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How emerging technologies can solve critical issues in organizational operations: An analysis of blockchain-driven projects in the public sector

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ABSTRACT

Blockchain technology emerged as a concrete and disruptive application in all sectors. Even if the public sector witnessed this technology's first applications and implementations, it took a while to spread even in that environment. Previous studies have shown that blockchain technologies are a powerful, essential, and effective lever for transforming government processes and procedures and improving the management of public benefits and policies. Following an analysis of a sample of 167 blockchain-oriented projects in the public sector, we explore in this article the extent of the effects of blockchain on fundamental public governance functions, and we further explore the information technology and strategic management literature in this regard. As a result, our study shows concrete evidence of how blockchain improves several government core functions: (1) public service governance, administrative efficiency, and open government capabilities; (2) process innovation in public services; and operational and administrative performance improvement. Via a fsQCA analysis, we explored how indicators characterizing blockchain-based transformation projects in the public sector led to radical transformations in public services. Our findings move forward the blockchain perspective on the public sector by enriching the literature, bringing insights to policymakers, and opening new research directions to scholars and practitioners.

1. Introduction

With the advent of the fourth industrial revolution (Industry 4.0), companies are adopting these technologies to improve their business and be more competitive (Queiroz et al., 2022). Distributed ledger technologies (DLTs), including Blockchain, are among this fourth industrial revolution's most disruptive and transformative technologies (Scholl & Bolívar, 2019). They are bringing about significant changes in the behavior of individuals, organizations, and governments, and their effects cannot be underestimated (Chen, 2018; Queiroz et al., 2022; Scholl & Bolívar, 2019). By 2027, 10% of global GDP will be stored on the blockchain (Mckinsey, Brant, Giulio, Patricia, & Askhat, 2018). With an estimated market size of $67.4 billion by 2026, the global blockchain industry is expected to grow at a compound annual growth rate of 85.9% between 2022 and 2030 (Ruby, 2023). Blockchain brings valuable opportunities to businesses: transparency, privacy, fault tolerance, security, risk control, democratization, tokenization, immutability, durability, and reliability (Angelis & Ribeiro da Silva, 2019; Garg, Gupta, Kapil, Sivarajah, & Gupta, 2023; Hughes, Park, Kietzmann, & Archer-Brown, 2019; Scholl & Bolívar, 2019). Besides, these characteristics of blockchain technology are aligned with the objectives of governments, which, through several policies, laws, and regulations, wish to optimize public services, public management, public governance, and their public institutions/organizations (Ølnes, Ubacht, & Janssen, 2017; Scholl & Bolívar, 2019; Shahaab, Khan, Maude, Hewage, & Wang, 2023).

Therefore, all this evidence of blockchain's added value and effects on business opportunities cannot leave governments indifferent, as they have also begun to modernize their services/processes, even though they continue to lag in user-facing digitization (Hong, Kim, & Kwon, 2022; Ning, Ramirez, & Khuntia, 2021; Scupola & Mergel, 2022; Sharma, Dwivedi, Misra, & Rana, 2023). It is the case today with

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blockchain, where it is possible to observe several years of government interest through various national and international funding and research projects, policies, and programs (e.g., "*European Union blockchain observatory & forum, research programs FP7 and Horizon 2021-2027*") (Allessie, Sobolewski, Vaccari, & Pignatelli, 2019; Bellia et al., 2019). Digital technologies such as blockchain in public administration, public governance, and public management are now considered critical and strategic (Ning et al., 2021; Ølnes et al., 2017; Treiblmaier & Sillaber, 2020). However, research on the interaction between blockchain and the public sector still needs synthesis studies on the effects and added value of using blockchain in public administrations. This is important since many blockchain projects in the public sector are still in the testing or implementation phase (Galici et al., 2021; Tan, Mahula, & Crompvoets, 2022). Likewise, previous studies on the impact of blockchain in the public sector are content to link the effect of this technology (or related technologies) in the public sector solely to the characteristics of this technology (Kassen, 2022; Ølnes et al., 2017; Rukanova et al., 2023; Shahaab et al., 2023; Tan et al., 2022). However, in the case of blockchain implementation in the public sector, more generally, we are talking about large-scale transformation projects of various core government functions (Allessie et al., 2019; Bosch, Tangi, & Burian, 2022), which, in addition to the impressive features (capabilities) of blockchain, depend on other contextual variables, characterizing the project itself.

Despite the presumed maturity of the research field and the growing flow of literature on blockchain's business value in organizations and industries, very little is known about the evidence of using this technology within the public sector will affect the core government functions (Bustamante et al., 2022; Cagigas, Clifton, Diaz-Fuentes, & Fernández-Gutiérrez, 2021). In agreement with other researchers who consider case study exploration to be particularly appropriate for emerging topics (Ponelis, 2015; van Noordt & Misuraca, 2022; Wamba-Taguimdje, Fosso Wamba, Kala Kamdjoug, & Tchatchouang Wanko, 2020; Yin, 2009), we argue that an exploratory case study-based strategy is necessary to synthesize and highlight the extent to which blockchain technology is being used to support public sector functions and services. Thus, this study first aims to answer the following research question (RQ): ***(RQ1)*** *What are the effects of using blockchain for improving core public government functions?* ***(RQ2)*** *What are the main configurations of blockchain-based transformation projects that highly affect the core public government functions?*

To answer these two research questions, we mobilized a database of 167 cases from a mapping of blockchain-enabled public sector transformation projects from "*IPSO: Innovative Public Services Observatory*" coordinated by the "*European Commission and Joint Research Centre (JRC)*" (Bosch et al., 2022). The answer to research question RQ1 is based on an exploratory analysis of this database. In contrast, the answer to research question RQ2 is based on a fsQCA approach requiring the mobilization of the strategic management literature review.

By exploring several blockchain-oriented transformation projects in the public sector, this article lays the groundwork for blockchain adoption and its effects on improving core public government functions. It extends previous research on the benefits of implementing blockchain (or emerging technologies) in the public sector (Ølnes et al., 2017; Rukanova et al., 2023; Scholl & Bolívar, 2019; Shahaab et al., 2023; Tan et al., 2022; van Noordt & Misuraca, 2022; Zuiderwijk, Chen, & Salem, 2021). Given the innovative nature of blockchain, this study adopts an approach that advances our understanding of the implementation conditions for such technologies that highly affect the core public government functions.

The remainder of this paper is organized as follows: Section 2 reviews the existing literature on the use of blockchain in organizations and the public sector. Section 3 delineates the research methodology adopted for the study. In particular, in this section, a few excerpts from blockchain use case studies have been selected from the sample analyzed and supported by existing studies as part of coding variables for the fsQCA analysis underlying the research. Section 4 presents the results, followed by a discussion in Section 5. Finally, the implications of our study are examined in Section 6, coupled with the contributions (theoretical, practical, and policy) and limitations, while Section 7 serves as the conclusion.

2. Literature review

2.1. Blockchain technology in organizations

Whether blockchain or related technologies, it needs Distributed Ledger Technology (DLT) as an enabling technology (Scholl & Bolívar, 2019). DLT refers to the infrastructure and protocols that enable computers located in various places to suggest and authenticate transactions while simultaneously updating records synchronized across a network (Allessie et al., 2019, p. 9). Therefore, blockchain "*is a distributed ledger usually managed by a peer-to-peer*" (Chen, 2018, p. 567; Scholl & Bolívar, 2019), which tracks a set of transactions in a decentralized, secure, and transparent way in the form of a chain of blocks (Fosso Wamba, Kala Kamdjoug, Epie Bawack, & Keogh, 2020; Min, 2019). Further, "*DLT refers to a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers). This technology allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network participants*"- and blockchain "*is a particular type of data structure used in some distributed ledgers which stores and transmits data in packages called 'blocks' that are connected in a digital 'chain' … Blockchains employ cryptographic and algorithmic methods to record and synchronize data across a network in an immutable manner*" (WorldBank, 2017, p. 13). According to (Bauer, Parra-Moyano, Schmedders, & Schwabe, 2022), blockchain is often used as a broad term for a collection of technologies. The defining features of blockchains include their distributed database architecture that allows for the storage and access of transactions across multiple parties, their consensus mechanism that enables decentralized agreement on transaction validity without the need for a central authority, and their cryptographic logic that creates an immutable and transparent system (Bauer et al., 2022, p. 399). Notably, (1) decentralization means blockchain is a distributed technology, meaning a single entity does not control it; (2) transparency characterized by all transactions on the blockchain being recorded in a public database and anyone can see what transactions have taken place; (3) security, an important feature, materializes that blockchain uses cryptography to guarantee data security; and (4) immutability means that once a transaction has been recorded on the blockchain, it cannot be modified or deleted and makes blockchain highly reliable for storing essential data for organizations (Angelis & Ribeiro da Silva, 2019; Garg et al., 2023; Hughes et al., 2019). Nevertheless, "*the system is secure as long as honest nodes collectively control more CPU (Central processing unit) power than any cooperating group of attacker nodes*" (Nakamoto, 2008, p. 1).

Blockchain-based systems allow for managing unique digital assets in a distributed and decentralized setting, making decentralization the defining element of these systems, which practitioners have enthusiastically embraced (Bauer et al., 2022). From a practical standpoint, the blockchain is a distributed ledger that organizes value exchange transactions, such as those involving Bitcoin or other tokens (Allessie et al., 2019). These transactions are grouped into blocks linked in a chain (Nakamoto, 2008). This chain is then recorded immutably across a peer-to-peer network using cryptographic evidence instead of trust and assurance mechanisms (Nakamoto, 2008). Depending on the implementation, these transactions can also include programmable behavior (Allessie et al., 2019; Bauer et al., 2022). For example, bitcoin's payment system is unique in allowing two parties to transact directly without needing a third party to act as an intermediary (Nakamoto, 2008). This system enhances security, providing a safe and fair platform for electronic payments (Bauer et al., 2022). Even though Bitcoin remains the most well-known cryptocurrency based on blockchain technology today, other promising applications are beginning to emerge – for example, the case with smart contracts, Ripple, Ethereum, Corda, and NFTs (non-fungible tokens) (Baudier, Chang, & Arami, 2022; Bellia et al., 2019).

Indeed, the key characteristics of blockchain make it an indispensable asset for organizations (Angelis & Ribeiro da Silva, 2019). In several industries, blockchain allows for transferring digital assets in a peer-to-peer network (currencies, securities, votes, shares, commodities, etc.), tracing data (financial assets, products, and other goods), and automatically managing contracts of all kinds (insurance, programmable payments, etc.) (Cunha, Soja, & Themistocleous, 2021; Fosso Wamba et al., 2020; Grover, Kar, Janssen, & Ilavarasan, 2019; Hughes et al., 2019). Blockchain's effects will spread across all sectors, from finance to industry, renewable energy, and governments (Allessie et al., 2019; Galici et al., 2021; Garg et al., 2023; Sharma et al., 2023). For example, the banking industry has the highest market value for blockchain (Garg et al., 2021; Garg et al., 2023; Khalil, Khawaja, & Sarfraz, 2022), to the point where its use by financial institutions would save them up to $12 billion each year (Ruby, 2023). As for banks' infrastructure costs, blockchain can potentially reduce them by 30% (>10 billion dollars annually) (Tuwiner, 2023). Blockchain can create decentralized payment systems, such as crypto-currencies (Garg et al., 2021; Garg et al., 2023). In the same industry, banks benefit from blockchain's comparative advantage in trade finance, compliance, security, customer services, and cost operations (Garg et al., 2021). In the healthcare sector, blockchain technology is expected to reach $231.0 million by the end of 2023, with a growth rate of 63% over the next six years (Ruby, 2023). In terms of application in the healthcare ecosystem, blockchain will help to the "*redesign of the information flow and the development of new forms of collaboration*" (Aloini, Benevento, Stefanini, & Zerbino, 2023, p. 1), brings new ways of creating value (Spanò, Massaro, & Iacuzzi, 2023), or provide the privacy, security, interoperability, and immutable audit trails in electronic healthcare records management (Saxena & Verma, 2020). In entrepreneurship, blockchain and related technologies applications (e.g., bitcoin, NFT, and smart contracts) provide entrepreneurs with new ways to raise funds, engage stakeholders, and tap into new business opportunities for the informal/formal sector – providing innovators with a new way of developing, deploying and disseminating decentralized applications, and thus democratizing entrepreneurship and innovation (Baudier et al., 2022; Chen, 2018; Hashimy, Jain, & Grifell-Tatjé, 2023; Hughes et al., 2019; Larios-Hernández, 2017). Additionally, this technology is already proving its worth in improving corporate business, competitive, organizational/firm, operating/operational, or low-carbon performance (Fernando, Rozuar, & Mergeresa, 2021; Fosso Wamba & Guthrie, 2020; Garg et al., 2023; Kim & Shin, 2019; Truong et al., 2017; Tseng, Liang, & Nguyen, 2023), process and relational innovation (Fosso Wamba & Guthrie, 2020; Khalil et al., 2022), partnership efficiency and partnership growth (Kim & Shin, 2019), or business model innovation (Marikyan, Papagiannidis, Rana, & Ranjan, 2022; Morkunas, Paschen, & Boon, 2019).

Nevertheless, the DLT technology on which blockchain is built "*is still evolving and may pose new risks and challenges, many of which are yet to be resolved. The most commonly cited technological, legal, and regulatory challenges related to DLT concern scalability, interoperability, operational security & cybersecurity, identity verification, data privacy, transaction disputes & recourse frameworks, and challenges in developing a legal and regulatory framework for DLT implementations, which can bring fundamental changes in roles and responsibilities of the stakeholders*" (World-Bank, 2017, p. 11). However, blockchain enables disintermediation with various applications, not just in banking but also in healthcare, insurance, real estate, education, entrepreneurship, the energy sector, music, and even the public sector (Aloini et al., 2023; Hughes et al., 2019; Kitole, Lihawa, & Mkuna, 2023; Rana, Dwivedi, & Hughes, 2022).

2.2. Public sector and blockchain

Firstly, digital technology usage behaviors are evolving in the public sector – and new tools are infiltrating the public sphere: publishing platforms, data visualization, decision support algorithms, and sometimes even emerging digital technologies (e.g., artificial intelligence, big data, and blockchain) (Allessie et al., 2019; Ruijer, Grimmelikhuijsen, & Meijer, 2017; Zuiderwijk et al., 2021). Secondly, several digital technologies are being implemented to transform public services and government structures (Allessie et al., 2019; Ning et al., 2021; Treiblmaier & Sillaber, 2020). Based on their research into digital innovation in the public sector, (Hong et al., 2022) argue that the following drivers are central to the diffusion of digital technologies: (a) "*public organizations respond to citizen demands for innovation,*" (b) "*electoral competitiveness leads to a higher level of public sector innovation,*" (c) "*public organizations emulate their neighbors in adopting innovative practices,*" and (d) "*younger policymakers are more active innovators.*" Among other things, these catalysts also contribute to the adoption of blockchain in the public sector. Blockchain possesses features in favor of citizens' rights and demands for public services-for example, the transparency and efficiency of public services/institutions and the protection of their privacy (Bustamante et al., 2022; Treiblmaier & Sillaber, 2020). It fits perfectly into the context of the digital republic, where there is a demand for effective technologies to manage sensitive data and foster open governance (Bosch et al., 2022; Tan, Kleizen, Simonofski, Willem, & Sabbe, 2020). Blockchain, in particular, can solve issues related to transparency, trust, public policies, and service quality (Shahaab et al., 2023). The adoption, implementation, or integration of blockchain technologies by governments and public institutions can benefit all stakeholders (Tan et al., 2022). For example, blockchain can contribute to optimizing data management between public service organizations, not only in terms of interoperability, trust, and transparency but also regarding accuracy, coordination, traceability, and data integrity. It helps to maintain the existing organizational and management structures (Ning et al., 2021; Shahaab et al., 2023). Blockchain, therefore, appears to be the solution for governments to handle significant public sector challenges such as transparency and fairness in processes and procedures (Ning et al., 2021; Yfantis, Leligou, & Ntalianis, 2021). In energy consumption, (Galici et al., 2021) show that a blockchain is essential for tracking and monitoring public buildings' and communities' energy footprint data. This type of blockchain application aims to create transparency in the sustainability indicators of public buildings and facilities and to track their improvements toward sustainability goals (Galici et al., 2021). Blockchain can benefit public services more as it does not challenge public organizations and entities' organizational forms and structures (Shahaab et al., 2023).

Moreover, the potential benefits and promises of blockchain can be seen at several levels in the public sector: strategic (transparency, avoiding fraud/manipulation, and reducing corruption), organizational (increased trust, increased control, increased predictive capability), economic (reduced costs, increased resilience to cyberattacks); informational (data integrity, data quality, data sharing, data interoperability, privacy); and technology (security, resilience, and reduced energy consumption) (Ølnes et al., 2017). Regarding public value, blockchain technology improves administrative efficiency, develops open government capabilities, ethical behavior, and professionalism, enhances public services, trust, and confidence in government, and consolidates social value and well-being (Shahaab et al., 2023). Furthermore, (Brinkmann & Heine, 2022) demonstrate that blockchain can support public and non-public stakeholders in creating public services in co-production networks. Following this perspective, governments seeking methods to effectively coordinate co-production networks (Brinkmann & Heine, 2019) or to facilitate collaboration between citizens and government can rely on blockchain. Its role includes streamlining and automating procedures securely while maintaining privacy and secrecy (Aliti, Leka, Luma, & Trpkovska, 2022). In social finance and innovation, blockchain technology simultaneously adapts to the monetary system and upgrades the potential of existing laws (Paladini, Yerushalmi, & Castellucci, 2021). In addition, blockchain can be seen as a common good for citizen philanthropy and social entrepreneurship (Jain & Simha, 2018).

Furthermore, the fundamental challenge of blockchain in the public sector lies in its ability to decentralize consensus and trust between unknown actors in any network of interactions and transactions (Santana & Albareda, 2022; Tan et al., 2022; Van Rijmenam, Schweitzer, & Williams, 2017). As a result, its application in the public sphere will result in the decentralization of trust in a consensual way through peer-to-peer interactions and the strengthening of coordination between authorities, citizens, and all other stakeholders within the territory of a community, region, country, or economic zone (Tan et al., 2022). In this case, the main properties of the blockchain (trust, consensus, and knowledge) are the possibilities this technology offers for improving the effectiveness and efficiency of the public sector - characterized by fragmented, vertical governance between several authorities, departments, and institutions with limited powers. One of blockchain's key contributions is its ability to (1) implement a (citizen)people-centric agenda and policy; (2) governance based on transparency and new opportunities to renew the social contract between public institutions, private actors, and citizens; (3) address the decentralized approach to development; (4) promote new models of consumption and production of state resources; (5) analyze the reduction of natural resource consumption and mobilize other resources essential to achieving sustainable development goals and complying with climate change laws (Cagigas et al., 2021; Galici et al., 2021; Hojckova, Ahlborg, Morrison, & Sandén, 2020; Paladini et al., 2021; Rukanova et al., 2023; Scupola & Mergel, 2022; Shahaab et al., 2023). Although the adoption of blockchain in the public sector is still in its infancy, it can potentially transform how governments operate. Besides, the various benefits of this technology can be seen at all levels of a government's core functions (Bosch et al., 2022; Yfantis & Ntalianis, 2022).

Generally, the public sector is characterized by its public service, which pursues four main functions: order and regulation, social and health protection, education and culture, and the economy (COFOG, 2019; Yfantis & Ntalianis, 2022). These four functions encompass national defense, justice, civil safety, professional associations, social security, public hospitals, education, research, public broadcasting, and transport (Table 1) (COFOG, 2019; Yfantis & Ntalianis, 2022).

According to many available studies, blockchain is undoubtedly one of the most innovative digital technologies that must be considered simultaneously in developing policies (new governance) and delivering government services (Hughes et al., 2019; Morkunas et al., 2019; WorldBank, 2017).

While blockchain technology can potentially benefit various sectors, including the public sector, it is essential to recognize that it can also present challenges and limitations (Shahaab et al., 2023). Implementing blockchain technology can be a complex task, especially for public administrations. Integrating this technology into their existing systems can be challenging, given the need to train staff, ensure interoperability with other systems, and resolve specific technical issues (Shahaab et al., 2023; Upadhyay et al., 2021). Regulatory issues and the risk of information leaks are critical challenges for blockchain-based automation of public information processes (Kassen, 2022). For example, software code exploits, hardware tampering, or theft of credentials are used to undermine the information security of blockchain transactions. It is, therefore, possible for public databases to be attacked and consequently damaged (Kassen, 2022). Likewise, using telecommunications infrastructures (equipment and software) that have been compromised can lead to theft of information and identity (Kassen, 2022). This happens because the equipment and software may not have sophisticated tracking features and depend on other stakeholders needed to run the blockchain software (Kassen, 2022). Projects may be abandoned or fail due to these difficulties.

Additionally, deploying blockchain-based solutions can initially incur significant costs in terms of infrastructure, software development, and training (Cagigas et al., 2021; Upadhyay et al., 2021). For many

Table 1
Examples of blockchain effects on core government functions.

Core government functions	Second-level (sub-sectors)	Examples of blockchain technology's effects
General public services	Executive and legislative organs, financial and economic aid; general services; basic research; R&D related to general public services; general public services n.e.c.; public debt transactions, transfers of a general character between fiscal affairs, external affairs; foreign different levels of government;	• Improve efficiency and traceability for governments regarding public records management, public procurement, or digital entity management (Cagigas et al., 2021). • Simultaneously improve security, trust, transparency, privacy, and anonymity for citizens (Cagigas et al., 2021; Shahaab, Maude, Hewage, & Khan, 2020). • Improve citizens' access to services (Tiwari & Pal, 2023). • Cutting costs for the government (Tiwari & Pal, 2023). • Reduce the bottleneck of paperwork and bureaucratic interventions for administrative processes in several public services (Cagigas et al., 2021). • Decrease daily human errors in the tasks performed by civil servants (Cagigas et al., 2021). • Improve the abilities of tax authorities to detect fraud and errors faster and more effectively (Cagigas et al., 2021). • Improve public service delivery and trust in government (Bustamante et al., 2022). • Improve the effectiveness of crisis response by reducing fraud and corruption during operations (Bustamante et al., 2022).
Defense	Military defense; civil defense; foreign military aid, R&D related to defense; defense.	• Using blockchain for trusted verification of detected events in disaster management and emergency response using social media platforms as a central element (Shahbazi & Byun, 2022). • Fake media detection (Shahbazi & Byun, 2021). • Protect smart and cyber-infrastructure (Tibrewal, Srivastava, & Tyagi, 2022).
Public order and safety	Police services; fire-protection services; law courts; prisons; R&D related to public order and safety; public order and safety n.e.c.	• Provide a completely decentralized system to ensure there is no central point of failure in the system and complaints are managed securely and protected from unauthorized access (Hingorani, Khara, Pomendkar, & Raul, 2020).
Economic affairs	General economic, commercial, and labor affairs; agriculture, forestry; fishing and hunting; fuel and energy; mining,	• Mobilizing blockchain technologies in overcrowded localities to rationalize transport, protect the environment

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Table 1 (*continued*)

Core government functions	Second-level (sub-sectors)	Examples of blockchain technology's effects
	manufacturing and construction; transport; communication; other industries, R&D related to economic affairs; economic affairs, n.e.c.	against pollution, and convince residents to use public transport (Enescu, Bizon, Serban, & Hoarcă, 2021). • Enhance trust, transparency, and auditability in social business activities (Mukkamala, Vatrapu, Ray, Sengupta, & Halder, 2018). • Enables community-wide renewable energy systems in which residents can share costs and benefits equitably (Choudhry, Dimobi, & Isaac Gould, 2019). • Increase the efficiency of land registration (Bustamante et al., 2022). • Issue commercial licenses faster(Bustamante et al., 2022). • Help countries' central banks solve major problems related to government securities transactions (Bustamante et al., 2022). • Dematerialize commercial and government transactions (Bustamante et al., 2022). • Increase the efficiency of public sector transactions (Bustamante et al., 2022).
Environmental protection	Waste management; water waste management; pollution abatement; protection of biodiversity and landscape; R&D related to environmental protection.	• Provides financial management for waste collection in the municipality (França, Amato Neto, Gonçalves, & Almeida, 2020). • Blockchain provides automatic execution of protocols, information consistency and traceability, data synchronization and sharing, and waste recycling supply chain (Jiang et al., 2023). • Improvement of hospital waste management (Jiang et al., 2023). • Enables instant detection of any violation of water pollution control laws so that the appropriate sanction can be applied to offending organizations (Alharbi, Althagafi, Alshomrani, Almotiry, & Alhazmi, 2021). • Promote appropriate drinking water use by implementing an effective water resource management system (Sundaresan, Suresh Kumar, Ananth Kumar, Ashok, & Golden Julie, 2021). • Reduce water contamination by industry by providing a secure and reliable real-time monitoring system to indicate anomalies (Alharbi et al., 2021; Sundaresan et al., 2021). • Blockchain fosters sustainable forestry, minimizing illegal logging and conserving biodiversity (He & Turner, 2022). • Optimizes water distribution by providing a consumption-oriented system (Alharbi et al., 2021).
Housing and community amenities	Housing development; community development; water supply; street lighting; R&D related to housing and community amenities; housing and community amenities n.e.c.	• Facilitate access to housing in connection with the transfer and registration of real estate (Nasarre-Aznar, 2018). • Promote secure, transparent, and dynamic energy distribution to multifamily dwellings and neighborhoods with a renewable energy network (Choudhry et al., 2019).
Health	Medical products, appliances, and equipment; outpatient services; hospital services; public health services; R&D related to health; health n.e.c.	• Building a unified ecosystem where various stakeholders (e.g., patients, physicians, assurance firms) communicate transparently and securely (Cagigas et al., 2021). • Keep track of all accesses/changes to patients' electronic medical records (Cagigas et al., 2021; Saxena & Verma, 2020). • Provide privacy, trust, security, interoperability, and immutable audit in the public healthcare domain (Saxena & Verma, 2020). • Contribute to the enrichment of water sources and the absence of disease for humanity in smart cities (Sundaresan et al., 2021). • Provide "*security, privacy, trust, visibility, decentralized tracking and tracing of the medical product, avoids counterfeit drugs, avoids the damage to medical components, authentication, reduces the cost and provides the status of the products during the shipment process between manufacturers to end-user*" (Nanda, Panda, & Dash, 2023). • Giving patients total control over their healthcare data (Saxena & Verma, 2020). • Integrating blockchain technology can improve the speed and accuracy of public health data for scientists, healthcare professionals, and officials (Bustamante et al., 2022).
Recreation, culture, and religion	Recreational and sporting services; cultural services; broadcasting and publishing services; religious and other community services; R&D	• Protecting people's culture by regulating authentication on art markets (Bustamante et al., 2022).

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Table 1 (*continued*)

Core government functions	Second-level (sub-sectors)	Examples of blockchain technology's effects
	related to recreation, culture and religion; recreation; culture and religion n.e.c.	
Education	Pre-primary, primary, secondary, and tertiary education; post-secondary non-tertiary education, education non-definable by level; subsidiary services to education, R&D; n.e.c.	• Provide efficient educational authentication and certificate management solutions, multiple evaluations for online learning or Massively Open Online Courses, copyright certificate storage, trading, and knowledge securitization (Chen et al., 2022; Skiba, 2017). • Streamline the administration of the admission process (Bhaskar, Tiwari, & Joshi, 2021). • Optimize the evaluation of students' participation in extracurricular activities (Bhaskar et al., 2021). • Assist in building a stronger alumni network: provide transparent record-keeping for relationships and communications (Bhaskar et al., 2021). • Efficiently manage library and information services (Bhaskar et al., 2021). • Provide transportation facilities to students and staff using blockchain-based ridesharing apps (Bhaskar et al., 2021). • Protect the intellectual property rights of teachers and researchers at school (Bhaskar et al., 2021). • Use to improve citizens' socio-environmental education (França et al., 2020).
Social protection	Sickness and disability; old age; survivors; family and children; unemployment; housing; R&D; social protection and social exclusion n.e.c.	• Fostering social welfare (Hsu, Tu, & Huang, 2020). • Improve efficiency in administering unemployment benefits (Bustamante et al., 2022). • Improve citizens' financial and social inclusion through blockchain-based social money (França et al., 2020). • Guarantees that data will not be falsified or replace any loss of family records (Sunarya, Henderi, Khoirunisa, & Nursaputri, 2020). • Ensure human rights protection (Upadhyay, Mukhuty, Kumar, & Kazancoglu, 2021) • Enhance healthcare patient confidentiality and welfare (Upadhyay et al., 2021).

Note: n.e.c.: Not elsewhere classified.

public sector entities, these costs can represent a significant obstacle to adopting this technology. Furthermore, the introduction of blockchain in the public sector may fail if there are problems with acceptability (resistance to change, perceived loss of control, and fear of job loss), new governance models, and legal and regulatory support (Batubara, Ubacht, & Janssen, 2018; Shahaab et al., 2023). Public sector bureaucracies can sometimes resist change, making it challenging to adopt new technologies, even if they offer potential benefits. The transition to blockchain can be hampered by cultural and organizational reticence (Shahaab et al., 2023).

Although blockchain is often considered secure, concerns about data confidentiality persist. Some types of blockchains, such as public blockchains, can make transactions and information accessible to anyone, which may be inappropriate for specific sensitive government applications (Lai & Lo, 2023). If the blockchain project does not guarantee the immutability and security of the information recorded and the sharing of information between public service organizations, and between public service organizations and other entities (businesses and citizens), while respecting existing rules and regulations on data confidentiality, ownership, and control, we may end up with failure (Shahaab et al., 2023). The success of blockchain implementation also depends on the type of blockchain model put in place: public blockchain (any member can submit a transaction; he can read, write, or modify the database), private blockchain (to be able to submit a transaction, one must possess the necessary permissions) (Lai & Lo, 2023). Compared to the public blockchain, private blockchains prioritize performance over security (Lai & Lo, 2023). Add to this the "*permissioned*" or "*permissionless*" characteristics (Miller, 2019; Wüst & Gervais, 2018), and it becomes a challenge for blockchain projects in the public sector. (1) "*permissioned private blockchain (only permissioned private participants can read from and write to the ledger, provide transparency of transactions and transaction validation for the permissioned participants only)"; (2) "Permissioned public blockchain (everyone can read from the ledger, provide transparency of transactions to the public, but only permissioned participants may write to the ledger and validate transactions among each other)"; (3) "distributed unpermissioned or permissionless blockchain (everyone can take part, provide full transparency and access … Everyone can validate transactions as long as preset rules are obeyed by, access criteria are met, and consensus among participants about the validity of the transaction is established)"* (Scholl & Bolívar, 2019, p. 602).

In the case of permissionless blockchains, which are open and decentralized, no central entity manages members or bans illegitimate readers or writers (Wüst & Gervais, 2018). This raises security issues and privacy threats (Alketbi, Nasir, & Abu Talib, 2020; Ølnes, 2021; Peng et al., 2021; Wüst & Gervais, 2018). Indeed, as the government is not the central entity and has no administrator rights over the technology it deploys in these core functions, how can it take advantage of this technology while guaranteeing security and privacy? However, the case of permissioned blockchains, where a central entity decides and assigns to individual peers the right to participate in blockchain writing or reading operations (Wüst & Gervais, 2018), is better suited to the public sector (Berryhill, Bourgery, & Hanson, 2018), where governments must likely to control activities and process. However, such a blockchain system may cause tensions between transparency and privacy (Ølnes, 2021; Wüst & Gervais, 2018), even though it may offer high security. Indeed, in this type of system, the public verifiability that allows anyone to check the accuracy of the system's status is not available - nor is the transparency of the system's data, as the state controls it (Batubara et al., 2018; Wüst & Gervais, 2018). Furthermore, given this complexity, how can the public sector guarantee transparency and trust (which are the foundations of the digital republic) while leveraging the features of blockchain to revolutionize the public sector? For example, in a public blockchain, the sensitive personal information of marginalized or vulnerable people can be disseminated as open data (Belen-Saglam, Altuncu, Lu, & Li, 2023; Shahaab et al., 2023). Blockchain will also involve the traceability of digital traces of personal information, which raises ethical issues (Belen-Saglam et al., 2023; Shahaab et al., 2023) (Belen-Saglam et al., 2023; Shahaab et al., 2023).

Nevertheless, in the current literature, much emphasis is put on the design/conception (Galici et al., 2021; Ølnes et al., 2017; Tan et al., 2022), adoption (Ølnes et al., 2017), implementation (Galici et al., 2021;

Garg et al., 2021), challenges (Ølnes et al., 2017; Sharma et al., 2023) of this technology for (private) organizations in general (Ølnes et al., 2017). Indeed, very little attention is paid to exploring the actual effects of blockchain in the public sector. Likewise, the public sector is more conducive to blockchain than any other industrial sector (Treiblmaier & Sillaber, 2020). Therefore, for this technology to move from mere innovation to an indispensable technology for the public sector, which is generally resistant to the adoption of IT, we need to propose new research that reveals this blockchain's benefits in the public sector. Indeed, the aim is to go beyond simply presenting the effects of blockchain in the public sector and see how this technology affects essential public sector core functions/services. While this technology represents a crucial element in the digital transformation of the public sector, there is little empirical evidence on how blockchain-based projects are implemented to affect the core public governance functions highly.

3. Methodology

This article is based on a rich exploratory analysis of case studies of public service transformation projects based on blockchain technology on a European scale. For this purpose, 167 observations were downloaded from the "*European Commission's Joint Research Centre*"[1] database. The case study data used in our research are secondary, as they were collected and analyzed shallowly in the project "*IPSO: Innovative Public Services Observatory.*" This database contains an updated list of selected cases from European public sector institutions on adopting and implementing blockchain technology. The data collection tools mobilized by the organization responsible for this project align with the principles of triangularization (Eisenhardt & Graebner, 2007). Indeed, "*the case collection continued until December 2021, combining different sources of information: (1) International and local initiatives or direct contacts with Member States or other institutions -for example, we included several cases from the European Blockchain Observatory and Forum or the Dutch Blockchain Coalition; (2) Internet scouting: news articles collected through internet search; (3) scientific and grey literature; (4) a collaboration with the Digital Agenda Observatory of the Politecnico di Milano*" (Bosch et al., 2022, p. 15). The aim is to understand blockchain-based use cases available in the public sector and their effects. The database's case studies are related to projects of different statuses: "*in development, implemented, not in use anymore, pilot, and planned.*" We considered all these projects regardless of their implementation status. For each case study, the experts provided information on name of project, website links, description of solution, geographical extent, geographic coverage country, geographic coverage NUTS ("*Nomenclature of Territorial Units for Statistics*" 2021), responsible organization, responsible organization category, functions of government (COFOG level I), functions of government (COFOG level II), status, start year, end year, process type, application type, technology (blockchain and nothing else), crosssector, crossborder, uptake, interaction, effects (improved public service, improved administrative efficiency, open government capabilities), and source of data (Bosch et al., 2022). To avoid ambiguity and remain consistent, the experts focus on the blockchain without giving importance to its technologies (e.g., cryptocurrencies, NFT, DLT, and smart contracts) (Bosch et al., 2022).

Our study was built on an early study by (Bosch et al., 2022) based on the same dataset. This insightful study offers a contextual analysis of the use of blockchain in the public sector (with a particular focus on challenges and policies) within the European Union. Based on the previous study carried out by (Bosch et al., 2022), our research relies on a theoretical foundation in IT and strategic management to extend such previous research, notably by (a) analyzing in-depth the indicators of blockchain-based transformation projects that are often overlooked in the literature on IT adoption and strategic management; and (b) provide the effects of blockchain on core government functions. We conducted a second analysis based on a fsQCA, as we aimed to generalize the observations made by (Bosch et al., 2022) in their report. Indeed, in the public sector, IT adoption/implementation is generally seen as a project that depends on several variables and indicators (e.g., project coverage or area of activity). As a result, the perspective of studies on IT adoption/impact and strategic management in the public and private sectors should consider an in-depth analysis of the variables or indicators describing these transformation projects.

So, based on the input initially made available in the database, we turned toward the literature on IT and strategic management to reconcile the indicators present in the database with the theoretical concepts/variables current in the literature. Subsequently, given that blockchain represents a massive opportunity for the public sector, we thought it would be helpful to highlight how the influence of the characteristics of these blockchain-based transformation projects, which are often overlooked in the IT adoption literature, can help characterize transformation projects in the public sector. The public sector is known for its ongoing interoperability challenges due to organizational differences, such as corporate structures and management processes. In addition, implementing technologies in the public sector must consider the characteristics and variables indirectly linked to this interoperability. Thus, we use these variables (e.g., cross border, cross-section, or process type) for our analyses, as digital transformation projects in the public sector generally have broader coverage involving several government functions or organizations. Public services, institutes, and organizations are characterized by departments that span one or more communities or regions (Verma & Sheel, 2022). Furthermore, transforming public service via digital technologies has repercussions on several entities, departments, and other public services (Verma & Sheel, 2022). Therefore, using these variables to characterize the adoption of blockchain in the public sector seems legitimate.

3.1. Data collection

First, we retrieved our database as an Excel file with the corresponding glossary. Given the different variables in the file, we conducted a more in-depth analysis of this database. The diagram below describes the several variables and their modalities in the database (cf. Fig. 1). For a more detailed description of the different variables in the database, see Appendix (**Fig. A1 and A2**). The blue and yellow variables characterize the adoption of blockchain in public services (Fig. 1). These variables help to characterize transformation projects in the public sector. Indeed, the public sector is known for its ongoing interoperability challenges (e.g., cross-government agencies collaboration or seamless information exchange and communication between core government functions) due to organizational differences, such as corporate structures and management processes (Margariti, Stamati, Anagnostopoulos, Nikolaidou, & Papastilianou, 2022; WorldBank, 2023). In this study, interoperability refers to "*the ability of disparate and diverse organizations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organizations via the business processes they support, by means of the exchange of data between their respective information and communication technology (ICT) systems*" (Ølnes, 2010, p. 317). Therefore, implementing technologies in the public sector must consider the characteristics and variables indirectly linked to this interoperability. Thus, we use these variables (Fig. 1) for our analyses, as digital transformation projects in the public sector generally have broader coverage than those in private companies, which concern only a single entity. Public entities typically have departments and services that often span one or more communities or regions. Furthermore, a public service restructured via (digital or emerging) technologies leads to repercussions for several other public entities, departments, and

[1] European Commission, Joint Research Centre (JRC) (2022): Selected blockchain cases in the public sector. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/8b6240ad-926f-404f-b685-04a2d3ae93d6

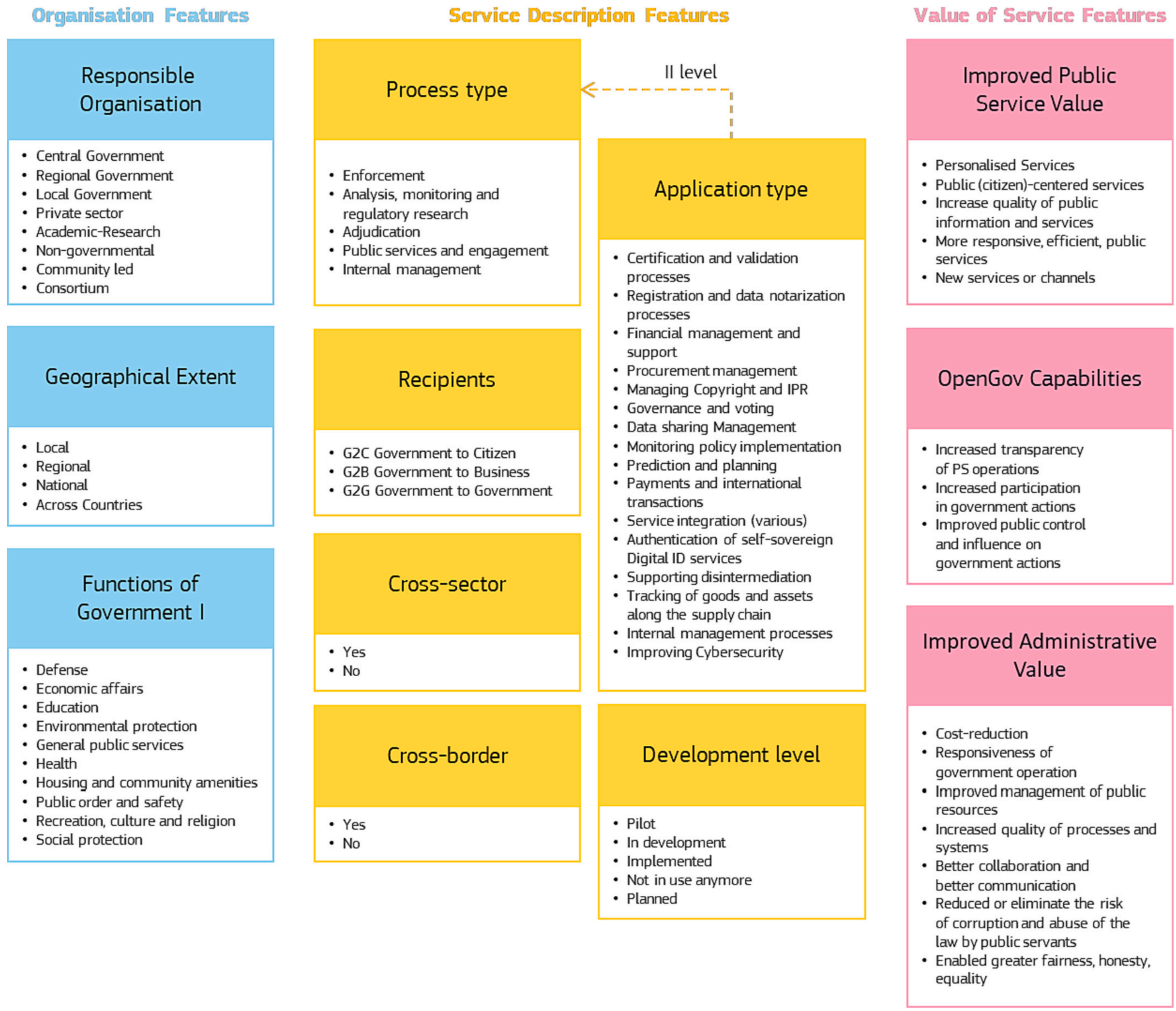

Fig. 1. Taxonomy for blockchain case categorization and variables (Bosch et al., 2022, p. 16).
Notes: G2C: Government to Citizen, G2G: Government to Government, and G2B: Government to Business.

services. Using these variables to characterize the adoption of blockchain in the public sector seems legitimate.

3.2. Data codification

First, the variables chosen for our analysis are those shown in Fig. 1, as there is information in the database about their descriptions and how they were developed and collected. The first step in our coding was to replace the modalities of each indicator with decimal values in each case. Therefore, the modalities of each variable in Fig. 1 have been codified by replacing them with decimal digits for variables with more than two modalities. For example, in the case of the "recipients" variable, the qualitative data was replaced as follows: "*1= Government to Citizen (G2C), 2= Government to Government (G2G) and 3= Government to Business (G2B)*". For the Cross-sector and Cross-border variables, which have two modalities each, we have replaced "No" by 0 and "Yes" by 1. Concerning the pink-colored variables (Fig. 1), we replaced "X" with "1" when there was evidence of the presence of one of the modalities linked to a variable and "0" otherwise. Then, each observation's modality scores for each variable were added to give an overall score (cf. Appendix, Fig. A3) to facilitate subsequent data analysis. This type of method is familiar to studies of the impact/effects of digital technologies on businesses (Wamba-Taguimdje, Wamba, Kamdjoug, & Wanko, 2020).

Additionally, regarding process and application types we retain this link between process and application types because the taxonomy is consistent with other research in the public sector (Bosch et al., 2022; Luca, Colin, Marco, Dietmar, & Francesco, 2022; Shahaab et al., 2023; Twizeyimana & Andersson, 2019; van Noordt & Misuraca, 2022). The application types are mapped onto the central public administration sectors. In contrast, the process type is used to quantify with a finer degree the kind of governance process inside the public sector for each blockchain-based transformation project (Appendix: Fig. A2). Thus, we retained these classifications in this study because they give us more detail in describing transformation projects in the public sector.

The second step of codification was to relate the variables describing the effects of blockchain in the public sector (Fig. 1) to the social science and management literature, specifically in IT and strategic management. This transformation is motivated by our desire to generalize the results by linking the observations in the case of this study to the global social and management science literature. Therefore, we explored this literature to match the modalities of the output variables of Fig. 1 to the existing concepts or variables in the general IT and strategic management literature. This led to the model shown in Fig. 2. Thus, how we moved from Fig. 1 to Fig. 2. Indeed, the categorization of blockchain benefits in Fig. 1 by (Bosch et al., 2022) in the public sector was made based on an earlier study on AI (and blockchain) in the public sector by (Luca et al., 2022; Shahaab et al., 2023; Twizeyimana & Andersson, 2019; Zuiderwijk et al., 2021). While this classification proposed by these authors is in line with many previous studies on the influence of technologies in the public sector (Shahaab et al., 2023; van Noordt & Misuraca, 2022), the fact remains that the variables and indicators present in their classification can be grouped according to the social science and management literature. This makes it easier to generalize the results. So, to begin with, we took a general look at how the indicators of each of the three variables measuring the effects of blockchain (Fig. 1) corresponded to the items of existing variables in IT and strategic management related to public sector management.

Further, the variables used to describe the effects of blockchain in essential government functions are derived from an empirical exploratory analysis mobilizing several data collection methods and have already been mobilized in other research (Bosch et al., 2022; Luca et al., 2022; van Noordt & Misuraca, 2022). Therefore, we use these data, as their reliability and viability have already been tested and evaluated by previous studies. Based on these variables, which have a solid empirical foundation, we looked in the literature to see whether the indicators used to describe each effects variable exist in the IT or strategic management literature, specifically on blockchain. We looked broadly at studies exploring how IT affects organizational processes and organizational performance (Anand & Fosso Wamba, 2013; Hamledari & Fischer, 2021; Reyes, Gravier, Jaska, & Visich, 2022; Wamba-Taguimdje, Fosso Wamba, et al., 2020) and technologies (blockchain and AI) effects in the public sector (Table *1*) (Shahaab et al., 2020; van Noordt & Misuraca, 2022; Zuiderwijk et al., 2021). Once these studies had been selected, we explored the definitions of the variables and their measurement indicators (cf. sections 3.2.1, 3.2.2, and 3.2.3 for references). This exploration enabled us to reclassify the indicators of the three variables measuring the effects of blockchain in Fig. 1 into three main variables known from the social science and management literature: process innovation, operational performance, and administrative performance. Subsections 3.2.1, 3.2.2, and 3.2.3 illustrate these variables derived from exploring social science and management literature and empirical observations based on the information in the database. For each variable, extracts from some case studies have been added to justify our transformation of the output variables in Fig. 1 into the three dependent variables in Fig. 2. The data to explain the blockchain adoption (blockchain-based transformation project features in the public sector) variables are presented in the appendix (see Fig. A1).

3.2.1. *Process innovation in public services*

The case studies provide data-based evidence of first-order effects on the processes used by organizations, indicating efficiency, productivity, and flexibility about such processes. In particular, automational, informational, and transformational effects (Reyes et al., 2022) are proved. The influence of blockchain technology (capabilities) on automational effects refers to the replacement of human work by the efficient and effective automation of public organizations' activities, processes, and procedures (Bhaskar et al., 2021; Bustamante et al., 2022; Cagigas et al., 2021). The informational effects refer to making information on business processes available and disseminating it to all stakeholders using blockchain's capabilities. The technology can potentially improve information and data collection, storage, processing, and dissemination between public services and organizations (Bustamante et al., 2022; Hamledari & Fischer, 2021; Reyes et al., 2022). The informational effect is also reflected in our case studies when there are blockchain-driven improvements in decision quality, transparency, responsiveness, and resource utilization in public services (Bustamante et al., 2022; Fosso Wamba & Guthrie, 2020; Reyes et al., 2022; Yfantis et al., 2021). Finally, blockchain has transformational effects on the processes of public services. These effects refer to the value derived from blockchain's ability to facilitate innovation and deep process transformation (Cagigas et al., 2021; Reyes et al., 2022; Spanò et al., 2023). Indeed, the ability of digital (emerging) technologies (e.g., blockchain, RFID, and artificial intelligence) to influence business processes via automational, informational, and transformational effects (especially at the organizational level) has already been demonstrated in the literature (Anand & Fosso Wamba, 2013; Hamledari & Fischer, 2021; Reyes et al., 2022; Wamba-Taguimdje, Fosso Wamba, et al., 2020). For example, one of our case studies shows how UK hospitals use blockchain to track the temperature of coronavirus vaccines, which is quite innovative (cf. Appendix: Fig. A4).

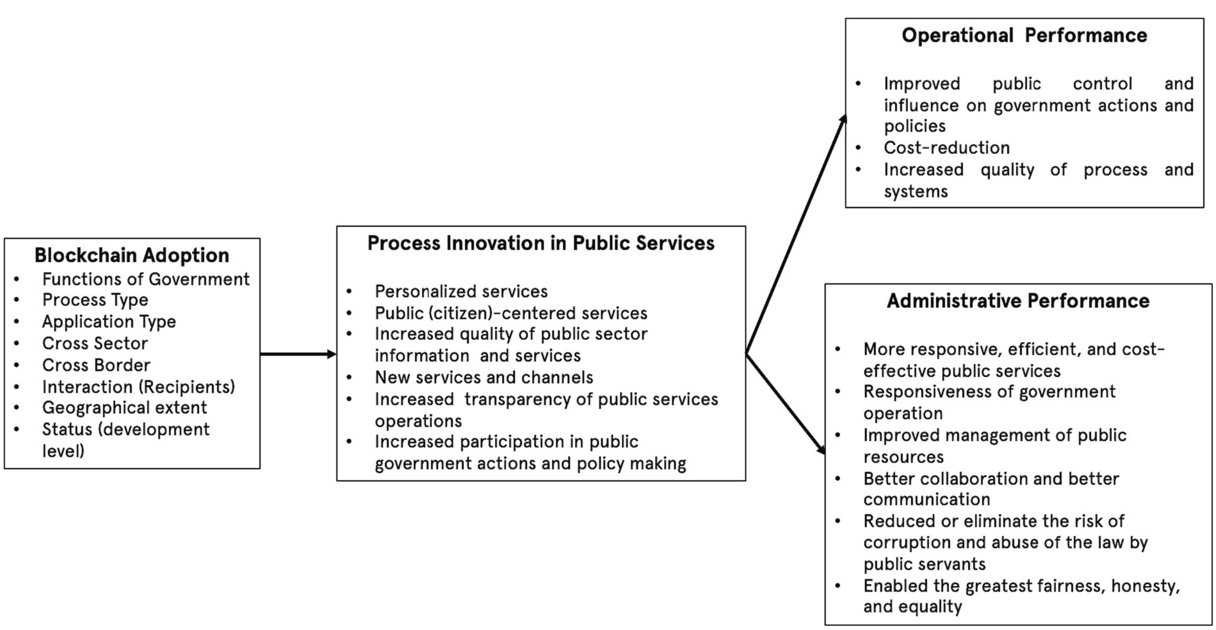

Fig. 2. Proposal of a research model based on comparing case studies data and management literature.

3.2.2. Enhancing operational performance

Whether it is in industries or critical functions of an organization (Kim & Shin, 2019), operational performance "*refers to the ability of a company in reducing management costs, order-time, lead-time, improving the effectiveness of using raw material and distribution capacity*" (Truong et al., 2017, p. 4). Indeed, operational performance is essential for public services. It contributes to improving the efficiency of production or delivery activities and creating high-quality public services, resulting in increased revenues (costs reduction in the public sector) and benefits for public institutions and organizations (Allessie et al., 2019; Bosch et al., 2022; Skelaney, Sahin, Akkaya, & Ganapati, 2023; Verma & Sheel, 2022). Operational performance is characterized by "*cost, quality, delivery, and flexibility*" (Hardcopf, Liu, & Shah, 2021; Kim & Shin, 2019). Indeed, blockchain technology has the potential to securely enhance efficiencies in the delivery of public services across multiple core public departments and functions (Skelaney et al., 2023). For example, a pilot project transformation in Vienna shows enormous opportunities for the administration's future (cf. Appendix: Fig. A4).

3.2.3. Improving administrative performance

Administrative performance is at the heart of the public sector literature (Kaliannan & Awang, 2009;Vigoda, 2002 ; Vigoda-Gadot & Yuval, 2003). It is one of the primary objectives of implementing IT in public organizations or institutions (Bosch et al., 2022; Kaliannan & Awang, 2009). In the public sector literature, administrative performance entails a renewed control of public services and organizations over resources and strengthened coordination between and within the different public services and organizations (Vigoda, 2002; Vigoda-Gadot & Yuval, 2003). It is also materialized by "*responsiveness and citizens' satisfaction*" (Vigoda-Gadot & Yuval, 2003, p. 506). The way public services (agents) are managed affects administrative performance, leading to higher levels of citizen trust in government and public services (Kaliannan & Awang, 2009; Van de Walle & Bouckaert, 2003; Vigoda-Gadot & Yuval, 2003). Moreover, the trust of citizens in government and public services, which mediates the relationship between the quality of public service management and administrative performance, is optimized by blockchain technology. Administrative performance is observed in public organizations' processes and procedures and at the level of the providers of these services of general interest (Vigoda, 2002; Vigoda-Gadot & Yuval, 2003). Thus, in the case studies provided by IPSO institutions, we notice that blockchain can improve the quality of public agents' management. In the actual literature review, blockchain can significantly enhance public agents' managerial attributes such as "*human quality, transparency and accountability, morality and ethics, and innovation and creativity*" (Bosch et al., 2022; Bustamante et al., 2022; Vigoda-Gadot & Yuval, 2003, p. 506). For example, to certify the competencies of civil servants, the Italian government relied on blockchain technology, and the effect on administrative performance was highly significant (cf. Appendix: Fig. A4). We also have an illustrative example from a non-EU regarding the advantages of blockchain technology for the public sector (cf. Appendix: Fig. A4).

3.3. Data analysis

Firstly, to answer research question **RQ1**, we performed an exploratory analysis of the case study database. The aim was to make cross-references to highlight the effects of using blockchain for improving core public governance functions. All the information needed to characterize, for each project, the government function and sub-sector concerned, the type of application and process in which blockchain is integrated, and the effects of blockchain were already present in the database.

Secondly, regarding the RQ2, we used the fsQCA approach to analyze data (Fiss, 2011; Ragin, 2006; Ragin, Strand, & Rubinson, 2008). The fsQCA method examines the relationship between an outcome of interest and a set of input factors–by using a set-theoretic approach to explore all possible Boolean combinations of input factors across observations (Bosch et al., 2022, p. 9; Fiss, 2011; Ragin, 2006). Moreover, "*to capture combinations of conditions that are sufficient for an outcome to occur, fsQCA uses both qualitative and quantitative assessments and computes the degree on which a case belongs to a set, thus creating a bridge between qualitative and quantitative methods*" (Pappas & Woodside, 2021, p. 5). Therefore, in the case of this study, mobilizing the fsQCA approach will enable us to highlight the main configurations of blockchain-based transformation projects that highly affect the core public governance functions. This implies that the characteristics of blockchain-based transformation projects and their effects on public services should be identified in a database and that the relevant features of technology adoption are clearly illustrated to affect public services. Other authors have already used the fsQCA approach to review the contextual data related to technology adoption. For example, (Veríssimo, 2016) mobilized the fsQCA to examine variables from the adoption literature and contextual variables such as age and income to explore the adoption of mobile banking apps. In addition, (Vedula & Fitza, 2019) applied the fsQCA approach to explore the regional entrepreneurial ecosystem for U. S. venture capital-backed startups. However, the fsQCA approach has been criticized for the following limitations. Firstly, this approach can be complex and challenging to implement. Computations can be lengthy and require specialized software (Pappas & Woodside, 2021). Secondly, the results of fsQCA analysis can be complicated to interpret (Gligor & Bozkurt, 2020). Minimum causal configurations can be complex and non-intuitive. Finally, fsQCA results depend on data quality (Gligor & Bozkurt, 2020). If the data are complete or biased, the results may be accurate. Despite these limitations, the fsQCA approach is a powerful method that can be used to identify complex causal relationships between variables. It is advantageous when causal relationships cannot be modeled linearly, as in the case of this study. To overcome the limitations of this approach, we (1) used specialized software widely used by researchers to reduce the complexity of the calculations and improve the interpretation of the results and (2) mobilized a database built by an international organization over several years and already used in other studies.

We then calibrated the quantitative data from our coding process. The calibration approach aimed to set the total membership threshold at 0.95, the full non-membership threshold at 0.05, and the crossover point at 0.5. To convert the interval scale variables into fuzzy sets, we used the fsQCA software (v. 3.1b). As a result, we have a table of truth (based on fuzzy set data). The fsQCA software algorithm will then select the configurations to be analyzed and the causal conditions and outcomes to be minimized. The fsQCA method relies on both necessary and sufficient conditions. Following the analysis (with a consistency threshold of 0.80), the software provides three indicators: raw coverage (the proportion of the outcome explained by each term in the solution), unique coverage (the proportion of memberships in the result that can be defined solely by each solution term), and consistency (the proportion of memberships in the outcome explained by the entire solution) (Bawack, Wamba, & Carillo, 2021; Fiss, 2011; Ragin, 2006; Ragin et al., 2008). To strengthen the reliability of our results, (1) only configurations with a minimum frequency of three were used in the analysis, and (2) the configurations selected in this study (consistency) respect the rule of covering at least 80% of the cases to respect the extent to which a causal solution leads to a result (Bawack et al., 2021; Ragin et al., 2008). Regarding the fsQCA analysis, we first explored the conditions for achieving a high level of "*improved public service, open government capabilities, and improved administrative value*" (Fig. 1). Subsequently, a second analysis was carried out to identify the different conditions for achieving a high level of the variables in the model presented in Fig. 2 (operational and administrative performance).

4. Results

The exploration of case studies indicates that blockchain technology is deployed in five high-level decision-making tasks commonly implemented with basic processes/tools. The critical public service processes benefiting from blockchain are (1) enforcement, (2) analysis, monitoring, and regulatory research, (3) adjudication, (4) public services and engagement, and (5) internal management. Moreover, these key processes concern the critical government functions: general public services, economic affairs, education, health, social protection, environmental protection, public order and safety, housing, and community amenities. The blockchain-based public projects presented in the case studies show that, depending on the features of blockchain, several objectives or problems are targeted in public services. In this study, blockchain-driven transformation projects help the public sector improve several processes and procedures. Table 2 presents the key activities blockchain technology supports in the public sector and its percentage in the overall data sample.

As we explored the case studies in the database to answer **RQ1**, we realized that a blockchain-based transformation project designed for one of the government's core functions affected a sub-sector of another core function (see Table 1). Depending on the type of blockchain application in the different government functions, the effects are also diverse. Of the ten core government functions, only 08 are present in our study. We start with our sample's most minor representative functions, where only three projects were identified. These are "*housing and community amenities*" (1) and "*public order and safety"* (2), where the technology is used for open government capabilities (increased transparency of public sector operations). In the first case, blockchain is mobilized for "*registration and data notarization processes*" to contribute to improving public service (public (citizen)-centered services; increase quality of public service information and services; and more responsive, efficient, and cost-effective public services).

On the other hand, in the case of the "*public order and safety*" function, blockchain is mobilized for "*payments and international transactions*" and "*data sharing management*" to improve administrative efficiency (cost-reduction, responsiveness of government operation, improved management of public resources, increased quality of processes and systems, and better collaboration and better communication). Afterward, we summarized the results for government functions where blockchain is widely used. The numbers in brackets in Figs. 3, 4, 5, 6, 7, and 8 represent the number of projects per sub-sector or the recorded effects. The public sector function most affected by blockchain is "*general public services*" - with 77 projects. Most of these projects focus on "*general services,"* while blockchain is used for "*public services and engagement*" and *enforcement*. In terms of effects, blockchain is helping to improve public service and equip the public sector with open government capabilities for the most part (**Fig.** 3).

With 28 "*economic affairs*" projects, transport is the sub-sector with the most projects (Fig. 4). We can see blockchain has primarily had the following effect: "increased transparency of public sector operations," "public (citizen)-centered services," "increase quality of public service information and service," "more responsive, efficient, and cost-effective public services."

Moreover, with 17 projects, healthcare is one of the core functions of government, where blockchain already has the most possible applications in the public sector. The technology fits perfectly into all the processes of this government function. Moreover, it is in this function that we see many types of effects (see Fig. 5).

Out of 20 projects, the blockchain is mobilized in education for two main applications: "*certification and validation processes*" and "*authentication of self-sovereign digital ID services"* (Fig. 6). The effects of blockchain in this function is represented by "increased transparency of public sector operations," "*public (citizen)-centered services,"* "*increased quality of public service information and service,"* and "*more responsive, efficient, and cost-effective public services."* However, there were no effects at the "*improved administrative efficiency*" level, demonstrating that technology is not yet fully mobilized in this function of government and its sub-sector.

Table 2
Activities supported by blockchain technology in the public sector.

Activity type	Descriptions	Percentage
Authentication of self-sovereign Digital ID services	A system that enables the customer (citizen) authentication through some kind of Digital ID, maybe in a decentralized way.	8%
Certification and validation processes	The process of providing someone or something with an official document attesting or validating a status or a certain right.	18%
Data Sharing Management	Data reuse processes support access to public service data, considering interoperability and data licensing.	16%
Financial management and support	Management of an organization's finances (spending, taxes, budget) so that governmental activities comply with necessary regulations and succeed in their field. The process involves high-level planning and proper execution.	9%
Governance and voting	Management of governance process or voting processes.	4%
Improving Cybersecurity	Cybersecurity is the application of technologies, processes, and controls to protect systems, networks, programs, devices, and data from cyber-attacks.	1%
Internal management processes	"*Processes that provide management, control and decision support tools necessary to achieve public administrations' objectives*." For example: i. Taking decisions on benefits: Processes within the public sector used for making decisions regarding approval, validation, or revocation of benefits (e.g., social). ii. Facilitating internal organization procedures: Internal procedures in the public sector are linked to providing services or to internal organization and operations. iii. Facilitating cross-organization internal processes: Internal public-sector processes involving multiple organizations, even at different government levels (e.g., control system provided by a national public agency to local municipalities).	8%
Managing Copyright and IPR	Public processes for decision-making regarding concessions, demonstration, or revocation of rights.	2%
Monitoring policy implementation	Processes for follow-up and assessment of policies by stakeholders to ensure they are developed, endorsed, enacted, and implemented.	1%
Payments and international transactions	Systems to support payments and international transactions.	5%
Prediction and planning	Management of resources available with prediction models (typically AI-based), providing request predictions from defined models and predicted target values for them to support planning.	1%
Procurement management	Public procurement refers to the adjudication process related to the purchase by governments and state-owned enterprises of goods, services, and works.	4%
Registration and data notarization processes	System to support legal registration of information or data.	10%

(*continued on next page*)

Table 2 (*continued*)

Activity type	Descriptions	Percentage
Service integration (various)	Integration of services is about adapting different digital services (even from multiple providers) to create another delivery channel of these services (part of or differently structured) to citizens and businesses.	3%
Supporting disintermediation	Applications adopting decentralized network architecture distribute workloads among several machines instead of relying on a single central server.	4%
Tracking of goods and assets along the supply chain	Provide better handoff of goods: Tracking technology allows you to know the exact location of goods in real-time, so as to ensure accuracy and updating of transfers between supply chain partners.	7%
	Total	100%

Source: (Bosch et al., 2022) and European Commission, Joint Research Centre (2022), https://github.com/ipsoeu/data/tree/main/metadata

Figs. 7 and 8 show the effects of blockchain in functions of "*social protection*" (14 cases) and "*environmental protection,*" respectively. In these functions, blockchain is used extensively in various processes and applications. The most significant effect is on improving public services and open government capabilities.

Secondly, Tables 3 and 4 present the results of research question RQ2. Depending on the type of project or application, the effects of blockchain in the public sector (core government functions) are visible at different levels: improved public service, open government capabilities, and administrative value. Table 3 shows the configurations commensurate with blockchain adoption, leading to different output effects. The fsQCA results indicate an overall solution coverage of 0.971 for public service, 0.173 for government capabilities, and 0.138 for administrative value. The overall solution consistency (> 0.80) is 0.930, 0.817, and 1, respectively. Only configuration 1a covers a substantial proportion of the outcome, while configurations 1b and 1c have low coverage. This was expected, as more than one technology is required to facilitate open government capabilities and improve administrative value. Nevertheless, the results at least show how blockchain affects these two variables. In summary, blockchain-based transformation project characteristics like geographical extent, development level, responsible organization, government functions, process type, application type, and recipients are critical conditions for high levels of improvement in the public service, open government capabilities, and administrative value.

We have also explored the different configurations of blockchain projects that lead to high operational and administrative performance. Table 4 shows the configurations that are sufficient to achieve a high level of operational and administrative performance. The findings indicate an overall solution coverage of 0.992, 0.179, 0.1643, and 0.1494, respectively–and an overall solution consistency (>0.80) of 0.888, 0.498, 1, and 0.813, respectively. For overall configurations, the essential characteristics of blockchain-based transformation projects that enable high operational and administrative performance are geographical extent, development level, responsible organization, government functions, process type, application type, and recipients.

5. Discussion

This study started from the premise that the adoption of blockchain by public sector organizations can improve various government functions. Therefore, an exploration of the literature showed us that the use of blockchain technology by public administrations could overall a positive trend and that blockchain technology could significantly improve the effectiveness and efficiency of public administrations (Batubara et al., 2018; Bustamante et al., 2022; Cagigas et al., 2021; Ølnes et al., 2017; Shahaab et al., 2023; Verma & Sheel, 2022). This research has highlighted the potential benefits of blockchain to create an environment of trust and alleviate notorious red tape (Bustamante et al., 2022), manage and share secure data (e.g., protection of critical data, digital property ownership) (Bustamante et al., 2022; Ølnes et al., 2017),

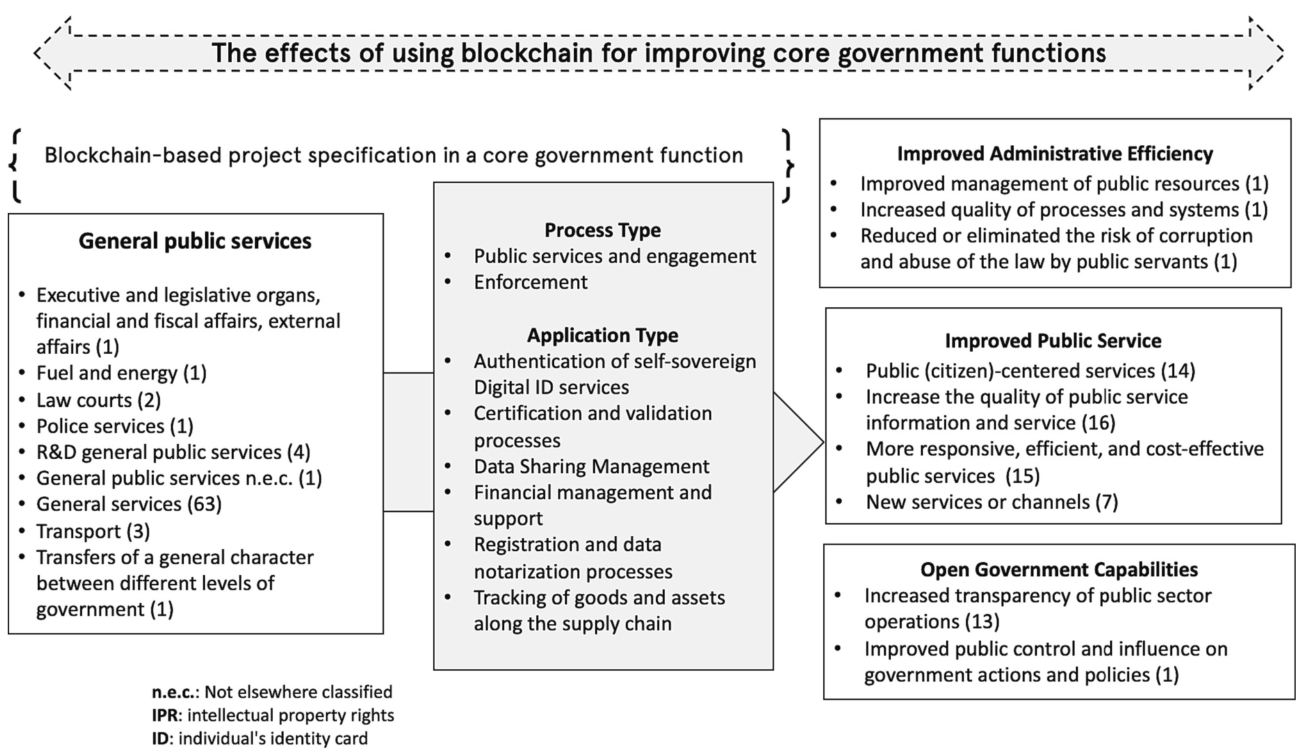

Fig. 3. Effects of blockchain on general public services.

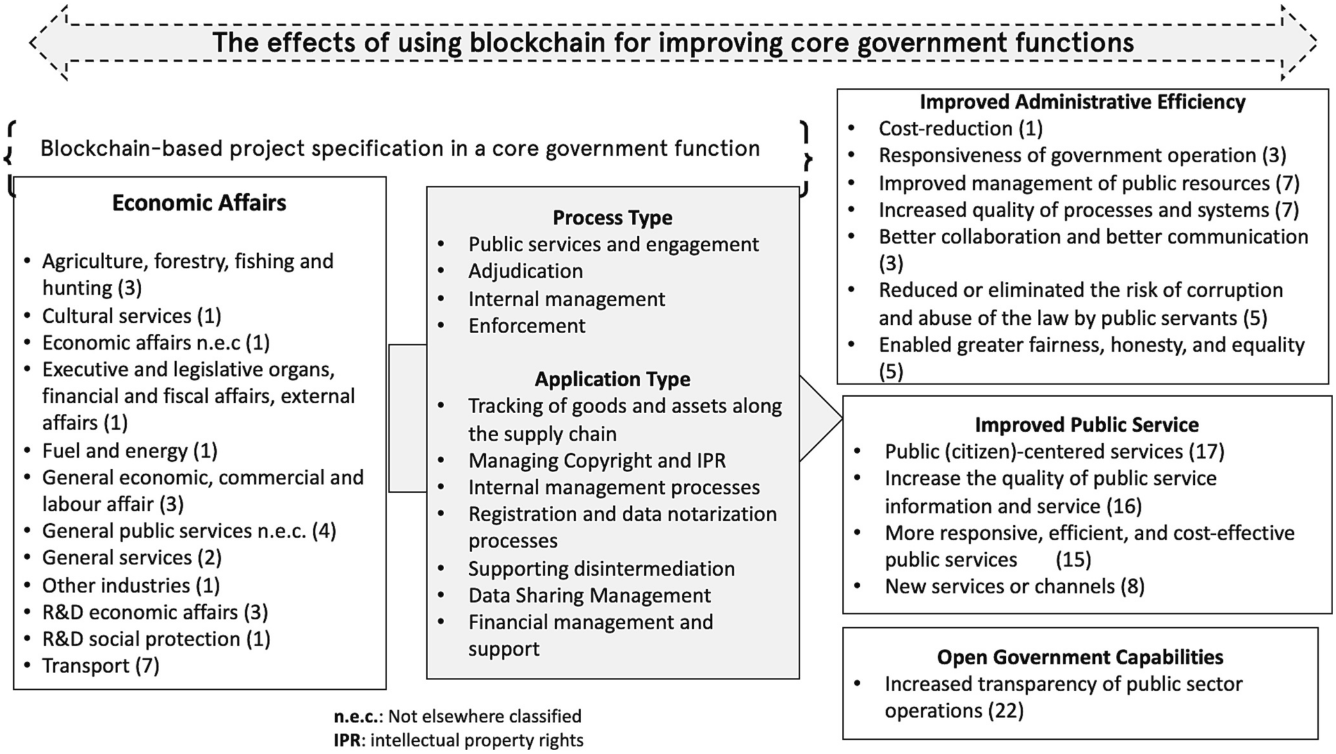

Fig. 4. Effects of blockchain on economic affairs.

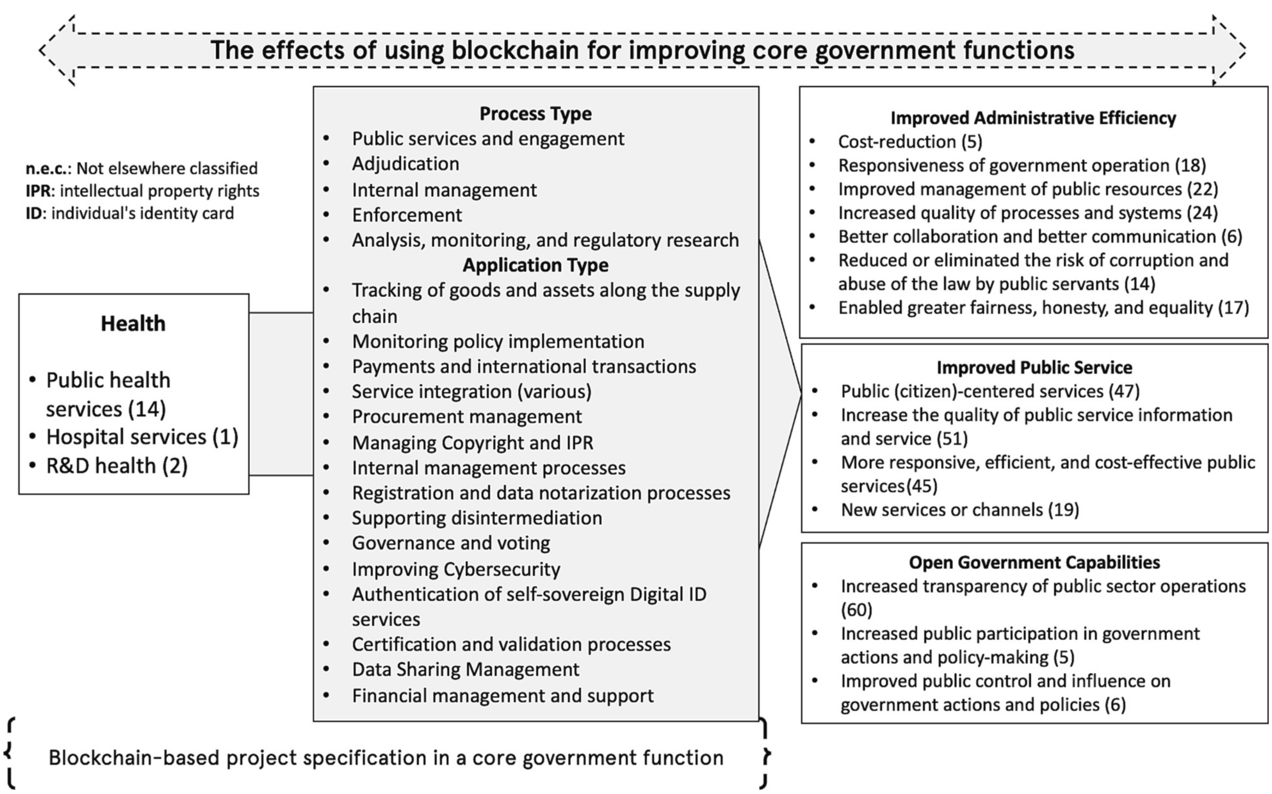

Fig. 5. Effects of blockchain on health.

build networked public services (Bustamante et al., 2022; Rukanova et al., 2023; Tan et al., 2022), reduce the risk of corruption and abuse by public officials (Bustamante et al., 2022; Reddick, Cid, & Ganapati, 2019; Yfantis & Ntalianis, 2022), increased trust in government (Cagigas et al., 2022; Ølnes et al., 2017; Treiblmaier & Sillaber, 2020), and track and traceability of government transactions (Bustamante et al., 2022). As public service is an economic activity of general interest defined, created, and controlled by the public authority and subject to a

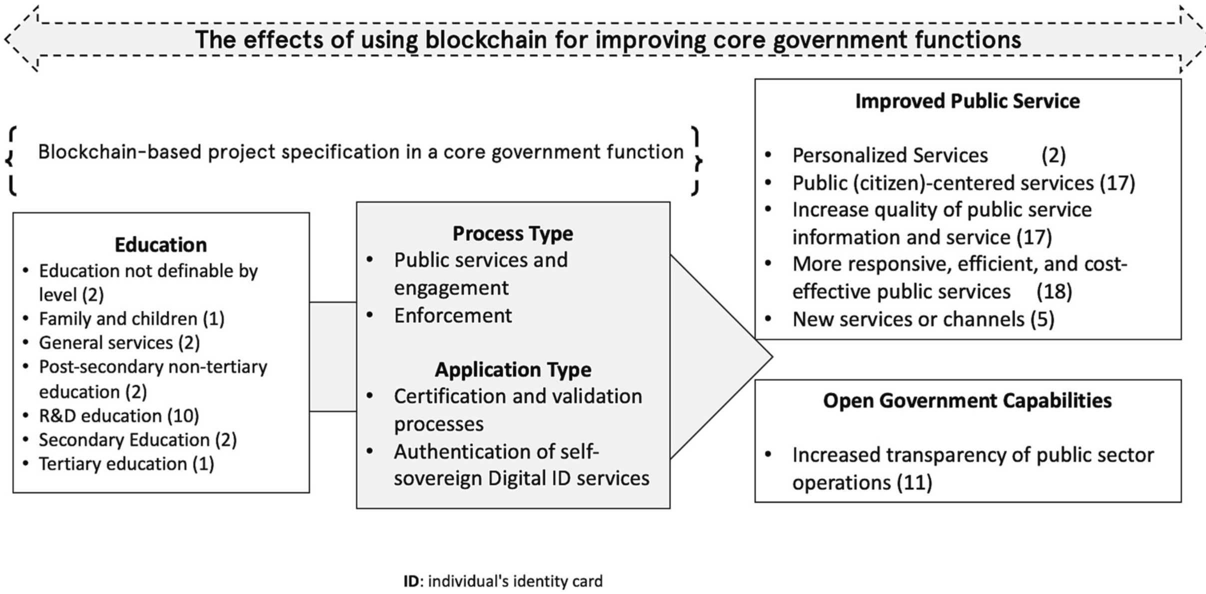

Fig. 6. Effects of blockchain on education.

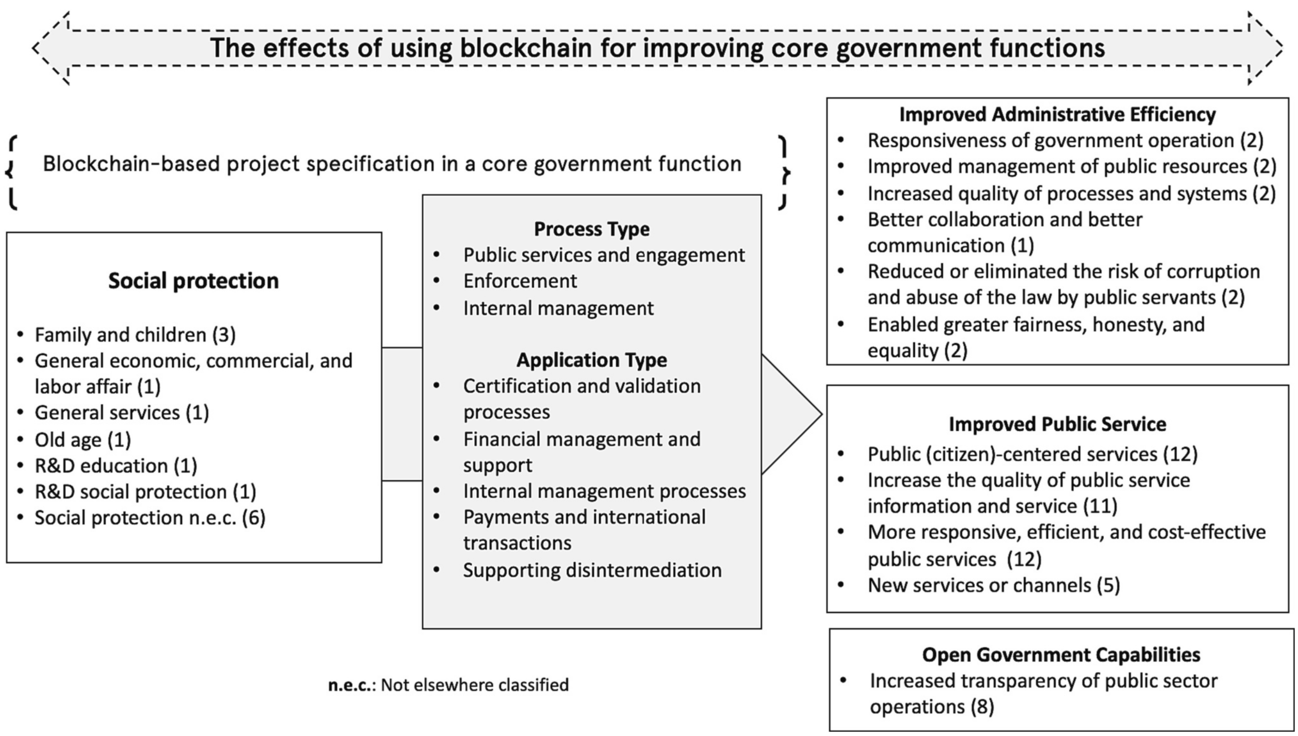

Fig. 7. Effects of blockchain on social protection.

particular legal regime to varying degrees, regardless of which organization, public or private, is responsible for actually providing it - blockchain is spreading widely across the various core functions of government (Allessie et al., 2019; Bosch et al., 2022). Among others, blockchain technology is commonly mobilized in functions (and their sub-sectors) such as "housing and community amenities" (Shahaab et al., 2023), general public services (Bustamante et al., 2022; Cagigas et al., 2022), economic affairs (Bustamante et al., 2022; Choudhry et al., 2019), health (Bustamante et al., 2022), and others (cf. Table 1). So, while the potential of this technology is significant, there needs to be more clarity between the expectations highlighted by the literature and the empirical research assessing the extent to which blockchain is currently being mobilized in transformation projects for the public sector. More specifically, there needs to be more understanding of the actual effects of blockchain applications in core government functions and the characteristics of these blockchain-based transformation projects that enable high effects to be generated in the public sector.

This article attempts to understand how implementing blockchain technology affects public services and organizations, mainly the core government functions. Following a database of blockchain-based transformation projects in the public sector across Europe, we show that the technology enables the public sector to improve public services, enhance the value or efficiency of public administration, and improve open governance capabilities. Furthermore, implementing

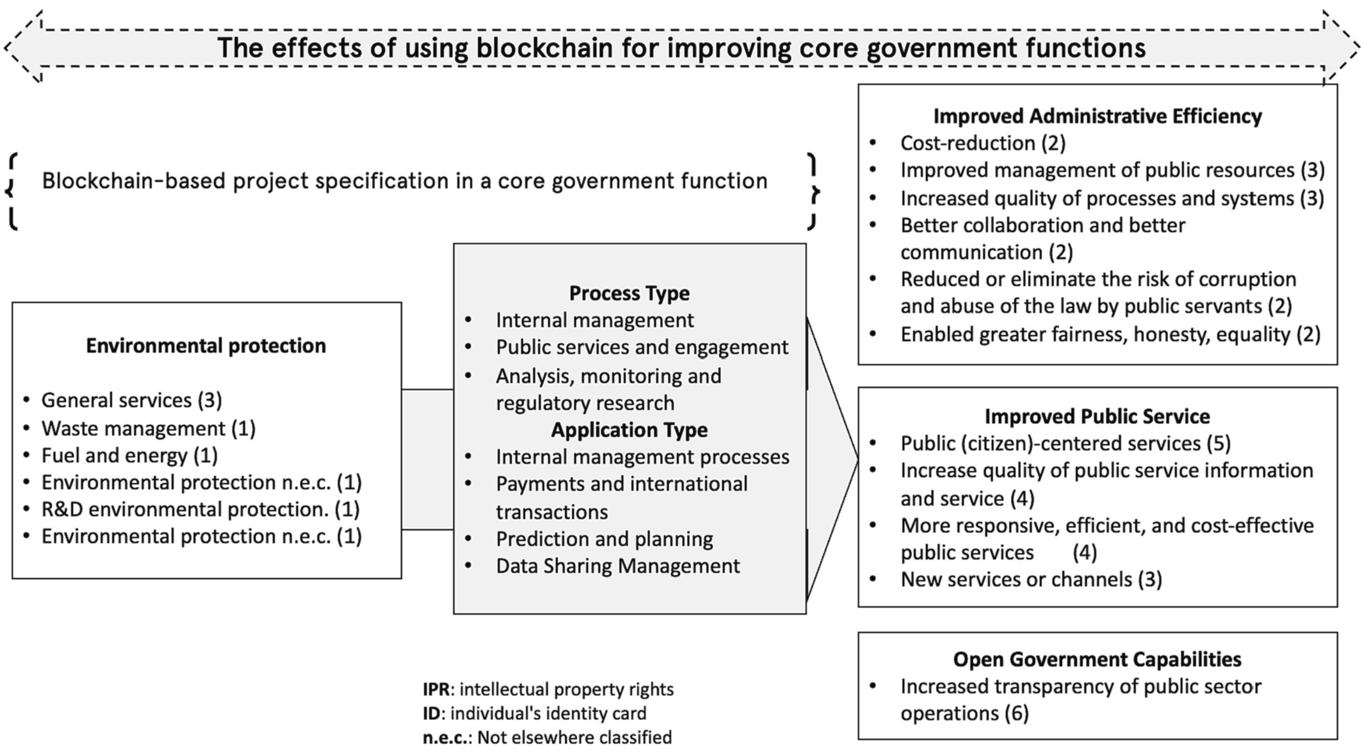

Fig. 8. Effects of blockchain on environmental protection.

Table 3
Main configurations of blockchain-based transformation projects that highly affect improvement in the public service, open government capabilities, and administrative value of core government functions.

Blockchain adoption features	Improved public service	Open government capabilities	Improved administrative value
	1a	1b	1c
Geographical Extent	●	●	●
Development level	●	●	●
Responsible Organization	●	●	●
Functions Government	●	●	●
Process Type	●	●	●
Application Type	●	●	●
Cross-Sector		●	●
Cross Border			●
Recipients	●	●	●
Raw coverage	0.971	0.173	0.138
Unique coverage	0.971	0.173	0.138
Consistency	0.930	0.817	1
Consistency cutoff	0.810	0.810	1
Solution coverage	0.971	0.173	0.138
Solution consistency	0.930	0.817	1

Table 4
Main configurations of blockchain-based transformation projects that highly affect administrative performance and operational performance of core government functions.

Configurations	Administrative performance		Operational performance	
	1a	1b	2a	2b
Geographical Extent	●	●	●	●
Development level	●	●	●	●
Responsible Organization	●	●	●	●
Functions Government	●	●	●	●
Process Type	●	●	●	●
Application Type	●	●	●	●
Cross Sector	○		●	○
Cross Border			●	
Recipients	●	●	●	●
Process innovation		●	●	○
Raw coverage	0.869	0.979	0.124	0.067
Unique coverage	0.012	0.122	0.096	0.039
Consistency	0.893	0.887	1	1
Consistency cutoff	0.886		1	
Solution coverage	0.992		0.164	
Solution consistency	0.888		1	

Legend: ● = presence of the variable; ○ = absence of the variable; blank = not considered in the solution.

transformation projects based on blockchain technology is generally geared toward improving public services. Blockchain-driven improvements stand at a 97.1% coverage rate in the public sector compared to 17.3% for "*open government capabilities*" and 13.8% for "*improved administrative value*." Indeed, the public sector uses blockchain first and foremost to improve its services (Bustamante et al., 2022; Rukanova et al., 2023; Scupola & Mergel, 2022; Spanò et al., 2023; Verma & Sheel, 2022). These results align with those of studies showing the added value of implementing digital or emerging technologies (e.g., blockchain, AI) in the public sector is the transformation of public services and organizations (Cagigas et al., 2021; Twizeyimana & Andersson, 2019; van Noordt & Misuraca, 2022; Zuiderwijk et al., 2021). In the case of blockchain, improvements in public services can be seen in the effects on: '*personalized services, public (citizen)-centered services; increased quality of public sector information and services; more responsive, efficient, and cost-effective public services; new services or channels*' (Bosch et al., 2022).

When it comes to improving administrative efficiency in the public sector, blockchain has effects on the following: cost reduction; responsiveness of government operation; improved management of public resources; increased quality of processes and systems; better collaboration and better communication; reduced or zero risk of corruption and abuses in law enforcement by civil servants; and enabled greater fairness, honesty, equality (Bosch et al., 2022). Other effects of blockchain on the public sector include increased transparency of public sector operations, increased public participation in government actions and policy making, and improved public control and influence on government actions and policies (Bosch et al., 2022). Several authors have already highlighted the advantages of integrating technologies in the public sector (Bustamante et al., 2022; Scupola & Mergel, 2022; Shahaab et al., 2023; Twizeyimana & Andersson, 2019; Zuiderwijk et al., 2021). For example, (Scupola & Mergel, 2022) demonstrates that public administrations' investments in the digital transformation of their citizen services and internal administrative processes enable them to improve service quality and generate public value (e.g., economic, social/societal, democratic, citizen, and administrative). Similarly, the application of blockchain in e-government improves administration (efficiency, open government capabilities, ethical behavior, and professionalism) and social value (public services, trust and confidence in government, social value, and well-being) (Bustamante et al., 2022; Ølnes et al., 2017; Rukanova et al., 2023; Shahaab et al., 2023).

Furthermore, this study highlights the transversal and universal nature of blockchain. Firstly, our results show that whatever government function has integrated this technology, we observe effects on the subsectors of that function. Secondly, integrating blockchain into a particular core function may affect a sub-sector of another core function. Indeed, blockchain can facilitate and optimize the secure implementation of networked public services, as the same project affects several core government functions. Our results also highlight that even for the time being, blockchain is widely diffused in the "*general public services*" function; the healthcare function remains where we find the possible applications of blockchain (Fig. 5). Indeed, healthcare is characterized by greater data sensitivity, which can be preserved and reinforced through blockchain (Aloini et al., 2023; Spanò et al., 2023; Upadhyay et al., 2021). As a result, in the public sector, blockchain is being mobilized to frame data-driven processes such as procurement, accreditation, data security, payment, or health insurance (Bustamante et al., 2022; Nanda et al., 2023; Spanò et al., 2023).

Concerning the results of the fsQCA analyses, we first note that there is one and only one possible configuration for achieving a high level of "*improved public service, open government capabilities, and improved administrative value*" (Table 2). However, there 02 configurations for achieving a high level of administrative and operational performance, respectively. The following section extends our observations from the fsQCA analysis.

5.1. Theoretical propositions for blockchain-based projects in the public sector

Owing to some fsQCA analysis of raw database inputs, our study highlights the critical implications of implementing blockchain-based transformation projects in the public sector. Firstly, while current literature focuses on how blockchain can be adopted and used in the public sector, this study takes a somewhat opposite track by focusing on the characteristics of public-sector transformation projects driven by blockchain. These characteristics should be considered when integrating digital technologies into the public-sector sphere. Such characteristics include the "cross-sector" and "cross-border" variables to be considered in technology adoption. So goes with those variables related to stakeholders in blockchain-based public transformation projects: "*central-government, local government, regional government, non-governmental, academic-research, private sector, community-led, consortium*." Depending on the category of blockchain project managers, the effects of implemented projects in terms of public service, administrative value, and open government capabilities can vary. Regarding the variable recipients in blockchain-based projects, according to (Shahaab et al., 2023, p. 13), "*another set of complex and multi-faceted socio-technical challenges remains within the interface between government organizations (G2G), between business and government (B2G), also between governments and citizens (G2C)*" can complicate blockchain-based projects. Based on these empirical observations, the following research propositions have been developed:

1) Proposition P1a: In the context of blockchain-based transformation projects in the public sector, in addition to adopting the technology itself, geographical extent, development level, responsible organization, government functions, process type, application type, and recipients are sufficient conditions for a high improvement in public services.
2) Proposition P1b: In the context of blockchain-based transformation projects in the public sector, in addition to the adoption of the technology itself, geographical extent, development level, responsible organization, functions of government, process type, application type, cross-sector, cross-border, and recipients are sufficient conditions for a high improvement of administrative value.
3) Proposition P1c: Besides adopting technology, geographical extent, development level, responsible organization, government functions, process type, application type, cross-sector, and recipients are sufficient conditions for high open government capabilities in the context of blockchain-based transformation projects in the public sector.

Despite slow diffusion in industries other than finance, blockchain managed to penetrate the public sector sphere, especially in the government's core functions. In the current literature, particular attention is paid to the adoption of blockchain in the public sector, emphasizing challenges, adoption factors, and benefits (Allessie et al., 2019; Berryhill et al., 2018; Luthra, Janssen, Rana, Yadav, & Dwivedi, 2023; Ølnes et al., 2017; Rana et al., 2022; Rukanova et al., 2023; Sharma et al., 2023). The adoption and use of blockchain in the public sector can transform public service processes, improve the value and efficiency of administration, and help governments develop open governance capabilities (Allessie et al., 2019; Berryhill et al., 2018; Ølnes et al., 2017; Rukanova et al., 2023). In this study, particular attention was paid to the link between contextual variables related to blockchain-based transformation projects in the public sector and impact variables, measuring the effects of the blockchain. Based on the results of the fsQCA analysis, two research proposals can be formulated:

1) Proposition P2a: Besides adopting technology, geographical extent, development level, responsible organization, government functions, process type, application type, cross-sector, recipient, and process innovation in public services are sufficient conditions for improved operational performance outcomes of blockchain-based transformation projects in the public sector.
2) Proposition P2b: Besides adopting technology, geographical extent, development level, responsible organization, government functions, process type, application type, cross-sector, recipient, and process innovation in public services are sufficient conditions for improved administrative performance outcomes of blockchain-based transformation projects in the public sector.

6. Implications

6.1. Implications for research

Firstly, this study addresses the concern raised by (Reyes et al., 2022), who recommended the need to extend research on blockchain by exploring case studies of implementations of this technology as it becomes universal in organizations. Our study focuses on a critical industry, the public sector, known to be the last to adopt innovative and digital technologies. Our study highlights the nature of blockchain technology's "General Purpose Technologies" (GPTs) in the public sector. Blockchain is not limited to a superficial adoption at the level of public services and organizations but radically transforms specific core processes and functions of public service. Likewise, our study provides a global view of blockchain effects on critical government functions. Future studies can build on our research to further explore the process of transforming each core government function through blockchain.

Secondly, we developed research propositions more deeply rooted in varied empirical evidence using multiple cases and the literature review (Fig. 2). Therefore, the framework we propose in this study is more generalizable and verifiable than the case with research on a single case study of a blockchain transformation project in the public sector. This aligns with (Eisenhardt & Graebner, 2007, p. 27), who argued that "*multiple cases also create more robust theory because the propositions are more deeply grounded in varied empirical evidence. Constructs and relationships are more precisely delineated because it is easier to determine accurate definitions and appropriate levels of construct abstraction from multiple cases.*"

Finally, using the fsQCA approach to analyze the data, we consider contextual variables related to blockchain-based transformation projects in the public sector. Therefore, we highlight configurations that can be interpreted in depth in future studies on adopting innovative technologies in the public sector. Our study contributes to the existing body of knowledge by moving from a more theoretical and anecdotal view (Jain & Simha, 2018; Reyes et al., 2022; Zhao, Qu, Xiang, Zhang, & Gao, 2023) to a more systematic analysis based on tangible examples.

6.2. Implications for practice

Firstly, this study serves as a tool to concretely popularize to actors (managers of public services and organizations or politicians) the added value of blockchain for core government functions in the public sector. Likewise, this study offers concrete evidence for leaders and managers of blockchain integration projects in core public sector functions, focusing on improving public services, open government capabilities, and administrative value. However, stakeholders must make significant organizational changes to implement blockchain before benefiting from these effects (Ølnes et al., 2017). For example, using blockchain to record government transactions and activities immutably improves transparency and makes officials more accountable to different stakeholders. This will involve profound changes to the opaque organizational structure of public services and functions to prepare public servants for the organizational transformations brought about by blockchain (Ølnes et al., 2017). Ditto for the use of blockchain to optimize administrative processes, which will automate not only administrative processes, reducing inefficiencies, delays, and costs but also make specific currently important positions/tasks in public functions disappear.

Secondly, the empirical evidence presented in this article can help decision–and policy-makers to identify applications, types of uses, and public service processes/procedures where blockchain can have a more significant influence. Indeed, this study does not only offer a mapping of blockchain in the public sector, emphasizing the different types of applications or processes supported by the technology and its effects on public services core functions. It also sheds light on indicators often overlooked in studies of blockchain adoption in the public sector. For example, the "*geographical extent*" indicator, which defines the geographical coverage of a blockchain-based transformation project, is crucial for any project in the public sector. Indeed, a project designed to transform public services via technologies at the national level differs from projects of only regional or local scales. This is also the case with the cross-sector, cross-border, and recipient variables, which remind us that the public sector encompasses several branches, organizations, and diverse stakeholders (often with local government and foreign services). So, to optimize the performance or capabilities of public services through blockchain, managers and executives need to consider these variables and their related challenges.

Finally, implementing blockchain in one core function of government also affected a sub-sector of another core function. As a result, those responsible for blockchain implementation projects in a core government function must simultaneously have a micro strategy (tailored for the government function in which blockchain is intended) and a macro strategy (taking into account other core government functions that will be affected by blockchain integration). Government officials in charge of public-sector-wide transformation projects are expected to develop relevant, appropriate strategies (for promoting sectoral adjustments around a common core) before tangible benefits from blockchain are gained in public services. First, they should consider planning and process transformation from a macro-organizational perspective (state or economic zone) while enabling strategy adaptation at a micro-organizational level (public agencies and services). Thus, they should (1) reinforce the excellence and structuring of state (regional or local) industrial sectors to deploy projects based on blockchain technology, (2) be at the forefront of technological issues regarding blockchain, (3) encourage innovative projects based on blockchain in several government functions, and (4) quickly adapt their blockchain strategy to recipients (G2G, G2C, or G2B).

6.3. Implications for policymaking

Blockchain technology can improve public administrations' effectiveness and efficiency. However, policymakers should carefully consider removing barriers to adoption (Batubara et al., 2018). Implementing use cases on a larger scale, facilitating collaboration, and ensuring legal certainty is crucial to progress in this area (Batubara et al., 2018; Skelaney et al., 2023).

Firstly, considering the benefits of blockchain technology in terms of data management issues (security, transparency, trust, interoperability) in the public sector, this technology could accompany the implementation of other data regulations at the country level (European Union's General Data Protection Regulation [GDPR]) (Belen-Saglam et al., 2023; Tatar, Gokce, & Nussbaum, 2020), especially in the various core government functions, as our study shows. Therefore, blockchain can (1) improve the quality of public information services, (2) increase the transparency of public services operations, and (3) increase participation in public government actions, and policy-making is sufficient evidence to make policymakers initiate and enforce relevant laws and regulations (Belen-Saglam et al., 2023; Schellinger, Urbach, Volter, & Sedlmeir, 2022; Tatar et al., 2020). In addition, this technology could help different socio-economic players implement personal data processing policies (frameworks or solutions) regarding several governments' core functions. For example, the immutability of actions performed on blockchain could facilitate the tracking of citizen-related data consent or actions in general public services (Belen-Saglam et al., 2023; Campanile, Iacono, Marulli, & Mastroianni, 2021; Schellinger et al., 2022; Tatar et al., 2020).

Integrating blockchain technology into the public sector is crucial for building open government capabilities. This requires policymakers to consider the role of blockchain as an important asset in achieving the objectives of open governance. Blockchain features should be regarded as in transformation projects in the public sector (Ølnes et al., 2017), as it can efficiently circulate information and enable stakeholders to understand better how public services operate, encouraging involvement and support for the collective project.

Thirdly, blockchain technology has the potential to improve public sector performance. However, its adoption must occur in compliance with laws and regulations. It can be challenging to integrate technologies into the public sector (Tan et al., 2020; WorldBank, 2023), but it is feasible with legal and policy strategies that integrate people, technology, and public entities. This is essential when planning the transition of processes to blockchain in the public sector. In this regard, political decision-makers should be able to assess the public service's capability to embrace blockchain, technological maturity, technical skills, and the match between the technology's potential and the service's needs. Likewise, a knowledge development policy for blockchain technology is welcome to prevent public officials' reluctance toward blockchain. Policymakers must develop strategies to assess the value of blockchain technology across different sectors and define targeted effects areas. Blockchain should be adapted to business applications, and policies for building an ecosystem adapted to blockchain technology should be promoted. Interoperability between various public services and organizations involved is crucial. Notably, silo-based public services with a high degree of heterogeneity in actors and systems are hard to comprehend and underpin with high-impact innovations like blockchain (Shahaab et al., 2023).

6.4. Limitations

In terms of limitations, it is worth mentioning that case studies are lowly accessible to the public, and this may hinder the generalization of our results to other activities. It would be interesting to add case studies from different sectors of activity to make the results more generalizable. Secondly, the database exploited contains case studies still being implemented or in the pilot phase. In such cases, a lack of final results potentially brings some bias in the evidence of blockchain effects. Future research may reuse this same database once these blockchain-based transformation projects are completed.

Third, the case studies presented in the database need to present the significant diversities across different public services and organizations. Indeed, the adoption or acceptance of technology differs from one public entity to another (Cagigas et al., 2022; Reddick et al., 2019). As a result, evidence about the effects of blockchain technology in public services and organizations may be diverged. Therefore, future studies may mobilize qualitative research to explore the changes brought about by blockchain in various core government functions (organizations). Moreover, as an improvement, this research could be complemented by a preliminary (quantitative) study on adopting or accepting blockchain technology in the public sector context. For such exercises, classical theories, models, and concepts (e.g., Technology Acceptance Model, Theory of Planned Behavior, diffusion of innovation theory, Technology Readiness Index, Unified Theory of Acceptance and Use of Technology, Trust, Regulatory Support, and Technology Affinity) may be deployed to understand better disparities in the different public services and organizations (cf. Kamble, Gunasekaran, & Arha, 2019; Reddick et al., 2019; Wong, Tan, Lee, Ooi, & Sohal, 2020).

Fourth, our study relied heavily on publicly available data, which limits its scope. While we used a database built by a European Union organization, the data was still secondary and had undergone prior processing. To improve future studies, using primary and secondary data is recommended by mobilizing multiple data collection tools.

Fifthly, this limitation is addressed by echoing (Twizeyimana & Andersson, 2019) concern about the lack of research into the application of digital technologies in the governments of the least developed countries. Future studies could conduct comparative research between these categories of countries to highlight other factors essential to blockchain's public sector transformation.

Finally, it would be interesting to explore in depth the effects of blockchain on the different government core functions, taking into account the two dualities of blockchain technology (permissioned [e.g., "*Hyperledger fabric*" and "*R3 Corda*"] vs. permissionless [e.g., bitcoin, Ethereum, and others cryptocurrency]) (Alketbi et al., 2020; Berryhill et al., 2018; Sedlmeir, Lautenschlager, Fridgen, & Urbach, 2022; WorldBank, 2017; Wüst & Gervais, 2018).

7. Conclusion

Following an exploratory case study approach supported by literature, this study explores the effects of blockchain technology on the public sector. One hundred sixty-seven case studies of blockchain-based transformation projects across Europe (Bosch et al., 2022) were analyzed, demonstrating a pervasive usage of blockchain in public sector services and organizations. Similarly, the cases show the envisaged effects of using blockchain-based applications to reduce the cost and time of information exchange between public sector stakeholders. The following effects of blockchain technology use are also noted: (i) reduced level of bureaucracy, discretion, and corruption; (ii) increase in automation, transparency, audibility, and accountability of information for the benefit of citizens and other stakeholders; (iii) increased citizen and business trust in government processes (Aliti et al., 2022; Bosch et al., 2022; Cagigas et al., 2022; Tan et al., 2022). Furthermore, the framework proposed in this paper illustrates how blockchain can affect process innovation and operational and administrative performance in public services and institutions.

CRediT authorship contribution statement

Samuel Fosso Wamba: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Serge-Lopez Wamba-Taguimdje:** Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Qihui Lu:** Conceptualization, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. **Maciel M. Queiroz:** Conceptualization, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

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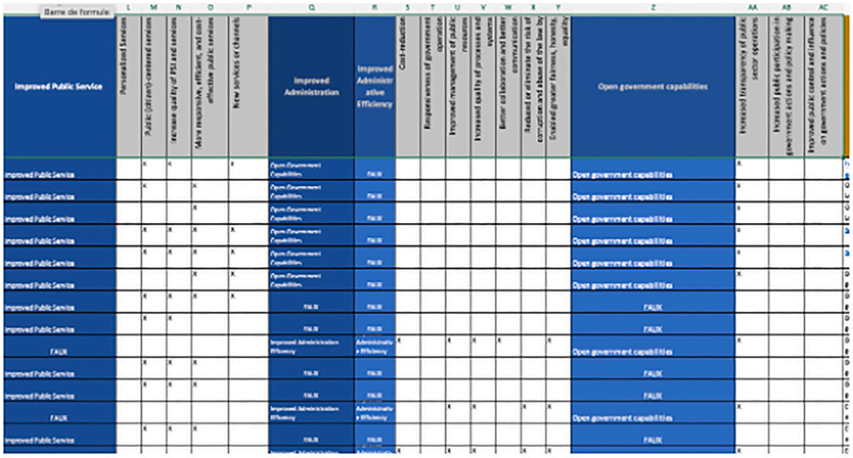
Appendix A. Appendix

Variables	Description
Responsible organisation	Public sector organizations are organized across eight categories: Central-Government, Local Government, Regional Government, Non- governmental, Academic-Research, Private sector, Community led, Consortium.
Geographical extent	This layer defines the administrative level where the case is being deployed. This indicator follows the administrative tiers as identified by Nomenclature of Territorial Units for Statistics (NUTS). It must be considered that some countries have 4 or 5.
Functions of Government (COFOG I)	The Organization for Economic Co-operation and Development (OECD) developed the COFOG classification as a standard for classifying the purposes of government activities. The United Nations Statistical Division publishes it, and this report uses the version from 1999.
Process type	Classification of five high-level types of government decision-making tasks commonly implemented with basic processes/tools and potentially governed by blockchain. This indicator is a first type of Algorithmic Governance (Engstroem, Stanford) classification inside the public sector. Blockchain Solution are classified by on how they support government decision making and implementation in certain type of common processes.
Recipients	Type of services classified by interaction: Government to Citizen (G2C), Government to Government (G2G) and Government to Business (G2B).
Cross- sector	This category refers to cases that involve different public administration sectors.
Cross- border	This category refers to cases that involve organizations from different countries.
Development level	This category refers to the implementation status of the cases: pilot, in development, implemented, no longer in use or planned.
Application type	This category refers to a particular purpose or use of technology in solving a problem or performing a specific function. It is a mean between different cases collection sources (not standardized).
Improved public Service	Refers to different service improvements offered by e-government based on blockchain.
Open Government Capabilities	Refers to impacts on openness, transparency, participation, communication, and collaboration to provide personal or corporate influence and control on government actions or policy.
Improved Administrative Value	Refers to the internal point of view of the administration and includes purposes of efficiency, effectiveness, and others, for better management of public resources and the economy.

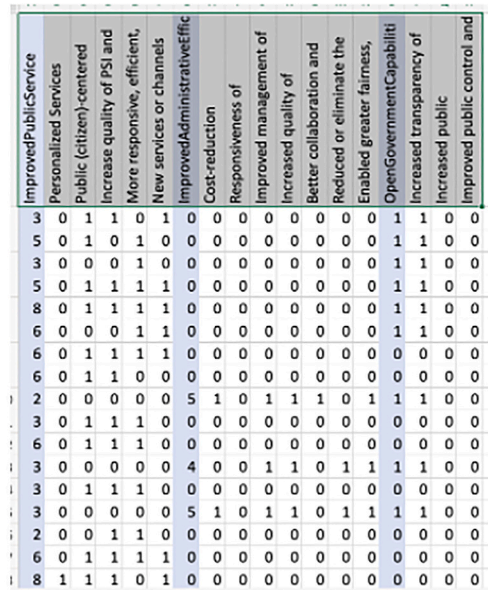
Fig. A1. Variables and descriptions.
(**Source**: (Allessie et al., 2019; Bosch et al., 2022))

Process Type	Application Type
Adjudication	Taking decisions on benefits Managing Copyright and IPR Monitoring policy implementation
Analysis, monitoring and regulatory research	Innovating Public Policy Information analysis processes Prediction and planning Management of auditing and logging Certification and validation processes Improving Cybersecurity
Enforcement	Predictive enforcement processes Supporting inspection processes Smart Recognition processes Registration and data notarisation processes Procurement management Internal primary processes
Internal management	Internal support processes Internal management processes Financial management and support Data Sharing Management Governance and voting Payments and international transactions
Public services and engagement	Supporting disintermediation Engagement management Authentication of self-sovereign Digital ID services Service integration (various) Service personalisation (various) Tracking of goods and assets along the supply chain

Fig. A2. Process Types and Application.
(**Source**: (Allessie et al., 2019; Bosch et al., 2022).)



(a) Raw data



ImprovedPublicService	Personalized Services	Public (citizen)-centered	Increase quality of PSI and	More responsive, efficient,	New services or channels	ImprovedAdministrativeEffic	Cost-reduction	Responsiveness of	Improved management of	Increased quality of	Better collaboration and	Reduced or eliminate the	Enabled greater fairness,	OpenGovernmentCapabiliti	Increased transparency of	Increased public	Improved public control and
3	0	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0
5	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0
3	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0
5	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
8	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
6	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0
6	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	5	1	0	1	1	1	0	1	1	1	0	0
3	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	4	0	0	1	1	0	1	1	1	1	0	0
3	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	5	1	0	1	1	0	1	1	1	1	0	0
2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

(b) Data after coding

Fig. A3. Examples of the data coding process.

Variables	Examples of case study
Process Innovation in Public Services	"The benefits of an immutable ledger to verify the validity of data as close to the source as possible has a positive effect on the accuracy of downstream analytics, where any error in source data would be magnified in output datasets, … We can absolutely verify the data that we've collected from every single device, … we make sure that data is accurate at source, and after that point we can verify that it's never been changed, it's never been tampered with. The system will allow us to demonstrate our commitment to providing safe patient care" (Case study 68, IPSO blockchain dataset). Source (s): http://rb.gy/aj6eh, http://rb.gy/7jngq, http://rb.gy/cr4a2, and http://rb.gy/gqjoh
Enhancing Operational Performance	"The first blockchain pilot OGD (open government data) – Change Protocol and Notarization enables independent checks to be made as to whether data records of the city of Vienna existed at a specific time. The checksums of OGD of Vienna are stored in public blockchains and can be retrieved by the interested public. The users can thus view and check the authenticity and history of the data independently of an intermediary institution. The application of blockchain solutions in administration seems paradoxical at first, because it questions the authority as a mediator between state and citizens, on the other hand, we see great potential in simplifying administrative processes and democratic interaction" (Case study 12, IPSO blockchain dataset). Source(s) : http://rb.gy/al9zm and http://rb.gy/gqjoh.
Improving Administrative Performance	• "After months of experimentation and hard work I am proud of the result achieved. The correct enhancement and traceability of the skills is for us at Lirax a strategic point on which Italy and Europe can rebuild their value … Enhancing and objectively tracing educational and work skills will undoubtedly be the keystone for the national relaunch," said Alessandro Civati, president and CEO of Lirax (Case study 12, IPSO blockchain dataset). Source(s) : http://rb.gy/knecp and http://rb.gy/gqjoh • "Dubai stands to unlock 5.5 billion dirhams in savings annually in document processing alone – equal to the one Burj Khalifa's worth of value every year: Moreover, for the acceleration and facilitation of blockchain solution prototyping, the Blockchain Platform as a Service was created in partnership with telco Du to give all government entities the freedom to build on a shared framework based on their business needs. Smart Dubai is going paperless. Dubai is digitizing the 1 billion sheets of paper produced each year by digitizing all services, including visa applications, bill payments, and license renewals. These previous records will now be securely transacted using blockchain technology". Source(s) : https://rb.gy/an7d7 and http://rb.gy/54e6s).

Fig. A4. Examples of case study extracts.

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