and asset tracking and auditing. These domains introduce different benefits and underlying values of Blockchain with its embedded core technologies for government and public services.

Digital Identity Management

Digital identity (ID) management is the most valuable implementation case of Blockchain which is also in the agenda of many countries especially for enabling security goals of authentication and non-repudiation of the user identity. A digital identity can include usernames with passwords, driver's license number, online search activities, medical data and even biometrics that describes a person's identity. There are many alternative solutions for digital identity; they are commonly stores on centralized servers which may have vulnerabilities and can be exploited by a threat. Managing digital identities with Blockchain technology –in other words with a distributed ledger technology- provides a unified, interoperable and tamper-proof infrastructure for residents, companies, and even IoT (Internet of Things, IoT) devices today (ConsenSys, 2020).

For digital transformation of government and public services, digital identity is seen as the fundamental building block that governments need to focus on. Governments are the critical sources of key identity information of citizens. Blockchain enabled digital identities allows citizens to manage their assets; send and request credentials; authorize transactions, and securely manage data. Citizens can use their Blockchain based digital identity to produce legal documents and regulations by tamper proof smart contracts. With the help of these digital identities, they can notarize official documents such as birth certificates, marriage arrangements, testaments, business contracts, land titles (Alkebti et al., 2018). Hence, Blockchain based digital identity management provides significant opportunities -with the purpose of authentication and non-repudiation of citizens- for researchers and practitioners.

As indicated in the Report of JRC Science Policy Report by European Commission in 2019 (Allessie et. al., 2019), uPort decentralized identity management of the City of Zug in Switzerland is a valuable deployment example in terms of identity management. Accordingly, the City of Zug has launched their own Blockchain based identity - Self Sovereign Identity (SSI) - on public Ethereum platform. The city provides publicly verified identity credential to their city residents; by the way the city sometimes referred to as Crypto Valley. SSI is described by Consensys (2020) as “the concept that people and businesses can store their own identity data on their own devices; choosing which pieces of information to share to validators without relying on a central repository”. The main aim of Zug Digital ID is to advance access to digital government services, increase efficiency, data security and voting processes. Besides, one of the most significant implications of Zug Digital ID is seen in streamlining national e-voting processes. The main aim in this deployment is to improve the accessibility to direct democracy with a reliable authentication mechanism; the expensive, time-consuming and cumbersome flow of traditional voting mechanism is eliminated with the implementation of Blockchain based identity management in national voting (Consensys, 2020; Allessie et. al., 2019).

Secure Data Storage

Secure distributed network structure of Blockchain allows to enter data and record as online transactions in a shared ledger among nodes. Various governmental agencies as nodes can create a secure Blockchain network; and secure data entry, validation with consensus among all nodes, storage and interagency secure data management can be realized for different governmental operations and public services processes.

Blockchain allows for keeping a track of a ledger in other words keeping track of immutable history of transactions, which means data integrity for services. Secure recordkeeping driven by the use of algorithms and programmable smart contracts increases trust of citizens and companies. Automated secure Blockchain based systems can reduce bureaucracy, discretionary power and corruption. In terms of data entry and management perspective, valuable recent implementations can be highlighted as voting, land registration, tax declarations, registration of corporates, storage of judicial decisions and more. Some recent real world implementations and deployments are explained hereunder.

As mentioned, citizens with Blockchain based digital ID can authorize themselves, easily access and securely engage in e-voting systems. Besides, governments can benefit from Blockchain technology for realizing transparent voting processes with immutable and irreversible data records. Usage of programmable smart contracts in Blockchain allows that a voter can only vote once as well as allows to check if the vote is correctly stored (Ølness et al., 2017a). Voter frauds and manipulation of voting results can be avoided with the help of distributed network of nodes and consensus mechanism; which means strong data integrity for voting systems.

Regarding land registration, Blockchain-based land registry system of Republic of Georgia was launched in 2016 by the country’s National Agency of Public Registry (NAPR) (Allessie et. al., 2019). They transformed their land title registry process with Blockchain technology. It has significantly added transparency in the land registry system; and reduced operational costs and processing time of land registration and verification from three days to a few minutes. The accuracy of stored data increased reliability for citizen.

Another example from the JRC Science Policy Report by European Commission (Allessie et. al., 2019), Maltese government and Ministry for Education and Employment (MEDE) of Malta has initiated

Blockcerts project in 2017 which aims to develop academic credentials verification using Blockchain. The project provides secure management of academic records including creation, issuing, viewing and verification of certificates with the support of Blockchain technology. The system allows for greater control over educational achievements and certificates; and eliminates the need for hard copies and the risk of using fake certifications.

Pension Infrastructure implementation project with the collaboration between pension providers and Dutch National Government in Netherlands has started in 2018 (Allessie et. al., 2019). The project has several stakeholders from tax authority, payroll providers, pension funds to citizens. The Blockchain based pension management system allows for flexible and transparent transactions for citizens, and reduces pension management costs. As another sensitive and critical asset of citizens, Electronic Health Records are revolutionized with Blockchain technology by Estonia's government (E-Estonia, 2020). The health information is entered securely and accessible to only authorized individuals. Blockchain based e-health system assures data integrity and avoids threats to the sensitive data of citizens.

Asset Tracking and Auditing

Auditability and accountability to public is one of the primary responsibilities of governments. In addition to transactions recording and storage; monitoring and controlling, traceability and transparency of assets should be considered in governmental services. As stated by Antipova (2016), governments are responsible to provide an independent, objective, nonpartisan assessment of the stewardship, performance, and cost of government policies, programs, and operations. Beyond secure data entry and management, Blockchain based operations and processes allow governments to audit and control budget resources, and avoid misrepresentation, fraud and even corruption in government financial statements. This provides more trust of citizens and companies in governmental processes (Antipova, 2018; Allessie et. al., 2019).

The use of national digital currencies and performing cryptocurrency payments allows for transparent budgeting and accountability; and reduces corruption within governments. Beyond cryptocurrency payments; various other services regarding traceability and transparency are possible such as tracking vaccinations and prescription drugs, tracking loans and student grants, auditing customs and border patrols, tracking import and exports, government budgeting and financial transactions, traceability of supply chains, and auditing of other various assets of government.

In this regard, as a recent project example, U.S. Food and Drug Administration has launched a pilot project in order to protect public health by providing safety and effectiveness of human and veterinary drugs, vaccines and other medical devices (ConsenSys, 2020). The main aim of this project is to explore Blockchain technology for tracking and verification of drugs, regulate and ensure accountability to the movement of assets in nation's drug supply chain. Blockchain based systems with the use of smart contracts, allows to track critical governmental assets immediately; improve processes, lower transaction costs and increase efficiency. Reduced costs, time and complexity in information exchanges and tracking among government entities enhance the administrative function of governments.

Evaluation of Service Domains

Blockchain provides a distributed, shared data storage environment with a tamper-resistant ledger including chained blocks in distributed network which can record and secure transactions using cryptography between two or more parties efficiently and in a verifiable and permanent way. Blockchain allows trustless users to agree on an immutable data without the need of third party. These characteristics make Blockchain technology to receive extensive attention from government and public services. Three main service domains depending on their main purpose is summarized in Table 1 in terms of their underlying values. Each service domain provides different advantages and benefits for their users.

CONCLUSION

Blockchain technology in government and public services is an emerging research area. Being distributed and immutable increases the security and attractiveness of Blockchain for various services from identity management to customs and border patrols tracking. As a revolutionary DLT, Blockchain technology provides decentralized and transparent data management in an auditable and irreversible manner. This study examines benefits and underlying values of Blockchain technology for government and public services with recent pioneering implementation examples over the world. A classification of Blockchain based government and public services is presented depending on their main purpose: digital identity management services for authentication and non-repudiation of users; data storage for data integrity and accuracy; asset auditing and tracking services for accountability to movement or transfer of assets.

Table 1: Summary of Service Domains and Underlying Values

Service Domain	Underlying Values	Service Examples
Digital Identity Management	Secure authentication of users Non-repudiation of users Easy access and share of identity information Value added and customized services Elimination of intermediaries Improve citizens' quality of life	Voting, notarize official documents such as birth certificates, marriage arrangements, testaments, business contracts, land titles etc.
Secure Data Storage	Integrity and accuracy of data Real-time updating of data Easy and secure data exchange Eliminate the need for hard copy materials Improve workflows and processes	Land registration, tax declarations, registration of corporates, storage of judicial decisions, pension management, health data management etc.

	Reduce bureaucracy, discretionary power and corruption	
Asset Tracking and Auditing	Immutable, irreversible and permanent digital assets Increase accountability and trust among entities Elimination of intermediaries Improve workflows and performance Efficient resource control Avoid misrepresentation, fraud and corruption	Tracking customs and border patrols, import and exports, government budgeting and financial transactions, supply chains etc.

Blockchain based data sharing and communication allows to overcome challenges and issues of data manipulation, missing information, inconsistencies or spoofing (where data is sent by an unauthorized source), irrefutability and repudiation, and consensus problems among stakeholders of government and public services. Blockchain technology has a potential to provide transparent and immutable record management; simplify underlying process; reduce cost, time and user effort; and eliminate intermediaries in digital government ecosystem.

The classification provides valuable insights about the technology's development in government and public services domain, usability, adoption and acceptance issues. More intensive academic research will advance the maturity of this research field. Some open research issues are also explored that can be observed by researchers or practitioners: analysis of interoperability of different public services and architectures; identification of barriers to and critical success factors for Blockchain technology adoption in government and public services; exploration of user perception and preferences for Blockchain based government systems, implementation of longitudinal field studies on Blockchain usability with well-structured empirical results.

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