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Blockchain for Public Services: A Systematic Literature Review

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ABSTRACT Blockchain is heralded as being ''the next big thing'' that promises to radically transform society and the economy in near-future applications. While scholarly literature on blockchain has largely focused on bitcoin and cryptofinance, in recent years, a body of scholarship has started to emerge on blockchain in the public sector. The characteristics of blockchain have made it a promising technology to transform many activities related to public policy and public service provision, such as administrative processes, welfare provision and regulation practices. This article provides, to the best of our knowledge, the first systematic literature review of the use of blockchain across all the main public services. This systematic review identifies the public services most likely to be impacted by the introduction of blockchain. It also highlights the main potential benefits, costs and risks of blockchain for government, civil servants and citizens. Governments are found to benefit mainly from improvements in efficiency and traceability, while regulatory uncertainty and questions around scalability represent major costs and risks for them. Civil servants, the least studied actor in the literature, could benefit from blockchain through the reduction of red tape and improvements in coordination between agencies. Their lack of blockchain knowledge and skills represent a major cost as regards adoption. Regarding citizens, security and transparency are identified as being the most important benefits, while risks are mainly associated with data security concerns. The article concludes by noting several limitations in the literature and providing suggestions towards fruitful lines of research.

INDEX TERMS Blockchain, public services, government, civil servants, eGovernment, public sector innovation, systematic literature review.

I. INTRODUCTION

Blockchain is heralded as being ''the next big thing'' – one of the most important of the suite of technologies stated to have ''disruptive'' consequences for society and the economy in near-future applications. These technologies are labelled disruptive as it is claimed that, after initially taking root in simple applications in specific areas of economic activity, they will relentlessly scale upwards, eventually replacing previous technologies, and bring about profound changes in the ways in which processes are completed, delivering cost reductions and performance improvements [1], [2]. Blockchain is actually a particular example of Distributed Ledger Technology (DLT, henceforth). Specifically, blockchain uses DLT to store information that has been verified by cryptography among a group of users through a pre-defined network protocol, without the control of a centralized entity or authority [3].

Blockchain is promoted as being a key asset for governments to keep up with future trends: it is claimed blockchain will profoundly transform public service production and delivery [4]. However, the expectation that innovative technologies will automatically bring about positive transformations can lead to over-optimistic executions and biased assessments [5], [6]. Putting aside utopian claims, the benefits and risks of blockchain for public services need to be carefully considered. A glance at the literature on blockchain shows that by far the majority of attention has been paid to bitcoin and other cryptocurrencies. For example, a search using Scopus indicates that, in 2019, nearly two-thirds (61.2%) of the total number of publications that focused on

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blockchain were actually about bitcoin. However, in recent years, a body of scholarship on blockchain in the public sector has emerged. This literature is producing important insights into the potential of blockchain in the provision of public services. At present, these insights constitute a relatively disperse body of knowledge, in the sense that they are being produced across a broad range of disciplines, bridging both Sciences and Social Sciences. To date, a comprehensive review of the potential benefits, costs and risks of blockchain in public services, which brings together all the existent insights in a multidisciplinary perspective, is missing. It is this gap that this article seeks to address by conducting a systematic review.

At the same time, the number of projects and early stage applications of blockchain initiated by governments and public administrations around the world are increasing [7]. Most of these projects and applications seek to use blockchain in order to improve economic efficiency, transparency, and the accountability of bureaucratic processes. Three main uses of blockchain in the realm of public services can be identified. First is the establishment of blockchain-based, international public infrastructures, that seek to improve coordination and information-sharing between governments, businesses and citizens from different countries. One example is based in the European Union, where the European Blockchain Services Infrastructure (EBSI) is being developed. EBSI aims to develop a public-permissioned blockchain infrastructure for application upon public services, such as sovereign digital identity, notarization, diplomas and trusted data sharing. Second is the further development of ''Smart Cities''. Here, blockchain is expected to be the missing piece of the puzzle to integrate Internet of Things technologies (IoT), AI, cloud computing and Big Data. Blockchain's characteristics of immutability and traceability, along with its decentralized structure, are thought to help ensure progress towards a more efficient, secure, and transparent way of managing services and data. Third is supply chain management [8]. According to the Global Alliance for Trade Facilitation, supply networks account for two thirds of the total cost of traded products, while seven percent of the total value is the cost of documentation processes alone [9]. Blockchain is being used to address logistical complexity, by breaking down information silos, automating transaction and bureaucratic processes, increasing transparency, and guaranteeing authenticity along the supply chain. Public and private initiatives, such as *komgo*, the world's first blockchain-based platform for the commodity trade ecosystem, are expected to emerge in the near future [10]. A recent development regarding blockchain in public services is DApps, or decentralized applications, that run on a blockchain network, mainly Ethereum. DApps are similar to traditional Web applications but, instead of an application programming interface (API), DApps presents a wallet that communicates with the blockchain through smart contracts. Although the number of running DApps is still emerging, and focuses mostly on decentralized finance, marketplaces, games, gambling and crypto exchanges, it is probable that these applications will play a significant role in the future in the realm of public services.

The adoption of blockchain towards the provision of public services is expected to have important social, political and environmental implications. Blockchain can render societies more sustainable, understood as the harmony of three pillars: environmental, economic, and social [11]. Blockchain has the potential to improve the access and transparency of public registries, management of, and access to, energy and water, citizen participation tools and international cooperation, among other advantages. By so doing, blockchain applications could have a positive impact on several Sustainable Development Goals [12]: reducing inequalities (objective 10), sustainable cities and communities (objective 11) and peace, justice and solid institutions (objective 16). At the same time, blockchain could also lead to costs, such an indiscriminate replacement of physical staff by highly automated, opaque processes or a general disempowerment of citizens caused by a concentration of power in dominant positions away from democratic scrutiny [6]. The direction, shape and intensity of the transformations brought about by blockchain are not pre-determined, and will depend on many issues, including blockchain's technical development, social acceptance, and political will.

In this light, the aim of this article is to compile all the existing scientific knowledge about the use of blockchain in public services. To do so, a systematic review of the literature is performed, which comprehensively collects what is known (theoretically and empirically) about the potential benefits, costs and risks of the use of blockchain in the arena of public services. The contribution of this article is to provide, to the best of our knowledge, the first systematic review of the literature specifically on the use of blockchain for public services. The results of this systematic review will help academics and policymakers better understand, execute and communicate the potential of this technology.

The role of public services has been fundamental as regards the creation of modern states and societies, since they contribute to territorial consolidation, social cohesion and political stability [13]. We define public services from a functional approach, referring to those services which are provided in the public or general interest. We opt to focus on ''public services'', rather than on the ''public sector'', since many public services are delivered by non-governmental and private agents, or through mixed ownership partnerships, such as, corporations, inter-municipal cooperation, third sector or public-private partnerships [14]. ''Public services'', therefore, capture all of these activities, whether or not they are owned or controlled directly by the state. From the insights of this systematic review, this article sheds light on whether introducing blockchain is viable, feasible and desirable in public service production and delivery.

The introduction of an innovation such as blockchain is a complex process that presents diverse technological, socio-economic, legal, and cultural opportunities and barriers. The potential impact of the technology, therefore, will be different, depending on the specific public service in question. Furthermore, the implications of introducing blockchain into public services will differ—significantly—depending on the segment of society in question. For example, the implications of blockchain for governments responsible for managing or regulating the public service will likely be different to that of the civil servants who oversee public service production and delivery, as well as citizens, as users of public services. Therefore, our systematic literature review focuses on the following two research questions:

A) What are the main public services potentially affected by blockchain?

B) What are the main potential benefits, costs and risks of blockchain in public services for (1) governments, (2) civil servants and (3) citizens?

To answer these questions, we conduct a systematic review following Preferred Reporting Items for Systematic Reviews and Meta-Analyses or PRISMA guidelines [15]. This consists of a review of clearly formulated questions that follows systematic and explicit methods, including clearly stated objectives, a systematic search to identify all the studies that meet the eligibility criteria, and a systematic presentation of findings [16].

The rest of this article is organized as follows. Section II provides a discussion of related work. Section III presents our research strategy, including the methodology used to conduct the review. Section IV presents the background results and the main characteristics of the records found. Section V identifies the main public services impacted by blockchain. Section VI discusses the benefits, costs and risks of blockchain for governments, civil servants and citizens. Finally, Section VII presents our conclusions, limitations, and suggestions for future research.

II. RELATED WORK

A small number of literature reviews on issues related to blockchain applications to services, processes and business models have been published. Though some of these articles include analysis of blockchain in a limited number of public services, the literature does not yet include a comprehensive analysis and discussion of blockchain in public services. The first wave of literature reviews of blockchain applications focused on its potential use in the cryptofinance and cryptocurrencies sectors, particularly, bitcoin [17]. Most of these studies were technical, and proposed changes to protocols, mining processes and privacy issues [18], [19]. To date, five systematic literature reviews have been published which analyse blockchain applications in the public sector [20]–[24]. Of these studies, [20] focuses on blockchain in the context of Smart Cities, and includes analysis of a small number of public services associated with e-Government, energy, and education. Methodologically speaking, this article utilizes a component-based analysis framework to classify blockchain practices by design, protocols and platforms, and provides a cross-sector analysis. Reference [21] inquires which areas blockchain is impacting regarding the public sector. However, instead of using a systematic literature review scheme, it uses the keywords mapping method. This article identifies the most commonly used words in the literature related to the study of blockchain in the public sector, and tracks how those evolve overtime. While this article identifies those public services where blockchain is being used, it does not provide insight into the benefits, costs and risks of each of these applications. Reference [22] covers blockchain applications in specific sectors, including a small number of public services, but most attention is paid to industrial (private) sectors. However, the list of public services covered is not comprehensive and this article does not analyse the specific context of the agents involved in the innovation process. Reference [23] does not review public services *per se*, rather, it reviews the current state-of-the-art on privacy-preserving mechanisms, and blockchain's applicability to eGovernment, eHealth and Smart Cities. Similarly, [24] reviews the public governance challenges of blockchain which may indirectly affect public services. In particular, it analyzes the governance challenges of different blockchain types, governance stages, and governance layers. Our article differs from these previous ones, in that it provides the first systematic review specifically focused on the context of blockchain and the universe of public services, provided by all levels of public administration, including: a comprehensive list of public services where blockchain is having an impact; a detailed discussion on the context of blockchain innovation in public services; and information on the benefits, costs and risks of blockchain in public services. These benefits, costs and risks are discussed for each kind of public service. In addition, they are disaggregated by agent, hence, benefits, risks and costs of blockchain are identified for government, civil servants and citizens. This is discussed from the perspective of the diverse actors involved in public service provision, addressing their specific circumstances, motivations and concerns that may shape the innovation process. To this end, we identify the main benefits, costs and risks that governments, civil servants and citizens face as a consequence of the application of blockchain in public services. Our systematic review provides, therefore, the most comprehensive analysis of blockchain in public services to date, upon which further research, pilots and applications can build.

III. RESEARCH STRATEGY

Our systematic review follows PRISMA to ensure it is based on replicable and transparent steps that allow for the identification of all studies that meet the eligibility criteria and a systematic presentation of the findings. The checklist for each step is presented in the Appendix S.1.

A. ELIGIBILITY CRITERIA

Studies were included in the systematic review if they met all of the following criteria:

- *Type of Studies.* Records considered should include discussion of the social impact (on governments, civil

servants and citizens) of the use of blockchain in public services.
- *Topic.* Records included should deal with the use of blockchain technology in public services. We define public services from a functional approach, referring to those services which are provided in the public or general interest. Essentially, following the literature on this topic, public services are those services ''for'' the public, independently of whether they are ultimately publicly or privately owned [25].
- *Types of Participants.* The scope of our systematic review encompasses the implications of blockchain for three possible types of participants: I. Governments, defined as the public bodies/entities directly or ultimately responsible of public service provision; II. Civil servants, defined as those employees in charge of the provision and/or regulation of the public service; III. Citizens, defined as the individuals who are the potential recipients of the service.
- *Study Design.* The interest of our systematic review is both on the theoretical and the empirical implications of the use of blockchain in public services.
- *Language.* We restricted our sample of studies to those written in the English language.
- *Publication status.* We included published peer-reviewed journal articles as well as books and book chapters.

B. SEARCH STRATEGY

We used three search strategies to identify scholarship on blockchain on public services. Our main search strategy was primarily focused on the two most well-known international repositories: Web of Science Principal Collection and Scopus.[1] For both sources, we first conducted a search of records containing the word ''blockchain'' in the title, abstract or keywords.[2] Records had to be written in English and published as journal articles, book chapters or books, in the field of Social Sciences. Our search encompassed multidisciplinary publications also included in other fields such as Computer Science or Engineering. We found that interesting records included the word ''public'' (''public service/s'', ''public sector'', ''public administration'', ''public agency/ies'', ''public value/s'', ''public organization/s'', ''public actors'', etc.), and/or the word ''government''. In this light, we conducted a refined search in which the records included the word ''public'' (in any combination) or the word ''government'' in the title, abstract or keywords. This refined search resulted in 229 records from Web of Science and 150 records from Scopus. In order to minimize the number of false negatives, we developed a complementary search from Google Scholar. Records we searched for using Google Scholar had to include the word ''blockchain'', plus the word ''public'', or the word ''government'', in their title. This search resulted in 365 additional records. Searches were conducted on January 2020. A final search from the IEEE Xplore repository using the same criteria used for Web of Science and Scopus was also conducted. This search resulted in 244 additional records.

Two complementary search strategies were conducted. The second strategy led to a set of 35 additional records identified by blockchain experts. The final strategy consisted of updating the systematic review to include records from January 2020 to June 2020 using an innovative technique: an automatic search engine. ASReview is a new software that uses machine (deep) learning models in combination with active learning to facilitate the screening process of systematic reviews [26]. Firstly, we provided the software with a set of records identified from Scopus following the eligible criteria described in the primary search process. Secondly, two of these articles were selected as relevant by the authors and used by the software as a head start. Then, the search engine showed the abstract of the most related article considering the ones already selected. The researcher chose whether to include or not the new record based on the screened abstract. Once the decision was taken, a new calculation was made, and the next most related article was presented. When several non-interesting articles appeared in a row, the researcher stopped the screening process, since the rest of these articles were expected to be non-relevant. This represents a significant advantage, especially for systematic reviews with substantial initial samples of records. This strategy using ASReview serves to carry out new systematic reviews as well as updates of published systematic reviews.

C. RECORD SELECTION

In total, our search led to 1,070 records. Two of the authors were jointly responsible for the screening process and final election. If there was disagreement about the eligibility of a article, this was resolved through discussion and consultation with the other two co-authors. Our selection process is presented in Fig. 1. In a first step, records were screened based on title, abstract and keywords. We excluded duplicates, as well as records that did not share all the required criteria (i.e., those not written in English, not published as journal articles, books or book chapters). In a second step, the remaining records were screened by reading their full content. We specifically followed the first two principles of the eligibility criteria regarding type of studies and topic. Records not dealing with the social impact (on governments, civil servants and citizens) of the use of blockchain in public services were excluded. For example, several studies analysed the application of blockchain from the point of view of business or the private sector and others only include computer modelling of the blockchain. Those articles, along with records whose central feature was cryptocurrencies, were excluded. Ultimately, our record selection led to the inclusion of 92 studies in our systematic review.

[1] We conducted the searches following the same criteria both in Web of Science and Scopus. When the options available from Web of Science and Scopus search engines were not exactly the same, we followed the closest available criteria.

[2] In Web of Science, this included both the keywords selected by authors and those (defined as KeyWords Plus) identified by its search engine.

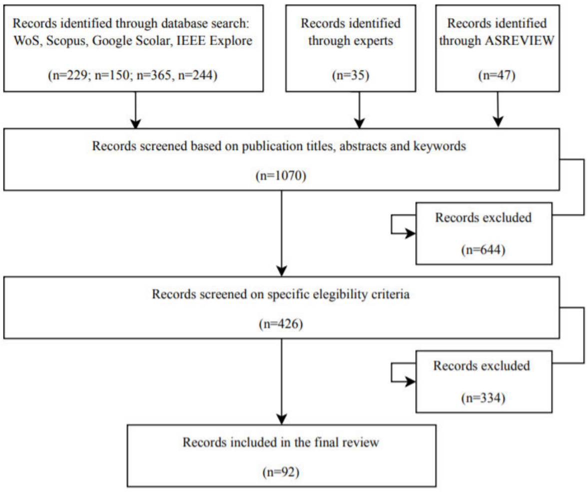

FIGURE 1. Flow diagram of the search strategy and record selection.

D. CODING

We used NVivo12 to facilitate the organization and extraction of information required for a systematic literature review [103]. We created a database of the records, coded them, and conducted the analyses. Nvivo is a software package built to analyse qualitative and non-structured data. It allows a more direct organization of text, video and audio using nodes, notes, cases, and conceptual maps. This process permits dividing the data into manageable segments while allowing rapid access to the relevant data when needed. The classification criteria can be introduced by researchers based on a priori field knowledge or with the help of available statistical language techniques, such as word counting, cluster analysis and other relational tools, including the Cohen's kappa coefficient (κ).

We used different tools to analyse the records of the systematic review. We used a word counting and a word cloud to quantify the most relevant concepts present in the literature. Additionally, we created different classifications in order to organize the data extraction process. Firstly, each record was catalogued regarding its general characteristics, including title, author, year, type of publication, method, journal and policy sector addressed. Next, we created a coding scheme, which we used to identify the benefits, costs and risks of blockchain for each of the three actors (citizens, government, civil servants).

The coding process was partly exploratory, since new categories for research methods and policy sectors were introduced whenever a record did not fit any of the available options. Regarding the research method, we differentiated five categories explained in the next section. Additionally, we identified 16 potential policy sectors for blockchain applications. The policy sectors are not mutually exclusive, which means that one record can examine one or several applications at the same time. Similarly, a study often discusses more than one benefit, cost and risk. Once all the information was classified, we used this to answer the research questions.

IV. GENERAL RESULTS

A categorization of each record included in the systematic review, by authors, year, method, policy sector and objectives, is included in Appendix S.2. The distribution of records by year of publication (Fig. 2) shows the use of blockchain in public services is an emerging topic. The number of publications on this topic has increased sharply since 2016 (when the first two records on this topic were published), to 45 in 2019. The records are published mainly as journal articles (86) and, to a lesser extent, as book chapters (6).

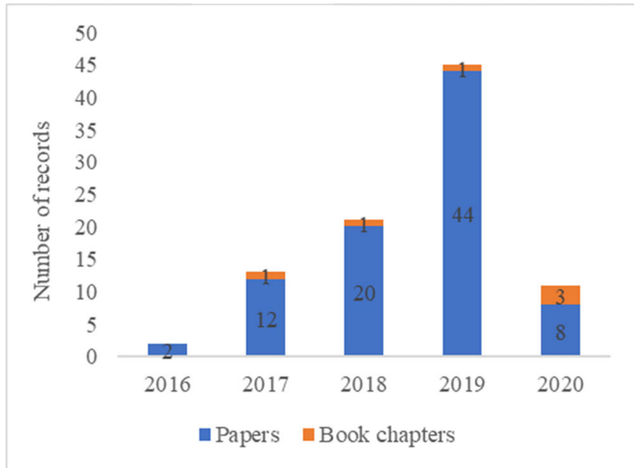

FIGURE 2. Distribution of records by year of publication.

As shown in Table 1, most records are found in publications in the field of Social Sciences (74 records, 80% of total). Nearly two thirds of records are in publications in the field of Science & Technology (58 records, 63% of total). Some 40 records (43%) are in publications simultaneously included both in Social Sciences and in Science & Technology. The journals which contain the largest number of articles are Information Polity (6), International Journal of Recent Technology and Engineering (4), International Journal of Information Management (4), IEEE Access (3) and Sustainability (3). Computer Law and Security Review, and International Journal of Production Research include two articles each, respectively. The other journals contain just one article each. The articles are also very broadly distributed by area, which shows blockchain is being studied by scholars across a largely multidisciplinary spectrum.

Records show a quite broad distribution across countries (Fig. 3). Records include authors from research institutions in 32 different countries. Research on this topic is led by the United States (23 records), followed by Australia, India and the United Kingdom, followed by Netherlands, Canada and China.

Records are predominantly theoretical (79) and only a few records are empirical (8). Among the theoretical articles we identify three different methods: Abstract Analyses, defined as those dealing with the topic of our review, but without a concrete or in-depth analysis; Theoretical Research

TABLE 1. Distribution of records by field and journal of publication.

Field of records	Number [a]
Social Sciences	74 (80%)
Science and Technology	58 (63%)
Journals with the largest number of articles	
Information Polity	6 (6%)
International Journal of Recent Technology and Engineering	4 (4%)
International Journal of Information Management	4 (4%)
Sustainability	3 (3%)
IEEE Access	3 (3%)
Computer Law and Security Review	2 (3%)
International Journal of Production Research	2 (2%)
Journal of Entrepreneurship and Public Policy	2 (2%)
Technology Innovation Management Review	2 (2%)

[a] A number of records are simultaneously included Social Sciences and Science and Technology areas. As a result, the sum of records in Social Sciences areas and records in Science and Technology areas is higher than the total number of records.

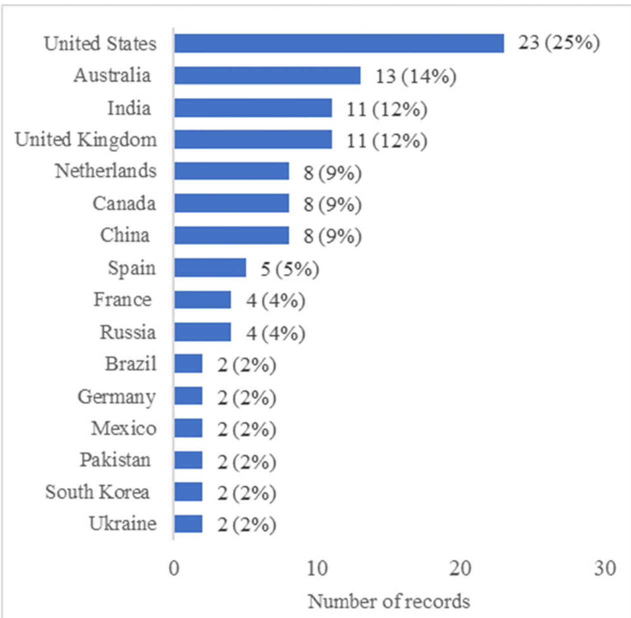

FIGURE 3. Distribution of records by country of publication.

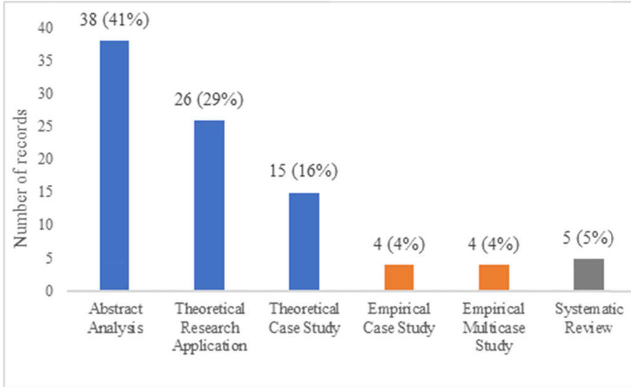

FIGURE 4. Distribution of records by method of analysis. Blue colour references theoretical methods while orange references an empirical method.

Applications, defined as analyses of a concrete application of blockchain in a public service without a specific location; and Case Studies, defined as concrete and in-depth analysis of a case or multiple cases in specific locations, not already implemented. Empirical articles examine cases that have actually been implemented. Among the empirical articles, we identify single Case Studies and Multi-case Studies. Fig. 4 summarizes distribution of records by method of analysis. Records are predominantly Abstract Analyses (41%) and Theoretical Research Applications (29%). A significant number of records are Theoretical Case Studies (16% of total). Only a few records are empirical (8%), where one half are single Case Studies and the other half are Multi-Case Studies. Five additional records are Systematic Reviews of related topics. These figures imply that albeit ex-ante analyses on the use of blockchain in public services are attracting increasing attention, quantitative analyses including empirical evidence on this issue are still scarce.

Finally, Fig. 5 illustrates the word cloud of the systematic review, obtained using NVivo. This is based on the whole set of 92 records, after setting a limit of 500 words and a minimum of five letters per word. The words that are most commonly cited are shown in a relatively larger size. The most commonly cited words are placed more centrally; less commonly cited words are further from the centre. Unsurprisingly, "blockchain" is the most highly

FIGURE 5. Word cloud based on the contents of the records included in the systematic review.

TABLE 2. Distribution of records by public services potentially affected by blockchain.

Public service	List of papers	Number
Records Management	[27-35]	9 (10%)
Healthcare	[35], [36-43]	9 (10%)
International Trade & Customs	[34], [43], [44-47]	6 (6%)
Voting	[35], [48-51]	5 (5%)
Environmental Protection	[52-55]	4 (4%)
Public Procurement	[35], [56-58]	4 (4%)
Food safety	[35], [59-61]	4 (4%)
Digital identities	[62-63], [78]	3 (3%)
Energy	[34-35], [64]	3 (3%)
Social Protection	[34-35], [65]	3 (3%)
Community Engagement	[66-67]	2 (2%)
Education	[34], [68]	2 (2%)
Public Accounting	[43], [69]	2 (2%)
Tax system	[70-71]	2 (2%)
Public Safety	[72-73]	2 (2%)
Recreational	[74]	1 (1%)

cited word by far: it appears 11,109 times throughout the 92 records. The second most common word is "technology", with 4,067 appearances. The third word is "information", which appears 2,724 times. "System" (2,416 times) and "public" (2,402 times) are the other two words included in the top five. Among the ten most cited words, we also find the words "smart" and "government". As regards the three sectors for which we analyse the implications of the use of blockchain (governments, civil servants and citizens), government(s) is the most mentioned (2,102 times), citizen(s) appears 609 times, and terms related to civil servant(s)[3] appear 98 times.

V. RESEARCH QUESTION #1: WHAT ARE THE MAIN PUBLIC SERVICES POTENTIALLY AFFECTED BY BLOCKCHAIN TECHNOLOGY?

We first describe the public services apt for transformation or disruption using blockchain for which the literature discusses relevant benefits, costs and risks. Records show a broad distribution across public services (Table 2). The sectors with the highest number of records are public records management (9) and healthcare (9), two public services where applications of blockchain technology appear promising. These are followed by a broad set of other sectors in which blockchain is seen to have significant applications, namely, international trade and customs (6), voting (5), environmental protection (4), public procurement (4), food safety (4), digital identities (3), energy (3) and social protection (3).

In the field of public records management, blockchain may facilitate making these records more accessible, thus reducing or eliminating delays in previously time demanding activities [74]. Blockchain could also reduce the costs of registering information and ensure records are updated in near real time for everyone in the blockchain. Several administrations around the world, such as the governments of Dubai and Georgia, are already transforming their public records systems using blockchain [77]. Since data are maintained by every node in the network, any failure by the central authority does not compromise the data, reducing the dependence on information silos [27], [29]. However, even though the benefits are clear, regulatory uncertainty regarding blockchain is still a major risk. Regulatory authorities should enact the necessary conditions required for blockchain agreements to be sufficient for the formation of a legal contract [81]. It is also necessary to establish ways to solve potential discrepancies between blockchain information and the version of property titles previously found in a physical parallel system, such as the original property registry.

Healthcare is another public service where blockchain could bring great disruption. Thanks to improvements in traceability brought by blockchain, every health item could be marked by a unique code which would be used to check its authenticity and composition [40]. Traceability refers to the ability to identify and monitor the information and events associated with a given good or service [46]. Thus, governments would be able to reduce prescription fraud and better scrutinise the production of health products [34], [39]. Regarding accountability, blockchain could also help with the storing of employee data for absence of leave, performance evaluation, and security measures for physicians—information that could be used to analyse the system and improve efficiency [27]. Blockchain could be a solution to promote citizens' exercise of greater personal control over their health data, while ensuring anonymity. A blockchain solution could also improve patient-physician communication, while further engaging the patients in their own care. However, this would require technical training, particularly in the case of elderly patients [40].

Governments could also benefit from the use of blockchain in the tax system and the cooperation between tax authorities and custom agencies [72]. Due to blockchain's properties of traceability and transparency, tax authorities could detect fraud and errors faster and more effectively [46], [71]. In the context of customs, blockchain could be used to improve inter-agency coordination between customs agencies. Moreover, customs could use the information contained in the network to manage cargos more efficiently, expeditiously clearing the ones already pre-screened and focusing examination on the ones specifically required. Regarding challenges, international standardization of blockchain legal requirements is essential for customs activities. Furthermore, it will be important to legally clarify which jurisdiction applies to international blockchains, and thus, which laws they should comply with [44].

Regarding voting and citizen participation, blockchain can enhance security, and facilitate transparency, while

[3]These include "civil servant(s)", public official(s), "government(s) official(s)","functionary/functionaries","bureaucracy(ies)/bureaucrats" and "public employee(s)".

maintaining the privacy and anonymity of citizens [48]. This technology could not only record the recount in a safe and rigorous way, but also to do it faster and more efficiently than conventional mechanisms. In the blockchain, votes are recorded accurately and permanently in a way that no one can modify or manipulate. Citizens could even check that their votes are actually being counted [65]. However, even with advanced encryption mechanisms, complete anonymity is impossible to achieve, since a node matching encrypted ballots with actual voters is still necessary [51]. In addition, there are scalability challenges regarding large-scale voting processes [48].

Blockchain could also represent a radical conversion of the way environmental protection policy is made. The amount of data related to production recorded in blockchain coordinated with IoT would increase the capabilities in analysis and interpretation of environmental issues [55]. Governments would be able to trace and track major emission sources of carbon dioxide and methane quite rapidly, enabling more proactive measures being implemented to fight climate change. Apart from regulating pollution, blockchain could also be useful for monitoring and managing the exploitation of natural resources in order to ensure sustainability [47].

Making public procurement data accessible in a blockchain could improve the transparency and accountability of governments from the citizen perspective. This technology could help to address corruption and other concerns [101]. For example, in the case of public procurement by health systems, a traceable system such as blockchain would allow local hospitals to purchase health products in a decentralized way, while at the same time centralizing information regarding quantities and prices, and making them available to all parties [65]. Furthermore, governmental entities can present their expenses on a public ledger, available for all citizens. This would not necessarily compromise privacy of agents, since a well-designed system would ensure anonymity [74].

Blockchain could also provide a significant improvement to governmental regulation practices and safety standards. A real-time tracking system, such as blockchain, would allow regulators to view all transactions and product history almost in real time [54]. For instance, it would allow the identification of each food product and assign it with tamper-proof data such as provenance, organic attributes, and labour conditions. This would allow regulators to do their job in a more efficient and effective manner, assuring the reliability of records as well as streamlining access and processing processes [44]. However, it is still unknown whether blockchain can efficiently manage the complexity of the information throughout large-scale supply chains [61].

Digital identity through blockchain is another key governmental activity that could be transformed into a more efficient and accessible public service. Blockchain may save governments vast sums of money on overhead costs related to physical office space, verification, and call centres [63]. Estonian e-Residency is a good example of where blockchain has changed the way citizens interact with government and other stakeholders, and how the administration has found a way to promote public and private Estonian services with very limited costs [78]. In terms of social protection, blockchain could be used to disintermediate governmental transfers to citizens. This secure, direct and transparent way of giving transfers could transform the way social policy is done [77].

Finally, blockchain could also bring about sustainable and eco-efficiency improvements in the energy system, by providing greater information about the energy process. For example, blockchain could record the provenance and type of energy, and build an automated process including criteria based on this information. This would ensure this system would not only improve the security of the grid, but also result in benefits in terms of eco-efficiency, transparency and potential sustainability.

VI. RESEARCH QUESTION #2: WHAT ARE THE MAIN POTENTIAL BENEFITS, COSTS AND RISKS OF BLOCKCHAIN IN PUBLIC SERVICES FOR GOVERNMENT, CIVIL SERVANTS AND CITIZENS?

Our approach studies the implementation of blockchain in public services from the different perspectives of the three main actors involved in the innovation process: Governments, civil servants and citizens, as shown in Fig. 6. For each actor, we identify the main benefits of blockchain for public services and then we discuss its negative consequences. Negative consequences can be classified into costs, the most probable ones, and risks, potential concerns, still to be confirmed. The order of presentation of benefits and costs/risks is based on the number of appearances throughout the articles of the systematic review.

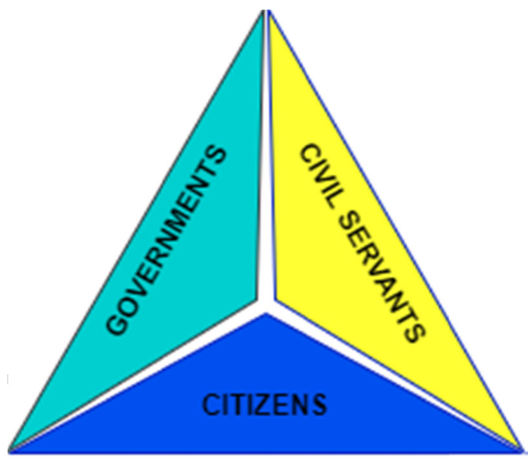

FIGURE 6. Three actors involved in the innovation process of public services.

A. GOVERNMENTS

Table 3 identifies the most important benefits, costs and risks of the use of blockchain for governments. According to the literature, the most significant benefits are related to two major issues: economic efficiency and traceability.

TABLE 3. Main Benefits, Costs and risks for Governments discussed in the literature.

Governments	Number of records
Benefits	
Efficiency	37 (40%)
Traceability	25 (27%)
Decentralization	20 (22%)
Disintermediation	7 (8%)
Institutional innovation	4 (4%)
Costs and risks	
Regulatory uncertainty	29 (31%)
Scalability	18 (19%)
High energy consumption	10 (11%)
Lack of early frameworks	8 (9%)
High capital investment	7 (8%)
Not a substitute for institutional trust	5 (5%)

Meanwhile, the most significant risk of blockchain for governments is regulatory uncertainty.

1) BENEFITS

The introduction of blockchain into public services has benefits for governments as regards its heralding of new ways of storing and sharing information that render processes more efficient, in the sense that results can be produced whilst using the smallest amount of resources such as time, material, capital or labour. Instead of lengthy, heavily bureaucratic procedures, blockchain proposes an automated means of storing data in a tamper-evident, secure, digital format. Blockchain can radically reduce the amount of human effort required for the operation of processes in many public services, leading to reduced costs [52]. Additionally, this implies a reduction of every-day human errors [45]. In sum, all public services that include managing large sets of records and involve sharing information (both internally and externally) with citizens, business and other sectors, could be potentially transformed by blockchain and increase their efficiency [46].

The second major benefit of blockchain, according to the number of references in the literature, is traceability. The characteristics and attributes linked to a product could range from the location, application, characteristics associated with its production, such as inputs, origin, labour and production standards and environmental issues. Traceability could bring other benefits to government—including authenticity, property rights, origin, product and service safety, and accountability—across different sectors. Each record of product data could also contain details about the labour conditions under which production was carried out, among other characteristics. This means traceability could also help to promote better assurance of human rights and fair work practices [79].

Other potential benefits for government from blockchain include its decentralized structure, which helps guarantee greater data security, since it reduces their dependency on information silos [28]. In this regard, once data is authenticated by the members of the blockchain, the information cannot be manipulated by a node without being detected by the rest of the nodes, which limits the risk and damage of single points of failure. Furthermore, blockchain has the potential to reduce the time and cost of transactions avoiding third party intermediation. Blockchain can also improve regulation mechanisms and public safety standards through the collection of data regarding the production and distribution of products. Similarly, when data are transparent, this can potentially lead to an improvement in accountability of both government and non-government organizations.

2) COSTS AND RISKS

According to the literature, the most significant costs and risks of blockchain for governments are related to regulatory uncertainty. Interoperability is one of these risks. Interoperability refers to the ability to easily share information, operate, and transact across various systems [46]. This is a fundamental problem to overcome, since the most probable scenario is that, instead of one single ledger (such as the internet), there will probably be multiple different public and private platforms which will require some kind of interoperability [76]. Several potential conflicts arise between blockchain and current law in many countries [80]. It is still unclear which type of legal recognition would be conferred upon the data inside the blockchain, and whether it will require extra conditions (and which ones) in order to be recognized as legal [81]. Another potential challenge arises from the fact that, as each node of a blockchain ledger is potentially located in a different part of the world, no consistent jurisdiction can be derived based on location [82]. More importantly, the disruptive properties of blockchain data might be legally problematic with respect to certain laws. For example, the fact that no one can easily remove or modify information off the blockchain might conflict with several European Union laws, such as the 1995 Directive or the GDPR [83].

A second, major, risk that arises from the application of blockchain is the scalability constraint, which is intimately related to the efficacy and efficiency of blockchain. The scalability challenge refers to the scale and speed at which transactions can occur on a blockchain network [38]. This transaction velocity determines the time it takes to put a transaction on a block or reach a consensus between nodes. The more nodes needed to verify the blocks, the slower the validating process is. Furthermore, when more data is included and block size is increased, it will become more difficult to generate and propagate blocks [84]. Thus, a trade-off is established between scalability and security. Blockchain technology is an immature technology in terms of scalability and still struggles to handle large number of transactions [79].

Blockchain also poses socio-economic costs for governments. Some consensus mechanisms, such as "proof-of-work", require every node to consume expensive energy resources in the mining process, causing increasingly high-energy costs. In order to reduce these costs, other consensus mechanisms have been proposed, such as ''proof-of-stake'', where validators prove their ''stake'' in the system through economic contributions that create disincentives for them to misbehave [90]. Several other mechanisms have been presented, but many of them still lack sufficient maturity for implementation on a mass scale [84]. Today, switching recording systems to a blockchain and scaling them to the level required to serve large populations could become expensive and damaging to the environment [75]. Another socio-economic cost involves the necessity of high capital investment. Previous studies focused on local applications of blockchain conclude that the current technological cost of switching to a blockchain might not outweigh the added security it provides [75]. In fact, the total initial capital investment is hard to estimate [84].

Finally, the introduction of blockchain as a trust mechanism also represents a risk. Although blockchain may offer many benefits for government, it cannot be considered an entirely trust-free system. In other words, blockchain is not a substitute for institutional trust and institutional infrastructure [71]. In fact, countries with higher degrees of good quality public and civil services adopt blockchain earlier and more successfully [78].

B. CIVIL SERVANTS

Civil servants have received, to date, much less attention than governments and citizens in the literature regarding the implications of blockchain in public services [85]. In our systematic review, we find only eight records (10% of total) that mention benefits of blockchain from the point of view of civil servants. Most of these records focus on transformations of the tasks and increased coordination. Additionally, we find eight records (10% of total) that describe costs or risks of the use of blockchain in public services from their point of view. Table 4 shows the distribution of records according to the specific implications. These records focus mainly on the lack of necessary skills that staff have as the main potential cost/risk of blockchain.

TABLE 4. Main Benefits, Costs and risks for civil servants discussed in the literature.

Civil servants	Number of records
Benefits	
Reduction of paperwork	5 (5%)
Reduction of every-day human errors	3 (3%)
Coordination improvements	3 (3%)
Costs and risks	
Lack of knowledge and skills	6 (6%)
Cultural change	2 (2%)
Reduction of jobs	2 (2%)

1) BENEFITS

One of the main benefits of blockchain for civil servants is associated with the transformation and automatization of the tasks carried out. Several documents focus on the effect that the use of blockchain in public services may have on the time-saving effect of the reduction of paperwork and bureaucratic interventions for administrative processes [27], [46]. Tasks conducted by civil servants may also benefit from the reduction of every-day human errors resulting from the automated means of storing data provided by blockchain [45]. Once blockchain is introduced, the tasks of civil servants in certain public services would change, and focus on developing, maintaining and governing the blockchain application. However, whilst the literature clearly states the benefits in terms of time and economic efficiency this may bring to governments, [85] highlight there are no in-depth analyses on how these changes may affect administrative processes and organizations. Neither do analyses report on how the nature of civil servants' tasks may change as a consequence of the introduction of blockchain in public services.

Another significant benefit for civil servants is the increasing possibilities for coordination. On the one hand, blockchain could be used to enhance inter-agency coordination systems through a shared ledger of administrative documents. On the other hand, the use of blockchain may enhance communication and coordination between civil servants and other actors involved in public service co-production and provision. For instance, in the field of healthcare, blockchain may enhance direct communication between physicians and pharmaceutical staff/professionals [34], as well as between physicians and their patients [40].

2) COSTS AND RISKS

A lack of necessary skills of civil servants is identified as the major cost for civil servants identified the literature. Clearly, all stakeholders will require training on blockchain technology for its successful application [30]. However, blockchain is a complex technology, and blockchain literacy constitutes a challenge not only for citizens-as-users, but also for civil servants as managers and providers of public services. Given that blockchain is a new technology, the number of experts, programmers and developers familiar with it and its possibilities for public services is limited [32]. Most civil servants do not have this sort of knowledge and experience, and public entities would need to train and hire technical experts and skilled personal in order to develop the application of blockchain technology [71]. Moreover, the requisites for implementing successful training on blockchain technology would not be easy to accomplish, and would be limited to a few organizations, mainly at the national level.

Another related drawback is the cost associated with change in the organizational structure. Bureaucratic administrative systems governing any large institution are characterized by pre-defined processes and organized hierarchies [45]. It has been argued that these hierarchical structures are organized in order to facilitate the centralization of power in the hands of a few top civil servants [86]. The civil servants that benefit from the status quo will probably oppose internal resistance to the adoption of blockchain [50]. This cultural change constitutes another potential cost and risk of the use of blockchain in public services.

Finally, another significant potential cost of the implementation of blockchain for civil servants could be a reduction of jobs. The promise of blockchain to automatize many bureaucratic processes represents a threat to many civil servant jobs [87] and is likely to be highly uneven geographically and according to gender [6]. Jobs made redundant by the use of blockchain will be replaced by automated tasks and virtual labour. Low-skilled workers will be probably more intensively affected by this process. However, the transformation and consequences of blockchain for employment is an under-researched topic. Given the interest of this issue, this constitutes one of the major gaps on the literature on the use of blockchain in public services.

C. CITIZENS

The most relevant benefits, costs and risks for citizens identified in the literature are listed in Table 5. According to the literature, the most important benefits of the use of blockchain in public services for citizens are related to data security and transparency. The costs and risks for citizens associated with the use of blockchain in public services are diverse. The most important one, according to the literature, is related to potential security threats for blockchain data, discussed in 13 records (14% of total).

TABLE 5. Main Benefits, Costs and risks for CITIZENS discussed in the literature.

Citizens	Number of records
Benefits	
Security	40 (43%)
Transparency	36 (39%)
Self-sovereign of data	15 (16%)
Disintermediation	11 (12%)
Privacy	11 (12%)
Citizen participation	8 (9%)
Costs and risks	
Security threats	15 (16%)
Lack of flexibility of small contracts	11 (12%)
Not inherently trustworthy	7 (8%)
Risk of reidentification	7 (8%)
Minority rule	6 (6%)
Lack of knowledge and skills	6 (6%)
Lack of resources	4 (4%)

1) BENEFITS

The most important benefits of the use of blockchain in public services for citizens in the literature are related to security and transparency. The benefits for citizens related to security brought about by blockchain are derived primarily from the immutability of data. Immutability means that blockchains are based on an append-only data structure. Blockchain verifies every transaction through a consensus mechanism between nodes ensuring no single party has the unique power to alter it. As soon as a new block of data is verified and introduced in the chain, it is almost impossible to modify or remove this [68]. Additionally, the decentralised characteristic of blockchain is fundamental for guaranteeing the integrity of information. Since data is not stored centrally, blockchain is not vulnerable to single security breaches [33]. Furthermore, the process is developed transparently and accountable by every node [88]. Hence, technologically speaking, cybersecurity must arguably be a key advantage for citizens in countries that adopt blockchain technology.

As regards the benefits for citizens related to transparency, blockchain technology creates a new form of trust, allowing the public to easily monitor all actions taken inside the network [56]. Transparency of blockchain, in addition to blockchain's properties of security and traceability, enables the public to track every item included in the blockchain back to its original inclusion, and is an open for validation of authenticity [101]. Additionally, in a transaction between citizens, it is very easy to verify whether one participant in the network is in possession of an exact and unmodified copy of the historical data stream. The trust based on a secure and transparent distributed ledger eliminates the need to hire, pay and trust a third-party entity to supervise transactions, allowing a further disintermediation of processes [74].

Another benefit of blockchain is associated with the idea that individuals will be able to exert greater control over their personal data. Blockchain is designed to give the owner of data a unique ID to access it over the blockchain network and the ability to share specific pieces of data they wish to share [77]. Furthermore, all these personal records can be preserved in the same system so that every individual will have a comprehensive digital identity, including all their personal records, which contains reliable and secure personal information. When used in this way, blockchain could facilitate the authentication of personal identity as well as, when necessary, the provision of personal information, such as education certificates or health status.

Data inside the blockchain are encrypted in different manners, in order to assure the privacy of users. Some of the data of government departments and public services providers are closely related to citizens' personal information. The merging of data from multiple sources may be used to form a "full profile" of each citizen, which clearly affects privacy [28]. Using blockchain, different protocols can be used to encrypt the data and anonymise it, in order to avoid this risk [89]. As a result of trust in the technology, the nodes in the system can exchange data without knowing each other's identity and personal information, so the privacy of each participating node is protected [64].

2) COSTS AND RISKS

Though security is a major benefit blockchain may bring, it also poses the most important costs and risks, according to the literature. At least one cost and one risk are identified. Recently, consensus mechanisms are being adopted other than ''proof-of-work'', with the aim of reducing energy and computational resources the blockchain network needs.

However, this solution comes at a cost, since it undermines the security of the network, as these alternative consensus rules are less strict. In fact, several successful attacks have already occurred in blockchains [90]. Additionally, hackers could take advantage of breaking points caused by poor coding [40]. Moreover, a risk exists that the ''key'' of the blockchain system is stolen, or that malicious coordinated attacks are made to the network [57]. The possibility of stealing the key of the blockchain system exists, and may become grow in the future, depending on the development of computation.

Another cost of blockchain comes from the fact that, in an early stage of development, it lacks sufficient flexibility to adapt to distinct situations [80]. While immutability is a benefit for certain public services, it is also a cost for citizens. Blockchain data cannot be easily deleted or changed. However, a judicial authority could demand that certain information should be deleted from the server, due to right-to-be-forgotten laws [74]. Copyright materials may face similar problems when published in a blockchain without authorization. However, while a ''hard fork'' (a unilateral change of internal rules by the system managers) would be able to change the validity status of data blocks, it cannot actually remove them from the internet, and still would not satisfy certain laws such as GDPR [27]. Furthermore, the use of ''hard forks'' may end up challenging the credibility and trust on the blockchain, since it debunks the horizontality principle.

In addition, blockchain relies upon the data that has been validated by the nodes, and thus, it is not inherently trustworthy, since the technology does not guarantee information quality, but only the accuracy of the procedure. The quality and usefulness of the blockchain technology is ''as good as its users'' [39]. Therefore, substituting human (or multiple human) supervision by a blockchain in processes that demand high levels of accuracy represents an important cost.

Although encryption is useful to increase the privacy of blockchain users, the risk of reidentification is still present. Though each user in blockchain is linked to a public pseudonymous address, due to transparency of blockchain, the transactions are available to the public, and information is explicitly visible by all network participants [84]. An increasing amount of research suggests it is possible to de-anonymize individuals by using transactions details [58]. The more transparent the blockchain is, the bigger the risk of reidentification [46].

Blockchain is still a complex technology that requires specialized knowledge for creation and management. A minority of experts dictate the rules of the system and how it is governed: this constitutes an additional risk for citizens. Only a few individuals can modify the code, and the design of the system will likely represent their interests [6], [85]. Depending on the nature of the blockchain, sudden ''hard-forks'' can transform the way the network works, making it mandatory for the users to comply with the new rules. This position of power threatens the promises of decentralization and horizontal decision-making of blockchain. In the case of permission-based blockchains, private companies usually play a fundamental role in shaping how a blockchain infrastructure functions. Therefore, they could hold dominating powers, diminishing the capacity to integrate enough checks and balances into the blockchain network [48].

Moreover, the ''usability'' of blockchain technology is still a crucial barrier for mainstream adoption [46]. The term usability refers to the degree of ease with which products such as software and other technological applications can be used to achieve required goals effectively and efficiently. Lack of knowledge and technical skills impede several social groups of citizens to immediately benefit from the use of blockchain. Thus, it is imperative to improve intuitive blockchain interfaces and to assure some degree of blockchain literacy before it is introduced to the wider public. Finally, blockchain models and proposals require having access to internet connectivity and digital devices. which is not always the case of most citizens in certain contexts, especially in less developed countries [38], [58].

VII. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

Blockchain is considered one of the most important disruptive technologies as regards its potential to transform business and society in the near future, including the provision of public services. Even though blockchain is still a nascent technology, scholarship on the consequences of blockchain adoption is growing.

A. CONTRIBUTIONS OF THIS WORK

The major contribution of this work consists of providing the first systematic review of the literature on the use of blockchain in public service provision, analysing the specific benefits, costs and risks of the three key agents of the innovation process: governments, civil servants and citizens. The systematic review follows the PRISMA criteria, through clearly stated objectives and an eligibility criterion to identify studies. We provided a systematic presentation of our findings. We identified 92 published records from journals and books that cover blockchain applications on public services. Among them, we classify 79 as theoretical articles and eight of them as empirical, while another five were systematic reviews on related topics. The articles are broadly distributed by field and area of study, which shows that blockchain applications is being currently addressed from a multidisciplinary perspective.

We found blockchain applications are broadly distributed across a range of public services. We identified 16 different public services potentially affected by the introduction of blockchain. The public service that concentrates the greatest number of studies is public records management, which is addressed in 9 records. Blockchain is bringing to this public service efficiency improvements regarding time and costs and a more secure infrastructure, even though several uncertainties related to regulation arise in the process. The second most discussed public service is healthcare, where blockchain could improve the system through traceable tools, accountable transactions and more control over personal data. Other public services identified in this systematic review and discussed in more than two records are international trade and customs, voting processes, environmental protection systems, public procurement, food safety, digital identities, energy and social protection.

We propose an organizational approach to the benefits, costs and risks of blockchain in public services, by classifying the actors of society involved in the innovation process. We observe, first, that two actors concentrate the bulk of attention in the literature: governments and citizens. Civil servants receive less attention. Next, we analyse the implications of the use of blockchain in public services for each of these actors. For governments, we find that the most important benefits of blockchain are associated with efficiency and traceability, whilst the most significant costs and risks are related to regulatory uncertainty (interoperability and standardization, legal recognition of data, incompatibility with laws, jurisdiction requirements and accountability), and scalability. For civil servants, the literature discusses benefits associated with the transformation of tasks carried out and increased possibilities for coordination, while the most important costs and risks cited are linked to the lack of necessary skills, the change in organizational structure and jobs cuts. Finally, the literature on the impact for citizens focuses especially on benefits of blockchain related to security and transparency, whilst also a range of different costs and risks (in particular, those related to potential security threats) are discussed.

Several implications can be extracted as regards blockchain applications in public services, from the point of view of benefits, costs and risks for governments, civil servants and citizens. In the case of governments, blockchain has the potential to improve the economic efficiency of bureaucratic processes and data management. For example, blockchain-based land title registry in Georgia, where the registration of extract is now 400 times faster and the reduction of costs is over 90%, is an example of a successful case [92]. Estonia is another successful example of the use of blockchain as part of its e-government strategy on registries and administrative procedures, which have improved processes around tax, judicial, health and commercial code systems [93]. Moreover, services mainly focused on notarization that utilize blockchain as an append-only registry are close to market maturity. However, other disruptive services that make the most of the shared database and the traceability feature of blockchain still face many hurdles. Regulation is a major challenge, including setting recognizable standards, regarding the applicability of blockchain for these cases. A key implication, then, is that there is an urgent need to establish an initial set of methods, common practices, as well as technological and legal semantics at the highest administrative level, in order to ensure legal certainly for future blockchain applications. In addition, as identified in our article, government itself needs to enact a transformation of existing processes and structures in order be prepared for the disruptive potential of blockchain. This task will require dialogue and coordination from stakeholders in the network which will best be led by governments and, ideally, international institutions. The EU Blockchain Observatory & Forum is a promising example of this sort [94].

In the case of civil servants, reduction of red tape, paperwork, and every-day errors, are the main benefits blockchain applications will bring to public services. Additionally, improved coordination between agencies implies a reduction in the time employed by civil servants on tedious tasks through easier and faster access to information already uploaded to the administration network. Consequently, the quality of jobs could also increase. However, blockchain applications face several risks as regards its impact on civil servant jobs. Scholars have suggested disruptive technologies, including blockchain, artificial intelligence and machine learning, may pose a threat to unemployment without the support of appropriate public policy [95]. The need for reskilling to accommodate the new technology implies that substantial investments will be required. Potential rejection of new technology may need to be overcome with ensuring technology is human-centric as regards its design, including simple interface and easier ways of resolving and reporting potential errors [96].

From the point of view of citizens, the main benefits identified regarding the adoption of blockchain in public services are data security, transparency of public administrations and greater control of personal data. The use of blockchain for national land registries, healthcare systems and digital identities, are positive examples of how blockchain can eliminate excessive bureaucracy and physical displacement to the city hall in favour of remotely digital alternatives. Moreover, having a greater control over their personal data allows citizens to preserve their own privacy in a more effective manner and enhance their trust in the service provider. The COVID-19 pandemic has increased the attention paid to blockchain for supply chain management in times of uncertainty [97]. However, because blockchain-based services are mostly in a pilot phase, or operate on a small scale, these gains are only starting to be made visible. Despite recent progress, much more needs doing on the technical side regarding data security and flexibility of smart contracts. Finally, it is important to note that blockchain is just another piece of the digitalization strategy of public services. Thus, the added value of blockchain for citizens does not depend on blockchain alone, but from the successful articulation of the different technologies and functionalities in a whole system for public services of the future.

B. LIMITATIONS

The main limitations of this review are determined by the very infancy of the literature on blockchain in public services. One of the major shortcomings of the literature is a lack of empirical analyses on blockchain in public services [85]. As the application of this technology, particularly in public services, is still at a very early stage, most of the analyses are abstract or theoretical: most of them focus on discussing potential benefits, costs or risks of blockchain in public services without entering into specific cases already implemented, or focus in case studies without including sufficient empirical evidence. Clearly, until there are large scale implementations in government, there will be a lack of empirical research on real-world applications.

Regarding this article, even though the search and screening process has been carried out in great detail including three major datasets and recommendations of specific records from field experts, there is a possibility that some high-quality work has been left out. Additionally, the screening and reading processes inevitably carry with it a dose of subjectivity. Therefore, both potential selection and information extraction bias could be identified. Finally, this article focused on the use of blockchain application from the social and economic perspective, leaving aside the more technical and computational aspects.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

We have identified four specific issues which are neglected in the current literature and deserve further attention in the quest to develop a more coherent picture of blockchain for public services.

Recommendation 1 (From Theoretical to Empirical Analyses): As the number of projects and applications of blockchain increase, research on the use of blockchain in public services needs to move from descriptive/theoretical studies to empirical analyses of actual implementation and assessments based on real cases, in order to provide policymakers with ready-to-use material. Hence, it is important that researchers track developments and collect a greater amount of qualitative and quantitative data on blockchain applications to provide rigorous analysis of the benefits, risks and costs of blockchain in public services. In order to frame the initiative, two aspects should be carefully analysed. First, the internal validity of the case, consisting of an evaluation of whether the blockchain has provided a satisfactory and adequate solution to the initial problem and a comparison of this with different previously potential options, needs to be completed. Secondly, the external validity of the analysis needs to be verified, meaning whether the specific characteristics of the context makes this a comparable example for other technological, socio-economic, legal and cultural contexts. A rigorous evaluation of use cases based on these two aspects will lead to a better understanding of the potential of blockchain in public service provision.

Recommendation 2 (Diversity of Empirical Methods): We also encourage more cross-sectoral designs to expand our understanding of the differences in the use of blockchain between private and public sector organizations and between different public policy sectors. Further cross-national research can shed light on the antecedents and pre-conditions of public administrations for blockchain adoption. Finally, although there is no guarantee that the quality of external evaluation is better than internal reports [98], an overrepresentation of the latter can cause biased results. Thus, a greater number of external evaluations of the innovation process are needed.

Recommendation 3 (Address Major Technical Barriers): Much work remains for researchers to do in the technical field. Even though recent progress of the technical aspects of blockchain has been made, the development of blockchain technology is still at an early stage when comes to large-scale applications. Scalability is still one of the main constraints surrounding blockchain initiatives for public services. In the future, less computational demanding consensus algorithms are necessary, particularly when the blockchain aims to manage a large number of users and transactions. Energy consumption requirements also need to be reduced and transaction costs need to be low and predictable, otherwise public initiatives will be very hard to justify. In this regard, diverse technical and governance specificities need to be available, since different problems will be addressed by different sorts of blockchain. Moreover, technical experts and research institutions need to coordinate interoperable standards, which are essential to assure that all the technical advances take advantage of indirect effects and economies of scale.

Recommendation 4 (Differentiate Between Types of Blockchain): Future studies need to adopt a simple shared scheme and identify which is the preferable type of blockchain given the specificities of the specific public service and the problem addressed. Literature on blockchain for public services has paid very little attention to how the different characteristics of blockchain infrastructure might be implemented to achieve different policy objectives. This represents a major flaw in analysing blockchain for public services, since the specific characteristics of permissioning and infrastructure governance have important political and economic implications, such as transaction costs, performance, privacy, incentives and control of the network [5]. A public-permissioned network, where citizens and entities must identify themselves, and where there are no artificial barriers of entry for citizens, seems to be a promising proposal for a blockchain-based infrastructure for many public services in the European Digital Single Market [99], [100]. However, this might not be the case where established institutions are not sound, or where the legal requirements due to the characteristics of the information shared or the existing regulations are lax. Finally, in this respect, another useful avenue for research will be the analysis of the implications of potential DApps for public services developed in Ethereum and other decentralized platforms.

Recommendation 5 (Focus on Consequences for Civil Servants): While the existing literature on the use of blockchain in public services has focused on consequences for governments and citizens, research on the consequences for civil servants – the individuals responsible for public service provision – have been under-researched. New studies on the impact of a disruptive technology such as AI on the future on jobs are emerging [101]. In the case of blockchain, some of the key questions that still need to be adequately researched are the following: the consequences of blockchain on job displacement and job quality; the role of policy in shaping the consequences of new technology on jobs [95]; and the new skill sets that are required in order to manage the infrastructure, governance and organizational structures of transformed public services. To this end, a wide range of research methods will be useful, including case studies, comparative analysis, structured and semi-structured interviews and survey methods, and the use of quantitative data to measure macro-effects.

APPENDIX

Supplemental material S1: PRISMA Checklist. Supplemental material S2: Classification of records included in the systematic literature review.

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REFERENCES

[1] C. M. Christensen, H. Baumann, R. Ruggles, and T. M. Sadtler, "Disruptive innovation for social change," *Harvard Bus. Rev.*, vol. 84, no. 12, pp. 1–8. Dec. 2006.

[2] K. Lee, F. Malerba, and A. Primi, "The fourth industrial revolution, changing global value chains and industrial upgrading in emerging economies," *J. Econ. Policy Reform*, vol. 23, no. 4, pp. 359–370, May 2020, doi: 10.1080/17487870.2020.1735386.

[3] J. Berryhill, T. Bourgery, and A. Hanson, "Blockchains unchained: Blockchain technology and its use in the public sector," *OECD Work. Papers Public Governance*, no. 28, Jun. 2018, doi: 10.1787/3c32c429-en.

[4] D. Tapscott and A. Tapscott, *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business, and the World*. New York, NY, USA: Portfolio-Penguin, 2016.

[5] S. Ølnes, "Beyond bitcoin enabling smart government using blockchain technology," in *Electronic Government*, vol. 9820, H. J. Scholl, O. Glassey, M. Janssen, B. Klievink, I. Lindgren, P. Parycek, E. Tambouris, M. A. Wimmer, T. Janowski, and D. Sá Soares, Eds. Cham, Switzerland: Springer, 2016, pp. 253–264.

[6] M. Atzori, "Blockchain technology and decentralized governance: Is the state still necessary?" *J. Governance Regulation*, vol. 6, no. 1, pp. 45–62, 2017, doi: 10.22495/jgr_v6_i1_p5.

[7] *Which Governments are Using Blockchain Right Now?* Accessed: Sep. 27, 2020. [Online]. Available: https://consensys.net/blog/enterprise-blockchain/which-governments-are-using-blockchain-right-now/?utm_campaign=ConsenSys%20Newsletter&utm_source=hs_email&utm_medium=email&utm_content=80467613&_hsenc=p2ANqtz–zOUwxuYK6daqZLBVjcSvsDfB415GmyrmqQ1XAqQ0DBWsYHR6cYWw7Fnjsuktv-dBE40ojH5MBFbBgDSRn1mh1AV0So0Oxmwv6hGdQVMHowXCOCQY&_hsmi=80467613

[8] M. M. Queiroz, R. Telles, and S. H. Bonilla, "Blockchain and supply chain management integration: A systematic review of the literature," *Supply Chain Manage., Int. J.*, vol. 25, no. 2, pp. 241–254, Aug. 2019, doi: 10.1108/SCM-03-2018-0143.

[9] *Beyond Fintech: Leveraging Blockchain for More Sustainable and Inclusive Supply Chains*, EMcompass, Int. Finance Corp., World Bank Group, Washington, DC, USA, Tech. Rep. 45, Sep. 2017.

[10] *Komgo: Blockchain Case Study for Commodity Trade Finance*. Accessed: Sep. 27, 2020. [Online]. Available: https://consensys.net/blockchain-use-cases/finance/komgo/

[11] V. Paliwal, S. Chandra, and S. Sharma, "Blockchain technology for sustainable supply chain management: A systematic literature review and a classification framework," *Sustainability*, vol. 12, no. 18, p. 7638, 2020.

[12] A. R. Rocamora and A. Amellina, "Blockchain applications and the sustainable development goals. analysis of blockchain technology's potential in creating a sustainable future," *Inst. Global Environ. Strategies*, Aug. 2018.

[13] J. Clifton, D. Díaz-Fuentes, and M. Fernández-Gutiérrez, "Public infrastructure services in the European union: Challenges for territorial cohesion," *Regional Stud.*, vol. 50, no. 2, pp. 358–373, Feb. 2016, doi: 10.1080/00343404.2015.1044958.

[14] J. Clifton, M. E. Warner, R. Gradus, and G. Bel, "Re-municipalization of public services: Trend or hype?" *J. Econ. Policy Reform*, pp. 1–12, Nov. 2019, doi: 10.1080/17487870.2019.1691344.

[15] A. Liberati, D. G. Altman, J. Tetzlaff, C. Mulrow, P. C. Gøtzsche, J. P. A. Ioannidis, M. Clarke, P. J. Devereaux, J. Kleijnen, and D. Moher, "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration," *PLoS Med.*, vol. 6, no. 7, Jul. 2009, Art. no. e1000100, doi: 10.1371/journal.pmed.1000100.

[16] D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, and f. the PRISMA Group, "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement," *BMJ*, vol. 339, p. b2535, Jul. 2009, doi: 10.1136/bmj.b2535.

[17] M. Crosby, "Blockchain technology: Beyond bitcoin," *Appl. Innov. Rev.*, vol. 2, nos. 6–10, p. 71, 2016.

[18] T. I. Kiviat, "Beyond bitcoin: Issues in regulating blockchain tranactions," *DUKE LAW J.*, vol. 65, p. 40, 2015.

[19] G. O. Karame and E. Androulaki, *Bitcoin and Blockchain Security*. Norwood, MA, USA: Artech House, 2016.

[20] C. Shen and F. Pena-Mora, "Blockchain for cities—A systematic literature review," *IEEE Access*, vol. 6, pp. 76787–76819, 2018, doi: 10.1109/ACCESS.2018.2880744.

[21] H. J. Scholl and M. P. R. Bolívar, "Mapping potential impact areas of Blockchain use in the public sector," *Inf. Polity*, vol. 24, no. 4, pp. 359–378, Dec. 2019, doi: 10.3233/IP-190184.

[22] J. Abou Jaoude and R. George Saade, "Blockchain applications–usage in different domains," *IEEE Access*, vol. 7, pp. 45360–45381, 2019, doi: 10.1109/ACCESS.2019.2902501.

[23] J. Bernal Bernabe, J. L. Canovas, J. L. Hernandez-Ramos, R. Torres Moreno, and A. Skarmeta, "Privacy-preserving solutions for blockchain: Review and challenges," *IEEE Access*, vol. 7, pp. 164908–164940, 2019, doi: 10.1109/ACCESS.2019.2950872.

[24] O. Rikken, M. Janssen, and Z. Kwee, "Governance challenges of blockchain and decentralized autonomous organizations," *Inf. Polity*, vol. 24, no. 4, pp. 397–417, Dec. 2019, doi: 10.3233/IP-190154.

[25] J. Clifton and D. Díaz-Fuentes, "Evaluating eu policies on public services: A citizens' perspective," *Ann. Public Cooperat. Econ.*, vol. 81, pp. 281–311. Jun. 2010.

[26] R. van de Schoot, J. de Bruin, R. Schram, P. Zahedi, J. de Boer, F. Weijdema, B. Kramer, M. Huijts, M. Hoogerwerf, G. Ferdinands, A. Harkema, J. Willemsen, Y. Ma, Q. Fang, S. Hindriks, L. Tummers, and D. Oberski, "Open source software for efficient and transparent reviews," 2020, *arXiv:2006.12166*. [Online]. Available: http://arxiv.org/abs/2006.12166

[27] S. Bhatia and A. D. Wright de Hernandez, "Blockchain is already Here. What does that mean for records management and archives?" *J. Archival Org.*, vol. 16, no. 1, pp. 75–84, Jan. 2019, doi: 10.1080/15332748.2019.1655614.

[28] L. Fan, J. R. Gil-Garcia, and Y. Song, "Sharing big data using blockchain technologies in local governments: Some technical, organizational and policy considerations," *Inf. Polity*, vol. 24, no. 4, pp. 419–435, Dec. 2019, doi: 10.3233/IP-190156.

[29] J. Goonathilaake, N. Deshapriya, R. Jayakody, and M. Dharanidu, "Framework for data management in public service delivery applications in Sri Lanka using blockchain technology," *Eur. J. Comput. Sci. Inf. Technol.*, vol. 6, no. 3, pp. 34–56, Jun. 2018.

[30] Q. Shang and A. Price, "A blockchain-based land titling project in the republic of georgia: Rebuilding public trust and lessons for future pilot projects," *Innov., Technol., Governance, Globalization*, vol. 12, nos. 3–4, pp. 72–78, Jan. 2019, doi: 10.1162/inov_a_00276.

[31] M.-A. Sicilia and A. Visvizi, "Blockchain and OECD data repositories: Opportunities and policymaking implications," *Library Hi Tech*, vol. 37, no. 1, pp. 30–42, Mar. 2019, doi: 10.1108/LHT-12-2017-0276.

[32] V. Thakur, M. N. Doja, Y. K. Dwivedi, T. Ahmad, and G. Khadanga, "Land records on blockchain for implementation of land titling in india," *Int. J. Inf. Manage.*, vol. 52, Jun. 2020, Art. no. 101940, doi: 10.1016/j.ijinfomgt.2019.04.013.

[33] M. Warkentin and C. Orgeron, "Using the security triad to assess blockchain technology in public sector applications," *Int. J. Inf. Manage.*, vol. 52, Jun. 2020, Art. no. 102090, doi: 10.1016/j.ijinfomgt.2020.102090.

[34] S. Mariappan, "Blockchain technology: Disrupting the current business and governance model," *Int. J. Recent Technol. Eng.*, vol. 8, no. 3, pp. 6285–6292, Sep. 2019, doi: 10.35940/ijrte.C5905.098319.

[35] A. Ojo and S. Adebayo, "Blockchain as a next generation government information infrastructure: A review of initiatives in D5 countries," in *Government 3.0–Next Generation Government Technology Infrastructure and Services*, vol. 32, A. Ojo and J. Millard, Eds. Cham, Switzerland: Springer, 2017, pp. 283–298.

[36] K. Anitha Kumari, R. Padmashani, R. Varsha, and V. Upadhayay, "Securing Internet of medical things (IoMT) using private blockchain network," in *Principles of Internet of Things (IoT) Ecosystem: Insight Paradigm*, vol. 174, S.-L. Peng, S. Pal, and L. Huang, Eds. Cham, Switzerland: Springer, 2020, pp. 305–326.

[37] S. Bhattacharya, A. Singh, and M. Hossain, "Strengthening public health surveillance through blockchain technology," *AIMS Public Health*, vol. 6, no. 3, pp. 326–333, 2019, doi: 10.3934/publichealth.2019.3.326.

[38] D. Dhagarra, M. Goswami, P. R. S. Sarma, and A. Choudhury, "Big data and blockchain supported conceptual model for enhanced healthcare coverage: The indian context," *Bus. Process Manage. J.*, vol. 25 no. 7, pp. 1612–1632, Oct. 2019, doi: 10.1108/BPMJ-06-2018-0164.

[39] M. A. Engelhardt, "Hitching healthcare to the chain: An introduction to blockchain technology in the healthcare sector," *Technol. Innov. Manage. Rev.*, vol. 7, no. 10, pp. 22–34, Oct. 2017, doi: 10.22215/timreview/1111.

[40] I. Radanović and R. Likić, "Opportunities for use of blockchain technology in medicine," *Appl. Health Econ. Health Policy*, vol. 16, no. 5, pp. 583–590, Oct. 2018, doi: 10.1007/s40258-018-0412-8.

[41] B. Suma and G. Murali, "Blockchain usage in the electronic health record system using attribute-based signature," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2S11, pp. 993–997, Nov. 2019, doi: 10.35940/ijrte.B1166.0982S1119.

[42] B. Yong, J. Shen, X. Liu, F. Li, H. Chen, and Q. Zhou, "An intelligent blockchain-based system for safe vaccine supply and supervision," *Int. J. Inf. Manage.*, vol. 52, Jun. 2020, Art. no. 102024, doi: 10.1016/j.ijinfomgt.2019.10.009.

[43] E. A. Grigoreva, L. F. Garifova, and E. A. Polovkina, "The future of digital technology in Russia: Blockchain as one of the priority directions of development," *Int. J. Emerg. Technol.*, vol. 10, no. 2a, pp. 42–46, 2019.

[44] D. W. E. Allen, C. Berg, S. Davidson, M. Novak, and J. Potts, "International policy coordination for blockchain supply chains," *Asia Pacific Policy Stud.*, vol. 6, no. 3, pp. 367–380, Sep. 2019, doi: 10.1002/app5.281.

[45] D. Allessie, M. Janssen, J. Ubacht, S. Cunningham, and V. D. Harst, "The consequences of blockchain architectures for the governance of public services: A case study of the movement of excise goods under duty exemptions," *Inf. Polity*, vol. 24, no. 4, pp. 487–499, Nov. 2019, doi: 10.3233/IP-190151.

[46] Y. Chang, E. Iakovou, and W. Shi, "Blockchain in global supply chains and cross border trade: A critical synthesis of the state-of-the-art, challenges and opportunities," *Int. J. Prod. Res.*, vol. 58, no. 7, pp. 2082–2099, Aug. 2019, doi: 10.1080/00207543.2019.1651946.

[47] A. Vilkov and G. Tian, "Blockchain as a solution to the problem of illegal timber trade between russia and China: SWOT analysis," *Int. Forestry Rev.*, vol. 21, no. 3, pp. 385–400, Sep. 2019, doi: 10.1505/146554819827293231.

[48] D. Johnson, "Blockchain-based voting in the US and EU constitutional orders: A digital technology to secure democratic values?" *Eur. J. Risk Regulation*, vol. 10, no. 2, pp. 330–358, Jun. 2019, doi: 10.1017/err.2019.40.

[49] K. M. Khan, J. Arshad, and M. M. Khan, "Secure digital voting system based on blockchain technology," *Int. J. Electron. Government Res.*, vol. 14, no. 1, pp. 53–62, Jan. 2018, doi: 10.4018/IJEGR.2018010103.

[50] N. Kshetri and J. Voas, "Blockchain-enabled E-Voting," *IEEE Softw.*, vol. 35, no. 4, pp. 95–99, Jul. 2018, doi: 10.1109/MS.2018.2801546.

[51] S. Zenin, D. Kuteynikov, O. Izhaev, and I. Yapryntsev, "Applying technologies of distributed registries and blockchains in popular voting and lawmaking: Key methods and main problems," *Amazonia Investiga*, vol. 8, no. 20, pp. 330–339. May 2019.

[52] B. Fu, Z. Shu, and X. Liu, "Blockchain enhanced emission trading framework in fashion apparel manufacturing industry," *Sustainability*, vol. 10, no. 4, p. 1105, Apr. 2018, doi: 10.3390/su10041105.

[53] S. Hartmann and S. Thomas, "Applying blockchain to the Australian carbon market," *Economic Papers: J. Appl. Econ. Policy*, vol. 39, no. 2, pp. 133–151, 2020, doi: 10.1111/1759-3441.12266.

[54] P. Howson, "Building trust and equity in marine conservation and fisheries supply chain management with blockchain," *Mar. Policy*, vol. 115, May 2020, Art. no. 103873, doi: 10.1016/j.marpol.2020.103873.

[55] A. Zhang, R. Y. Zhong, M. Farooque, K. Kang, and V. G. Venkatesh, "Blockchain-based life cycle assessment: An implementation framework and system architecture," *Resour., Conservation Recycling*, vol. 152, Jan. 2020, Art. no. 104512, doi: 10.1016/j.resconrec.2019.104512.

[56] A. F. Rien and D. Susilowati, "Preventing corruption with blockchain technology (case study Of Indonesian public procurement)," *Int. J. Scentific Technol. Res.*, vol. 8, no. 9, pp. 2377–2383, Sep. 2019.

[57] R. Carvalho, "Blockchain and public procurement," *Eur. J. Comparative Law Governance*, vol. 6, no. 2, pp. 187–225, Jun. 2019, doi: 10.1163/22134514-00602002.

[58] J. Nicholson, "The library as a facilitator: How bitcoin and block chain technology can aid developing nations," *Serials Librarian*, vol. 73, nos. 3–4, pp. 357–364, Nov. 2017, doi: 10.1080/0361526X.2017.1374229.

[59] K. Gopi, D. Mazumder, J. Sammut, and N. Saintilan, "Determining the provenance and authenticity of seafood: A review of current methodologies," *Trends Food Sci. Technol.*, vol. 91, pp. 294–304, Sep. 2019, doi: 10.1016/j.tifs.2019.07.010.

[60] W. G. Johnson, "Blockchain meets genomics: Governance considerations for promoting food safety and public health," *J. Food Law Policy*, vol. 15, pp. 126–135, Dec. 2020.

[61] F. Sander, J. Semeijn, and D. Mahr, "The acceptance of blockchain technology in meat traceability and transparency," *Brit. Food J.*, vol. 120, no. 9, pp. 2066–2079, Sep. 2018, doi: 10.1108/BFJ-07-2017-0365.

[62] C. Sullivan and E. Burger, "E-residency and blockchain," *Comput. Law Secur. Rev.*, vol. 33, no. 4, pp. 470–481, Aug. 2017, doi: 10.1016/j.clsr.2017.03.016.

[63] G. Wolfond, "A blockchain ecosystem for digital identity: Improving service delivery in Canada's public and private sectors," *Technol. Innov. Manage. Rev.*, vol. 7, no. 10, pp. 35–40, Oct. 2017, doi: 10.22215/timreview/1112.

[64] J. Hou, H. Wang, and P. Liu, "Applying the blockchain technology to promote the development of distributed photovoltaic in China," *Int. J. Energy Res.*, vol. 42, no. 6, pp. 2050–2069, May 2018, doi: 10.1002/er.3984.

[65] M. Borole, A. Nilange, K. Velhal, and T. Joshi, "A survey on blockchain for enabling transparency in transactions of government direct benefit transfers (DBT)," *Int. J. Comput. Appl.*, vol. 181, no. 47, pp. 27–31, Apr. 2019, doi: 10.5120/ijca2019918637.

[66] O. Scekic, S. Nastic, and S. Dustdar, "Blockchain-supported smart city platform for social value co-creation and exchange," *IEEE Internet Comput.*, vol. 23, no. 1, pp. 19–28, Jan. 2019, doi: 10.1109/MIC.2018.2881518.

[67] H. Semenets, V. Yakobchuk, and M. Plotnikova, "Family homesteads settlements as the subjects of the public management in rural territories," *Manage. Theory Stud. Rural Bus. Infrastruct. Develop.*, vol. 40, no. 4, pp. 587–596, Dec. 2018, doi: 10.15544/mts.2018.51.

[68] A. Karale and H. Khanuja, "Implementation of blockchain technology in education system," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2, pp. 3823–3828, Jul. 2019, doi: 10.35940/ijrte.B2462.078219.

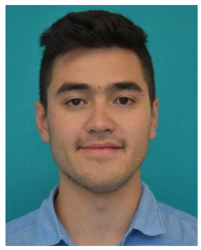
[69] H. Brown-Liburd, A. Cheong, M. A. Vasarhelyi, and X. Wang, "Measuring with exogenous data (MED), and government economic monitoring (GEM)," *J. Emerg. Technol. Accounting*, vol. 16, no. 1, pp. 1–19, Mar. 2019, doi: 10.2308/jeta-10682.

[70] D. Bentley, "Timeless principles of taxpayer protection: How they adapt to digital disruption," *eJournal oof Tax Res.*, vol. 16, no. 3, pp. 679–713.

[71] H. Hyvärinen, M. Risius, and G. Friis, "A blockchain-based approach towards overcoming financial fraud in public sector services," *Bus. Inf. Syst. Eng.*, vol. 59, no. 6, pp. 441–456, Dec. 2017, doi: 10.1007/s12599-017-0502-4.

[72] S. V. Engelenburg, M. Janssen, and B. Klievink, "Design of a software architecture supporting business-to-government information sharing to improve public safety and security: Combining business rules, events and blockchain technology," *J. Intell. Inf. Syst.*, vol. 52, no. 3, pp. 595–618, Jun. 2019, doi: 10.1007/s10844-017-0478-z.

[73] A. Gupta and D. V. Jose, ‘‘A method to secure FIR system using blockchain,’’ *Int. J. Recent Technol. Eng. (IJRTE)*, vol. 8, no. 1, p. 4, 2019.
[74] B. Abelseth, ‘‘Blockchain tracking and cannabis regulation: Developing a permissioned blockchain network to track Canada’s cannabis supply chain,’’ *Dalhousie J. Interdiscipl. Manage.*, vol. 14, pp. 1–11, Spring 2018.
[75] G. Gabison, ‘‘Policy considerations for the blockchain technology public and private applications,’’ *Sci. Technol. Law Rev.*, vol. 19, no. 3, pp. 327–350. 2016.
[76] D. W. E. Allen, C. Berg, B. Markey-Towler, M. Novak, and J. Potts, ‘‘Blockchain and the evolution of institutional technologies: Implications for innovation policy,’’ *Res. Policy*, vol. 49, no. 1, Feb. 2020, Art. no. 103865, doi: 10.1016/j.respol.2019.103865.
[77] D. Kundu, ‘‘Blockchain and trust in a smart city,’’ *Environ. Urbanization ASIA*, vol. 10, no. 1, pp. 31–43, Mar. 2019, doi: 10.1177/0975425319832392.
[78] R. Adeodato and S. Pournouri, ‘‘Secure implementation of E-governance: A case study about Estonia,’’ in *Cyber Defence in the Age of AI, Smart Societies and Augmented Humanity*, H. Jahankhani, S. Kendzierskyj, N. Chelvachandran, J. Ibarra, Eds. Cham, Switzerland: Springer, 2020, pp. 397–429.
[79] S. Saberi, M. Kouhizadeh, J. Sarkis, and L. Shen, ‘‘Blockchain technology and its relationships to sustainable supply chain management,’’ *Int. J. Prod. Res.*, vol. 57, no. 7, pp. 2117–2135, Apr. 2019, doi: 10.1080/00207543.2018.1533261.
[80] P. D. Filippi and S. Hassan, ‘‘Blockchain technology as a regulatory technology: From code is law to law is code,’’ *1st Monday*, vol. 21, no. 12, Dec. 2016, doi: 10.5210/fm.v21i12.7113.
[81] V. L. Lemieux, ‘‘Blockchain and public record keeping: Of temples, prisons, and the (Re)Configuration of power,’’ *Frontiers Blockchain*, vol. 2, p. 5, Jul. 2019, doi: 10.3389/fbloc.2019.00005.
[82] S. Davidson, P. De Filippi, and J. Potts, ‘‘Blockchains and the economic institutions of capitalism,’’ *J. Institutional Econ.*, vol. 14, no. 4, pp. 639–658, Aug. 2018, doi: 10.1017/S1744137417000200.
[83] M. Warkentin and C. Orgeron, ‘‘Using the security triad to assess blockchain technology in public sector applications,’’ *Int. J. Inf. Manage.*, vol. 52, Jun. 2020, Art. no. 102090, doi: 10.1016/j.ijinfomgt.2020.102090.
[84] J. Xie, H. Tang, T. Huang, F. R. Yu, R. Xie, J. Liu, and Y. Liu, ‘‘A survey of blockchain technology applied to smart cities: Research issues and challenges,’’ *IEEE Commun. Surveys Tuts.*, vol. 21, no. 3, pp. 2794–2830, 3rd Quart., 2019, doi: 10.1109/COMST.2019.2899617.
[85] S. Ølnes, J. Ubacht, and M. Janssen, ‘‘Blockchain in government: Benefits and implications of distributed ledger technology for information sharing,’’ *Government Inf. Quart.*, vol. 34, no. 3, pp. 355–364, Sep. 2017, doi: 10.1016/j.giq.2017.09.007.
[86] N. E. Long, ‘‘Power and administration,’’ *Public Admin. Rev.*, vol. 9, no. 4, p. 257, 1949, doi: 10.2307/972337.
[87] S. Manski, ‘‘Building the blockchain world: Technological commonwealth or just more of the same?’’ *Strategic Change*, vol. 26, no. 5, pp. 511–522, Sep. 2017, doi: 10.1002/jsc.2151.
[88] S. Myeong and Y. Jung, ‘‘Administrative reforms in the fourth industrial revolution: The case of blockchain use,’’ *Sustainability*, vol. 11, no. 14, p. 3971, Jul. 2019, doi: 10.3390/su11143971.
[89] J. Potts, E. Rennie, and J. Goldenfein, ‘‘Blockchains and the Crypto City,’’ *it-Inf. Technol.*, vol. 59, no. 6, Dec. 2017, doi: 10.1515/itit-2017-0006.
[90] S. Meiklejohn, ‘‘Top ten obstacles along distributed ledgers path to adoption,’’ *IEEE Secur. Privacy*, vol. 16, no. 4, pp. 13–19, Jul. 2018, doi: 10.1109/MSP.2018.3111235.
[91] C. G. Reddick, G. P. Cid, and S. Ganapati, ‘‘Determinants of blockchain adoption in the public sector: An empirical examination,’’ *Inf. Polity*, vol. 24, no. 4, pp. 379–396, Dec. 2019, doi: 10.3233/IP-190150.
[92] G. Eder, ‘‘Digital transformation: Blockchain and land titles,’’ in *Proc. OECD Global Anti-Corruption Integrity Forum*, Mar. 2019, pp. 20–21.
[93] *Estonia: E-Governance*. Accessed: Oct. 21, 2020. [Online]. Available: https://e-estonia.com/solutions/e-governance/
[94] *EU Blockchain Forum*. Accessed: Oct. 21, 2020. [Online]. Available: https://www.eublockchainforum.eu/
[95] D. Acemoglu and P. Restrepo, ‘‘The wrong kind of AI? Artificial intelligence and the future of labour demand,’’ *Cambridge J. Regions, Economy Soc.*, vol. 13, no. 1, pp. 25–35, May 2020, doi: 10.1093/cjres/rsz022.
[96] J. Clifton, A. Glasmeier, and M. Gray, ‘‘When machines think for us: The consequences for work and place,’’ *Cambridge J. Regions, Economy Soc.*, vol. 13, no. 1, pp. 3–23, May 2020, doi: 10.1093/cjres/rsaa004.
[97] P. Shukla, A. Rajput, and S. Chakravarthy, ‘‘How the massive plan to deliver the COVID-19 vaccine could make history-and leverage blockchain like never before,’’ World Econ. Forum COVID Action Platform, World Econ. Forum, Cologny, Switzerland, Tech. Rep., Jul. 2020.
[98] J. M. Conway and C. E. Lance, ‘‘What reviewers should expect from authors regarding common method bias in organizational research,’’ *J. Bus. Psychol.*, vol. 25, no. 3, pp. 325–334, Sep. 2010, doi: 10.1007/s10869-010-9181-6.
[99] J. Ruiz, ‘‘Public-permissioned blockchains as common-pool resources,’’ Alastria Blockchain Ecosyst., Spain, Tech. Rep., 2020.
[100] D. Geneiatakis, Y. Soupionis, G. Steri, I. Kounelis, R. Neisse, and I. Nai-Fovino, ‘‘Blockchain performance analysis for supporting cross-border E-government services,’’ *IEEE Trans. Eng. Manag.*, vol. 67, no. 4, pp. 1310–1322, Nov. 2020, doi: 10.1109/TEM.2020.2979325.
[101] M. H. Jarrahi, ‘‘Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making,’’ *Bus. Horizons*, vol. 61, no. 4, pp. 577–586, Jul. 2018, doi: 10.1016/j.bushor.2018.03.007.
[102] F. Bolici, A. Castelli, A, Hinna, ‘‘How blockchain reinforces transparency and accountability in PA’s new governance models,’’ in *The Social Issue in Contemporary Society: Relations Between Companies, Public Administrations and People*. Mumbai: IAP, 2019.
[103] QSR International Pty Ltd. (2020). *NVivo*. Accessed: Mar. 2020. [Online]. Available: https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home



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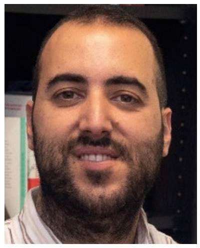

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