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Abstract

This report provides an overview and analysis of the status of blockchain technology implementation in Europe's public sector. An inventory of 167 blockchain technology use cases from national, regional and local European governments map the use of blockchain technology in public services. Each use case provides insights into the level of adoption of this technology. The findings highlight the use of blockchain technology by public administrations as an overall positive trend and that blockchain technology could significantly improve the effectiveness and efficiency of public administrations. However, public administration must take many steps before blockchain technology can solve their real-life challenges. The breaking down of barriers to blockchain technology adoption requires significant consideration by policymakers. Progress in this area will depend on increasing efforts to implement more large-scale use cases, facilitating collaboration between organisations and providing legal certainty. These results contribute to the existing body of knowledge on the topic by moving from a more theoretical and anecdotal view to a more systematic analysis based on concrete examples.

Executive summary

Objectives

The report's primary goal is to offer an overview of the situation in Europe regarding blockchain technology (hereafter blockchain) adoption in the public sector by analysing the collected data. Moreover, it seeks to provide a series of recommendations mainly addressed to public officials aiming to develop and use blockchain-based solutions within public administration. The evidence and insights of an inventory of blockchain-based use cases in the public sector serve as the basis for the analysis.

Policy context

The European Commission strongly supports blockchain on the policy and funding fronts, recognising the importance of legal certainty and a clear regulatory regime in areas related to blockchain-based applications. In addition, one of the most relevant parts of its blockchain strategy includes building with the European Blockchain Partnership (EBP), which regroups to date all the Member States, Norway, Liechtenstein and Ukraine as observer; the European Blockchain Services Infrastructure (EBSI), a blockchain based infrastructure governed by public authorities. Moreover, EUR 347 million of EU funding has been planned and used in the last 5 years to support blockchain-related research and innovation.[1]

Furthermore, the Commission recently released a proposal for regulating crypto assets, updating anti-money laundering rules for crypto assets and creating a pan-European regulatory sandbox for innovative blockchain solutions. Moreover, there are other policy initiatives related to blockchain ongoing in the EU, such as the new Regulation on electronic identification and trust services or the new Data Act. Finally, the Interoperable Europe Act will ensure that these different legislative initiatives are able to work in a highly complex and constantly changing trans-national European context, and thus current and future cross-border and cross-sector interoperability needs.

Key conclusions

Blockchain is still in its early stages with respect to technology and adoption in the public sector. The analysis highlights the growing evidence of early-adoption projects showing that public administration can use this technology in creative and interesting new approaches in providing services and fulfilling their requirements. Moreover, it reveals widespread interest on all levels of public administration and many other sectors to better understand this technology and embrace its benefits, accelerating the digital transformation of processes, services and organisations.

However, although blockchain has a clear disruptive potential, the reality shows that public administration must take several steps before blockchain can solve many of their real-life problems. Implementing a blockchain-based solution is more complex than a typical IT project as it presents a variety of technical, organisational, and legal challenges. Moreover, there is still a lack of empirical evidence to better understand the suitability of blockchain technology to solve the problems faced by public administration. Creating awareness inside public administration regarding the potentialities of this technology along with experimentation seems to be the way forward. In this regard, the launch of EBSI to create an interoperable and standard blockchain infrastructure that enables cross-border public services is fundamental in promoting support for blockchain-based services across Europe. This initiative helps for preparing and accelerating the digital transformation of public services, and the way they interact with citizens and businesses leveraging the new Web 3.0 paradigms.

Main findings

The study includes an overview of 167 blockchain-based use cases in the public sector across Europe, characterised by different features and qualities. The main results from this analysis are:

- The number of cases increased rapidly in 2018. In the following years, the overall positive trend continued but the rate of growth decreased.
- More than half of the use cases are pilot projects. Only 16% have been implemented, fully developed and used in daily operations within the public administration.

[1] https://digital-strategy.ec.europa.eu/en/news/overview-eu-funded-blockchain-related-projects

- National governments have developed more than half of the cases analysed, contributing the human and financial resources to sustain development. At the same time, 20% of the cases are at the local level and 11% at the regional level, meaning that blockchain is not only accessible to large national governmental agencies.
- The cases embrace various application types, sectors and governmental functions of the public administration, from certification and validation in the education sector to financial management for social protection, tracking of goods and assets in the supply chain, or governance and voting.
- Only 12% of the cases are cross-border. This number also indicates that the level of interoperable services is currently low.

Policy recommendations

Thanks to the evidence collected, it is possible to formulate some recommendations for public managers dealing with blockchain-based solutions and implementation. The recommendations focus on which elements public organisations should consider when approaching blockchain implementation in the public sector. The recommendations are:

- Public administration should raise internal awareness regarding the possibilities provided by blockchain by considering blockchain-based solutions as a real option and experimenting and discovering its benefits and potential to be exploited.
- Blockchain adoption should be treated as a complex project, which needs to include: the evaluation of suitability, scalability and feasibility with a pilot project, a clear roadmap for its implementation, along with risk and impact assessment analyses.
- Public administrations should increase and strengthen the collaboration with other public organisations and the private sector to experiment and implement new blockchain use cases. At European level, it is important to leverage the cooperation framework and infrastructure created through the European Blockchain Service infrastructure (EBSI).
- Public administrations should avoid the creation of digital silos by promoting interoperability and facilitating international collaboration with cross-border use cases deploying large-scale applications.
- Public administrations should consider legal aspects at the early stages of experimentation and implementation to become aware of the possible obstacles the project will face when moving into production after a successful proof of concept.

The European Commission, thanks to the European Blockchain Partnership (EBP) and with the launch of the European Blockchain Services Infrastructure (EBSI), is moving in this direction, i.e. towards the promotion, development, piloting and deployment of blockchain-based services across Europe.

1 Introduction

The origin of blockchain technology began in 1991. Stuart Haber and W. Scott Stornetta published an academic paper titled "How to Time-Stamp a Digital Document" (Haber and Stornetta, 1991), which envisioned the first "blockchain" architecture. The work introduced a practical computational solution to the time-stamping problem of digital documents. This is achieved by calculating hash values[2] of documents, saving them with a timestamp and linking the records in a data structure by including the hashes of previous records' certificates. This way, it is possible to prove that a document existed at a certain time in a specific version. In 1992, Bayer Merkle trees were added to the system (Bayer, Haber, and Stornetta, 1999). Years later, in 2008, an anonymous (or group of) author(s) called Satoshi Nakamoto (Nakamoto, 2009) took Stornetta and Haber's work to new heights adding a crypto-economic incentive layer using "proof of work" consensus to the blockchain data-structure. The consensus is based on a mechanism in which nodes in a distributed network agree on proposed transactions, making the blockchain completely decentralised. This way, there is no need for central intermediaries. This new concept has many disruptive implications because nobody would ever be in control of anything, such as improving transparency and digital trust. In other words, the blockchain is a secure peer-to-peer distributed ledger used to record transactions across many computers ensuring data integrity, immutability and consistency.

Nowadays, blockchain is a more mature technology, which is already in use and has the potential to be used even more in coming years. It can be implemented with significant advantages in different sectors. Among those, the public sector is one area where blockchain can exploit all its potential with significant benefits.

The journey towards the introduction of blockchain in government is still ongoing and in an initial phase. However, some important projects are starting to emerge. The time has now come to begin exploring the benefits and potentialities of the use of this technology within the public sector. For example, timestamping and document traceability, the first use case tackled by Stornetta and Haber, is a well-known blockchain use case employed by some governments in various applications.

Furthermore, many new projects and applications take advantage of the capabilities of blockchain technology and are introducing new concepts and ways to understand processes and services. These capabilities have caught the attention of governments as blockchain technology can reduce bureaucracy, increase the efficiency of administrative procedures, and increase trust in public recordkeeping (Allessie, Sobolewski, and Vaccari, 2019).

At policy level, the European Commission strongly supports blockchain. It recognises the importance of legal certainty and a clear regulatory regime in areas related to blockchain-based applications. In addition, one of the most relevant parts of its blockchain strategy includes building with the European Blockchain Partnership (EBP), which regroups to date all the Member States, Norway, Liechtenstein and Ukraine as observer; the European Blockchain Services Infrastructure (EBSI), a blockchain based infrastructure governed by public authorities. 347 million € of EU funding has been planned and used in the last 5 years to support blockchain-related research and innovation.

This study presents the results of mapping the use of blockchain technology to support public services in the EU. To our knowledge, the analysis is the first attempt to propose a landscape of the current state of the art in Europe. Overall, 167 use cases of blockchain in the public sector have been collected and analysed. The data provides an advanced overview of European government's efforts to integrate blockchain in their operations and adopt blockchain-based innovative public services in the public sector. Moreover, the entire database has been published as open data in the JRC data portal[3] to give policymakers and the research community access to the raw data in the hope of fostering further research based on this data collection.

This study focuses on answering the following research questions:

- What is the current state of adoption of blockchain technology in the public sector in Europe?
- Which blockchain applications are more often used to test and/or implement public services?
- Which public administration sectors are testing and/or implementing blockchain-based public services?

[2] The hash values are returned by a hash function being a cryptographically secure and collision free function that allows the verification of the integrity of data.

[3] https://data.jrc.ec.europa.eu/dataset/8b6240ad-926f-404f-b685-04a2d3ae93d6

– Which actions will accelerate the adoption of blockchain-based public services for the benefit of society and citizens?

There is insufficient knowledge of the impacts the actual use of blockchain technologies and their continued use, which opens the door for further research trials (AlShamsi, Al-Emran, and Shaalan, 2022). Analysing the current European landscape of blockchain-based public services is crucial to understand better and address the adoption challenges of this technology. In this direction, the main objective of this report is to provide an overview of the situation in Europe regarding blockchain adoption in the public sector by analysing the collected data. In this way, based on original evidence and insights on an inventory of blockchain-based use cases in the public sector, the study offers a series of recommendations, mainly addressed to public officials, aiming to develop and use blockchain-based solutions within public administration.

The study begins by providing an overview of the adoption of blockchain technology in Europe, addressing its potential impact on the digital transformation of Europe, its benefits and challenges (Section 2), and which strategy the European Commission follows (Section 3). Then, it describes the methodology used for collecting the use cases (Section 4) which form the basis of the quantitative analysis presented in (Section 5) with the objective of better understanding current trends in blockchain technology adoption in the public sector. The study ends with some policy implications and proposes recommendations based on the analysis conducted and reported in the previous sections (Section 6) and finally the conclusions (Section 7).

1.1 Blockchain definition and difference from distributed ledger technology

In this section, we briefly define blockchain technology, its characteristics and functionalities to provide fundamental knowledge about it. Moreover, it is important to highlight the differences between blockchain and distributed ledger technology (DLT), in order to avoid possible confusion or misunderstanding.

There are many definitions of blockchain technology, and because blockchain technology is developing rapidly, its associated terminology is also growing. For our study, we base the definition on the one provided by the report "Blockchain for digital government" (Allessie, Sobolewski and Vaccari, 2019).

Blockchain is a **type of distributed ledger**, this ledger has the following inherent characteristics:

- A peer-to-peer network (P2P) shares the ledger among the nodes of a computer network.
- The value exchange transactions (digital assets in the form of cryptocurrencies, tokens or information) are sequentially grouped into blocks.
- The network nodes validate the transactions through a "consensus mechanism".
- Every new block created is attached to the general ledger and chained to the previous block and recorded immutably across the network adding copies to all network nodes using cryptographic trust and assurance mechanisms.
- These blocks form a single chain, called a "blockchain".
- Depending on the implementation, transactions can include programmable behaviour (Smart contracts).

These characteristics of blockchain architecture and design provide properties such as transparency, robustness, auditability and security. Moreover, the innovation of blockchain technology is in the fact that it introduces a new management paradigm **removing the need for an intermediary**. It replaces traditional consensus mechanisms (hierarchical systems or third-party trust systems) with a distributed consensus mechanism that is transparent and community driven and open source (in the case of public blockchains). Removing the need for intermediaries can have many advantages in public administration, including reducing costs or increasing data integrity, as the failure of any node does not compromise the data. In addition, public organisations frequently deal with personal and confidential information and can benefit from safe and secure transactions preserving the confidentiality of the records.

DLT is also a decentralised database. Participants have decentralised control over data, and many nodes participate in the distribution, administration and data exchange. However, not all DLTs can be called a blockchain, and the difference is that blockchain organises data specifically into a series of blocks. In addition, despite both being usually decentralised, DLT allows the possibility of having a central figure granted some

degree of control over the entire network. In summary, we can state that blockchain is a type of DLT with a specific setting.

Regarding the application of blockchain or DLT, in many cases, both technologies are suitable since blockchain is an offshoot of DLT. An example of the use of DLT systems in the public sector is Central Bank Digital Currency (CBDC). Although DLT technology is still developing, many governments around the world are exploring its capacity and suitability to create CBDCs. CBDCs are one of the most relevant use cases where DLTs could be better suited than blockchain, as they allow a certain level of oversight.

2 Blockchain adoption for public services

2.1 Potential benefits

Blockchain has clear disruptive potential, allowing people and organisations who may not know or trust each other to collectively agree on and permanently record information without third-party authority. This way, by creating trust in data, blockchain has the potential to revolutionise how we share information and carry out transactions online. Fields such as research and public and private sectors are exploring its applicability to solve real-life problems. In this regard, many use cases have been proven, for example, in the private sector, especially those linked to cryptocurrencies, fintech and other financial services. In the public sector, use cases undertaken in recent years show that blockchain, as an emerging technology, can be used in interesting new approaches or services to answer public sector challenges.

Governments may find in blockchain an opportunity to transform internal processes, policies and services, allowing them to better respond to the real needs of citizens by enhancing the efficiency and effectiveness in delivering public services. The reasons governments want to use blockchain to digitally transform services and organisations bring together a wide range of drivers. The efficiency that blockchain-enabled services might bring to the public sector, for example, increasing transaction speed, could lead to cost savings or disintermediating trusted third parties. Other potential benefits might be increased transparency, technical trust in the recording of transactions on the chain (auditability), fraud avoidance, reduced corruption, resilience, better data quality, and security.

Defining specific use cases helps governments to realise the benefits of blockchain technology. In this regard, we have selected some illustrative examples to understand better how governments can embrace the benefits of blockchain.

Real estate and land registry

Real estate is one of the fields where blockchain is being tested to better understand its possible applications and potential benefits. Blockchain could be used as a tool for reflecting and accrediting legal property transactions where security and transparency are crucial. The *Lantmäteriet* (the official Swedish Land Registry) tested a blockchain-based solution for land-title transfers creating a secure, efficient and trusted process of land transfer in digital form end-to-end through the blockchain. It increased transaction speed by digitising the existing analogue process that recorded the transfer of registries. The time between signing a contract and the property title registration went from four months to a few days (McMurren, Young, and Verhulst, 2018), which should also lead to cost savings. Transparency and trust in the process also increase as the system captures all the information and makes it visible to all parties before signing. In addition, thanks to this transparency and the immutable properties of blockchain, the process is less vulnerable to error and fraud. It is auditable because the chain records all transactions permanently, and all parties can keep digital records. However, as the adoption of blockchain is still in its early stages, its potential benefits in the land registry field remain open. Although blockchain technology could allow the tokenisation of real estate assets and the possibility of registering the transmission of the tokens issued with full legal guarantees, blockchain cannot be set up as a legal registry of rights because, as a technology, it cannot perform an independent legal rights assignment and cannot carry out an independent and responsible legality control of the facts, acts or legal transactions that are reflected in its nodes (Sieira and Campuzano, 2019).

Digital academic credentials

Documents are easy to falsify and difficult to verify. Using a blockchain solution, governments can provide an attested and permanently time-stamped electronic version of a document anytime. An example of this is the issuing of academic credentials using blockchain. In this area, the European Blockchain Services Infrastructure (EBSI), has successfully piloted, on its pre-production network, the exchange of verifiable education credentials

in six cross-border pilots involving over 12 European countries.[4] For example, in one of these cross-border pilots a student can apply for a PhD with a bachelor's/master's degree from a foreign country. This pilot aims at simplifying the process behind issuing and verifying the credibility of bachelor's, master's and PhD credentials. Moreover, it brings together national projects from three countries (France, Greece and Romania). Around 20 universities have participated in the EBSI Multi university project in 2022 leveraging on the work of EC funded projects initiated at National level.

Another example of digital academic credentials is a use case implemented by the University of Lille, with the support of EBSI through the French governmental project fr.EBSI. Since July 2021, this university has issued digital credentials for all its graduates using blockchain technology[5]. University students receive a link to display a digital credential after their graduation. They can store it in a secure personal wallet and present it to any other university, administration or recruitment platform. Credentials are instantly recognised as valid and authentic without contacting the issuing university. This way, giving control back to citizens when managing their academic credentials can significantly reduce verification costs and improve authenticity trust. A trusted digital identity for citizens must supplement these verifiable academic credentials, which can also be a blockchain-based service, and this brings us to the following example.

Identity Management

Users need trustable digital identities to authenticate and log into, for example, e-government services. Based on a trusted third party, traditional identity management systems suffer from various design-inherent issues, including single points of failure, lack of interoperability and privacy issues (Pöhn, Grabatin, and Hommel, 2021). Thanks to blockchain technology, a trusted third party no longer plays a key role in the management of personal data, which become guarded precisely by the users. Open Government of Catalonia (AOC), in collaboration with Howest University and the company Validated ID deployed a use case in 2021, where students can obtain discounts on municipal utilities using their digital identity based on their college student ID card. This use case is a cross-border example of proof of interoperable verified credentials of European students to access discounts on public services of local councils.

Asylum process management

The current asylum process includes issuing various certificates on paper. However, in this procedure, there are many inefficiencies and security risks; for example, checking the authenticity and validity of paper certificates is a major challenge. In this regard, the German Federal Office for Migration and Refugees (BAMF) aims to migrate the current German asylum process to a blockchain-based system. Blockchain allows cross-organisational refugee management supporting the participating nations in reducing the duration and error rate of the European asylum process. BAMF developed a prototype (Guggenmos et al., 2019) used by staff at various public authorities involved in the asylum process to issue relevant certificates to asylum seekers in digital form, verify their authenticity and process their validity status. Asylum seekers may carry the certificates as a QR code, either in a smartphone app or paper printout. This solution reduces the effort in verifying the certificate's integrity, makes it more secure against forgery and reduces the administrative workload. The Asylum process management project is expected to be further developed in the context of the EBP and EBSI initiative.

2.2 Challenges

Challenges arise despite all the benefits and opportunities that blockchain technology can bring. According to the research paper "Challenges of Blockchain Technology Adoption for e-Government: A Systematic Literature Review" (Batubara, Ubacht, and Janssen, 2018) many studies indicate that blockchain-based applications have not yet materialised in full in the public sector. Furthermore, the efforts to utilise blockchain technology have only just begun, the adoption of blockchain-based applications is still minimal, and there is a lack of empirical evidence. Most of the analyses found in the literature focus on discussing potential benefits, costs or risks

[4] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Verifiable+Credentials+Success+Stories
[5] https://www.univ-lille.fr/fileadmin/user_upload/presse/2022/white_paper.pdf

without deep-diving into specific cases already implemented, or focusing on case studies without including sufficient empirical evidence (D. Cagigas et al., 2021).

Implementing a blockchain use case is difficult as a blockchain-based solution in the public sector faces a multitude of challenges. As a summary of the different challenges that may arise, **Table 1** categorises them following the technology, organisation, environment (TOE) and framework (Eveland and Tornatzky, 1990) applied to the adoption of blockchain technology (Batubara, Ubacht, and Janssen 2018).

Table 1. Challenges of blockchain adoption

TOE framework	**Technological**	**Organisational**	**Environmental**
Main Challenges	Security Scalability Flexibility	New governance models Acceptability	Laws Regulations support
Other Challenges	Reliability, Interoperability / Compatibility Cost effectiveness Computation efficiency General application platform Storage size, Immaturity Design variables	Business model / Organisational Risk of error for complex business Implications Trust, Auditing Organisational readiness	Support infrastructure Accessibility

Source: Batubara, F. R., Ubacht, J., & Janssen, M., (2018)

Another important challenge highlighted by the existing literature is the need for strong inter-organisational collaboration (Premkumar and Ramamurthy 1995). The adoption of blockchain is comparable to the adoption of inter-organisational systems (IOS) (Koster and Borgman 2020). It requires the cooperation and commitment of all the participating members. They may have complex economic and business relationships that can result in social, political and economic challenges that influence the blockchain's adoption and implementation. Trust plays an important role in this context and positively influences technology adoption. Conversely, adoption increases confidence among involved parties, as in the case of blockchain, it works as a "trustless" proof mechanism as parties can trust the system instead of intermediaries Furthermore, governments must develop strategies for collaborating and partnering with the private sector. The lack of blockchain-related technical expertise within governments makes it essential to build communities of practice across the sectors (OECD, 2019) and public-private partnerships (PPPs) to bring public agencies and private firms together to develop new blockchain-based public services. Examples include large consortia such as Hyperledger[6] and the Crypto Valley Association in Switzerland.[7],[8]

To summarise, during the implementation process of a blockchain-based solution many challenges arise due to its characteristics. Hence, it is crucial to separate hype from reality and have a close understanding of blockchain's scope of implementation. Although blockchain could be a suitable technology to solve many administration problems, at the same time its implementation can bring other novel problems. In some cases, many associated advantages of blockchain-based solutions could already be gained with traditional solutions. An example of this can be found in the area of land registries (Ooi, Kian Peng, and Soh, 2022).

[6] https://www.hyperledger.org/
[7] https://cryptovalley.swiss/
[8] Similarly, the idea behind the EBP/EBSI is to create such large consortia, putting public authorities in a leading role.

3 The European Commission's blockchain strategy

Co-authored with Maxine Lemm (EC DG DIGIT) and Pierre Marro (EC DG CNECT)

The European Commission strongly supports blockchain on the policy, legal and regulatory, and funding fronts. The most significant parts of its blockchain strategy include building its own blockchain infrastructure. It aims to protect consumers and provide legal certainty for businesses through The European Blockchain Services Infrastructure (EBSI)[9] and by developing a pro-innovation legal framework[10] for digital assets and smart contracts. The Commission recently released a proposal for regulating crypto assets[11] updating the anti-money laundering rules for crypto assets and creating a pan-European regulatory sandbox for innovative blockchain solutions.

Moreover, the EU provides funding for blockchain research and innovation through grants in the Horizon Europe programme[12] and supporting investments.[13] Furthermore, the EU supports the use of blockchain in fostering sustainable economic development, interoperability and standards, and blockchain skills development.[14] It interacts with the private sector, academia and the blockchain community through the International Association of Trusted Blockchain Applications (INATBA)[15] and the European Blockchain Observatory and Forum.[16]

3.1 Regulatory and policy context in the EU

There are different policy initiatives ongoing in the EU. The first one, Markets in Crypto Assets (MiCA), will apply directly across the EU without national implementation laws. The European Commission published a proposal on 24 September 2020, aiming to provide a regulatory framework for digital assets for Member States by 2025. MiCA is part of the European Commission's Digital Finance Strategy. On 14 March 2022, the European Parliament adopted its negotiating position on MiCA, subject to an intense debate concerning the environmental impact of mining activities. MiCA defines the regulatory treatment of crypto assets not covered by existing financial services legislation. The crypto assets that are included in the scope of MiCA are: e-money tokens, asset-referenced tokens (stablecoins) and utility tokens. Hence, MiCA, among other aspects, will support innovation and fair competition by creating a framework for issuing and provision of services related to these crypto assets. MiCA is now close to adoption; the European Parliament vote should happen in early 2023.

A new proposed Regulation (EU)14, of 3 June 2021, aims to amend the eIDAS Regulation by establishing a new regulation on **European e-ID**.[17] This proposal, which is not yet final, seeks to further enhance the eIDAS to create a paradigm shift in European digital identification of citizens and companies. The European e-ID proposal introduces a harmonised approach in a European Digital Identity Wallet, being a secure, trusted and efficient identification process based in Self Sovereign Identity, granted by the State, which offers a significant improvement as it gives complete control to the user. Moreover, the issuer of this wallet will not collect information about its use, and personal data will be physically and logically separated from any other data held by the user.

On 23 February 2022, the European Commission released the new **Data Act**[18]. Published as a proposal, it will ensure fairness in the digital environment, stimulate a competitive data market, open up opportunities for data-driven innovation and make data more accessible for all. In this context, smart contracts facilitate smooth data sharing while offering effective technical protection of the data and the underlying database. Moreover, Chapter VIII of the draft Data Act addresses smart contracts and interoperability, as smart contracts can take different forms depending on their nature, mode of activation, use and storage. More concretely, Article 30 lays down

[9] EBSI webpage: https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/EBSI
[10] Legal and regulatory framework for blockchain: https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-blockchain
[11] EU regulatory framework for crypto-assets: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12089-Financial-services-EU-regulatory-framework-for-crypto-assets_en
[12] Horizon Europe: https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[13] Blockchain funding and investment: https://digital-strategy.ec.europa.eu/en/policies/blockchain-funding
[14] Through the Digital Europe Programme https://digital-strategy.ec.europa.eu/en/activities/digital-programme and The Chaise Project https://chaise-blockchainskills.eu/about-the-project/
[15] The International Association of Trusted Blockchain Applications (INATBA) https://inatba.org/
[16] The European Blockchain Observatory and Forum https://www.eublockchainforum.eu/
[17] https://digital-strategy.ec.europa.eu/en/library/trusted-and-secure-european-e-id-regulation
[18] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113

the standards for smart contracts to be deployed under EU rules. The idea is to establish essential requirements for professionals who create smart contracts for others or integrate them into applications that support the implementation of agreements for sharing data. Harmonised requirements will promote interoperability and facilitate the use of smart contracts to provide data holders and recipients with guarantees that conditions for sharing data are respected.

All of these different legislative initiatives work in a highly complex and constantly changing transnational European context, and thus current and future cross-border and cross-sector interoperability needs to be ensured. The European Interoperability Framework (EIF) is the guiding document for the creation of interoperable solutions and public services. It gives recommendations on four different levels of interoperability, including: legal, organisational, semantic and technical.

Interoperability policy on the European level has been evolving in recent years. It has been recognised that a stronger legal framework is needed, and thus in November 2022, the European Commission came up with the **Interoperable Europe Act.** The aim is to ensure a consistent EU approach to interoperability, establish an EU-wide interoperability governance structure, and also to set up an ecosystem of reusable and interoperable solutions for public administrations. Chapter 3 of the Act sets out measures to support the implementation of the Regulation. These include support for innovation and innovative solutions. It promotes the uptake of these solutions in public administrations. In the context of blockchain, the work on interoperability is also supported by the International Association for Trusted Blockchain Applications (INATBA) as well as EBSI.

Finally, the European Commission is going to launch by end of 2022/early 2023 a European regulatory sandbox. It will be instrumental to enable regulators, users as well as providers of DLT and blockchain technologies to interact in a trusted environment. Projects in the sandbox will include both EBSI use cases and a broad range of other blockchain applications across key industry sectors. The goal of the regulatory sandbox is to foster a dialogue and cooperation between national and EU-level regulators and lawmakers with companies and thus remove legal uncertainties for use cases based on decentralized solutions on blockchain and potentially in combination with other technologies, such as Artificial Intelligence or Internet of Things. This initiative should help promote the establishment of an open European GovTech ecosystem, including increased cooperation with small and medium-sized businesses (SMEs) and start-ups.

3.2 The European Blockchain Services Infrastructure (EBSI)

The European Blockchain Services Infrastructure (EBSI) aims to accelerate the creation and delivery of cross-border blockchain-based services for public administrations and their ecosystems to verify information and make services trustworthy. Created in 2018 by the European Blockchain Partnership (EBP) as follow-up of a joint declaration at ministerial level, is a partnership between the 27 EU Member States and Norway, Lichtenstein, and Ukraine as observer, deploys a network of distributed blockchain nodes across Europe, supports applications focused on selected use cases, and is the first EU-wide blockchain infrastructure driven by the public sector.

EBSI focusses on developing use cases starting from four broad Use Case families, which all take advantage of the core features of blockchain technology (immutability, tamper-evidence, decentralisation). These are:

- Verifiable credentials use cases – **verification**: Using the internally recognised W3C's Verifiable Credentials standard to ensure interoperability, a self-sovereign information ecosystem is created where holders of credentials (*claims*) can control when and how their credentials are verified using EBSI's ledger to check the accreditation of the issuing entity. Verifiable Credentials make information hard to falsify, but easy to verify
- Track and trace use cases – **traceability**: Ensuring the integrity and tracing the evolution of data or documents; monitoring of products in the supply chain through their digital passport
- Trusted data exchange use cases – **accountability**: Enhancing the implementation EU policy and compliance procedures between administrations e.g., for asylum demand management or exchange of VAT numbers for import products, by providing means for secure data sharing among customs and tax authorities (and others)
- IP management use cases – **intellectual property**: Facilitating right holders' checking and management of intellectual property

Under these four use case families, domain-specific, cross-border use cases were identified and developed by EBSI. The most advanced Use Cases fall under the Verifiable Credentials family:

- Verifiable Credentials:
  - **Student mobility – Education Credentials:** A holder (student) can request an educational credential (e.g., diploma) from an accredited issuer (e.g., university) and present it a verifier (e.g., employer) using their digital wallet. The verifier can check the accreditation of the issuing university on ledger instantaneously. This reduces time and cost of verification, while preserving personal data and preventing forgery.
  - **Worker mobility – European Social Security:** Enables the exchange of the PDA-1 document of posted workers, which ensures the transfer of their social security entitlements across borders, and prevent social security fraud

Other Use Case families are also at various stages of development. An overview of some of EBSI's other use cases can be found below:

- Track & trace:
  - **SME Financing:** To facilitate new sources of funding, or the funding provision from different sources, in particular for innovative SMEs.
  - **Product and Document Traceability**: Which can be used in different areas, like the use of document charactering a product or specific steps in the supply of the product, which can be used for circular economy purposes or to facilitate the management of programmes/projects through the timestamping of documents and checking facilities.
- Trusted Data exchange:
  - **Asylum Process Management:** Facilitation of the management of cross-border and cross-authority processes in dealing with asylum applicants
- IP Management:
  - **EUIPO Anti-Counterfeiting:** Helps rights holders to manage their intellectual property along the entire value chain (from manufacturing to distribution)

Furthermore, the future evolution of EBSI requires new and improved solutions. In this respect, the European Commission launched the Pre-Commercial Procurement (PCP)[19]. The aim of the PCP is to go significantly further than what is offered by existing solutions by developing new services for EBSI. The tendering for the PCP started end 2020, with the objective to lead to the deployment of solutions within the next three years.

3.3 Other initiatives

Other initiatives in Europe promote and accelerate the use of blockchain in the public sector. One of them is the **European Digital Innovation Hubs (EDIHs)**,[20] which plays a crucial role in supporting public administrations in moving forward with the use of blockchain by assisting in the experimentation.

Another initiative is **Blockchain in Government (BLING)**.[21] BLING started in 2018 and is an Interreg North Sea Region Programme project. It aims to accelerate and reduce the risks of deploying blockchain-based services in governments across the North Sea Region. It brings together public authorities, knowledge institutions and SMEs to develop and deploy blockchain-based public services focusing on identity, direct democracy and customer services. BLING is one of the first dedicated platforms to bring these new tools and approaches into local and regional services.

Another initiative is the **TOKEN**[22] (Transformative Impact of Blockchain Technologies in Public Services) project. TOKEN is an EU-funded project launched in January 2020 and aims to develop an experimental ecosystem to enable the adoption of DLTs. It proves its value through highly replicable use cases by providing a range of decentralised agnostic technological components, thereby facilitating the piloting and adoption of blockchain/DLT-based public services. TOKEN is also a hub for actors interested in how decentralised

[19] https://digital-strategy.ec.europa.eu/en/news/european-blockchain-pre-commercial-procurement
[20] https://digital-strategy.ec.europa.eu/en/activities/edihs
[21] https://northsearegion.eu/bling/
[22] https://token-project.eu/

technologies can impact and improve public organisations. Moreover, the project provides four use cases in Belgium, Greece, Spain and Poland.

Finally, another relevant initiative is the project **Chaise**,[23] 4-year transnational initiative funded by the European Commission under the Erasmus+, Sector Skill Alliance call for proposals, to set forward a sectoral approach to blockchain skills development.

[23] https://chaise-blockchainskills.eu/

4 Blockchain case collection and validation methodology

The collection of blockchain-based public services use cases across Europe conducted by the authors and with additional contributors between 2020 and 2021 provides the basis for this report. Overall, 167 cases have been collected and analysed. The data allow the authors to draw a picture of the uptake of blockchain public services across Europe. This landscape can describe the state of development in Europe, display trends over time and identify gaps in technology take-up in specific sectors or areas. It is important to mention that during this period, the COVID-19 pandemic has increased the need to accelerate the digital transformation of public services and has boosted the learning process from the experiences of implementation and deployment of blockchain technology in public services.

The first batch of cases was published in 2020 with 65 cases. The cases were published in open data and made available to the community. After the publication, the case collection continued until December 2021, combining different sources of information:

- 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
- Internet scouting: news articles collected through internet search
- Scientific and grey literature
- A collaboration with the Digital Agenda Observatory of the Politecnico di Milano[24]

Each identified case went through a precise and structured procedure before its inclusion in the database, with a correct data assurance process and validation. This process consisted of the involvement of at least on other researcher to double-check the information and categorisation. For critical cases, the whole team was involved in making the decisions. For the cases collected at the beginning of this activity, a "maintenance" double-check of the information was undertaken after several months to examine any modification.

4.1 Applied taxonomy

One of the most important parts of our methodology is the application of an adequate taxonomy to categorise and analyse the collected cases. For this reason, we designed a broad taxonomy adapted to blockchain-based public services cases to describe its features and context of use. This way, we better understand the value that this technology can create. Furthermore, in addition to providing a categorisation and overview of the collected blockchain-based use cases, the taxonomy also provides a well-structured approach for categorising cases. The research community can benefit by reusing it since the use cases are available as open data for additional secondary analysis by others. The taxonomy for blockchain cases categorisation (Figure 1) includes:

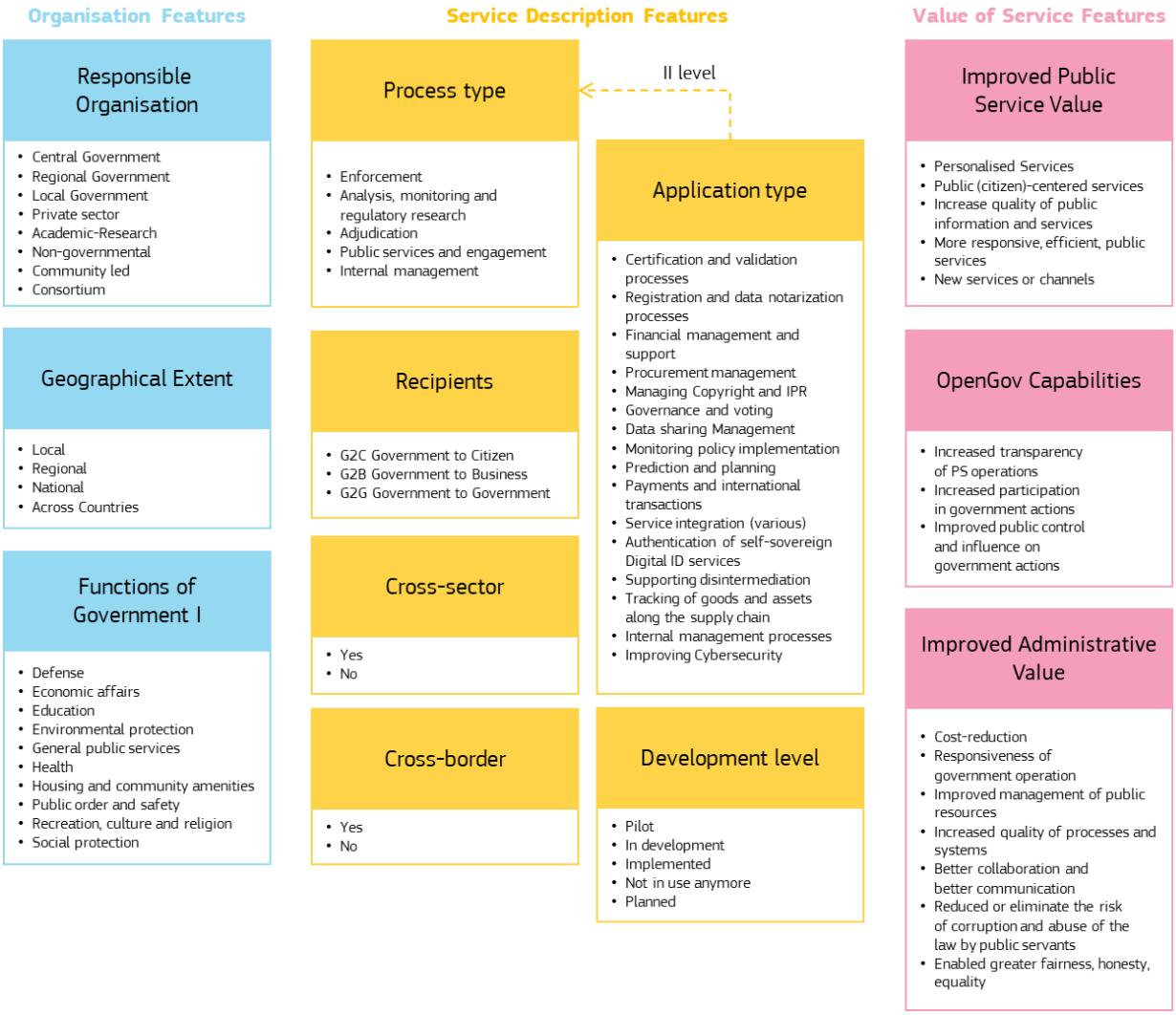
- General information of the use case: in particular, the name of the system, a description thereof and the start and end year – if any
- The status of the project: either planned, in development, implemented or no longer in use
- Contextual public sector related information: in particular, the level of government and the policy domain in which the system is being used (following the Classification of the functions of government, COFOG)

The overview is reported in **Figure 1**. **Table 2** provides a brief explanation and the main classification references.

Where applicable the taxonomy is coherent with other activities related to monitoring the adoption of emerging technologies in the public sector, for example, the taxonomy used on collecting artificial intelligence cases in the public sector (Tangi et al., 2022) and recently published by the Joint Research Centre of the European Commission. This creates consistency and potentially an easier comparison among data collection activities.

[24] https://www.osservatori.net/en/research/active-observatories/agenda-digitale.

Figure 1. Taxonomy for blockchain case categorisation



Source: JRC own elaboration

Table 2. Description and sources of the taxonomy's features

	Features	**Description**	**Source**
Organisation	Responsible organisation	Public sector organisations are organised across eight categories: Central-Government, Local Government, Regional Government, Non-governmental, Academic-Research, Private sector, Community led, Consortium	JRC's own elaboration
	Geographical extent	This indicator follows the administrative tiers identified by Nomenclature of Territorial Units for Statistics (NUTS)19.	Nomenclature of Territorial Units for Statistics (NUTS)
	Functions of Government	The Organisation for Economic Co-operation and Development (OECD) developed the COFOG classification as a standard for classifying the	OECD

	(COFOG I)	purposes of government activities. The United Nations Statistical Division publishes it, and this report uses the version from 1999.	
Service	Process type*	Classification of five high-level types of government decision-making tasks commonly implemented with basic processes/tools and potentially governed by AI	Freeman Engstrom et al., 2020
	Recipients	Type of services classified by interaction: Government to Citizen (G2C), Government to Government (G2G) and Government to Business (G2B)	JRC's own elaboration
	Cross-sector	This category refers to cases that involve different public administration sectors	JRC's own elaboration
	Cross- border	This category refers to cases that involve organisations from different countries	JRC's own elaboration
	Development level	This category refers to the implementation status of the cases: pilot, in development, implemented, no longer in use or planned	JRC's own elaboration
	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 standardised)	JRC's own elaboration
Value for Public Service	Improved public Service	Refers to different service improvements offered by e-government	Twizeyimana and Andersson, 2019
	OpenGov Capabilities	Refers to impacts on openness, transparency, participation, communication, and collaboration to provide personal or corporate influence and control on government actions or policy	Twizeyimana and Andersson, 2019
	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	Twizeyimana and Andersson, 2019

Source: JRC's own elaboration

The features "Application type" * and "Process type" * require a more in-depth explanation. The idea beyond this classification is to understand the purposes and activities of blockchain implementation, which reflects in establishing a governmental functional-related classification. The category "application type" seeks to detail more the activity for which the solution was developed (**Table 3**). The design of this classification aims to answer the question, "What activity does the blockchain technology support?" It should be considered an experimental proposal achieved following a pragmatic trial and error process.

Table 3. Application types descriptions

Application Type*	**Description**
Monitoring policy implementation	Processes that follow and assess policies implementation to ensure they are developed, endorsed and implemented
Prediction and planning	Processes for management of resources based on prediction models in order to support planning
Internal management processes	Processes that provide management, control and decision support tools necessary to achieve public administrations' objectives
Data sharing management	Data sharing processes that support accesses to data, consider interoperability and data licensing (e.g., open data)
Certification and validation processes	Processes where public administration provides citizens or other organisations with an official document attesting or validating a status or a certain right
Registration and data notarisation processes	Systems to support legal registration of information or data
Service integration (various)	Service integration is the management of the integration of multiple service suppliers and information sources in order to provide a tailored new specific service to citizens, other organisations or even for internal purposes
Financial management and support	Processes for providing social protection or financial support to citizens, other organisations or for internal purposes
Procurement management	Public procurement refers to the adjudication process related to purchases by governments and state-owned enterprises of goods, services and works
Managing copyright and IPRs	Processes within the public sector used for making decisions regarding concessions, demonstration or revocation of rights
Governance and voting	Management of governance process or voting processes
Payments and international transactions	Systems to support payments and international transactions
Authentication of self-sovereign Digital ID services	Decentralised system that enables user authentication through Digital ID, being the user the ultimate owner of his or her personal data
Supporting disintermediation	Applications that adopt decentralised network architecture distributing workloads among several machines, instead of relying on a single central server
Tracking of goods and assets along the supply chain	Tracking technology that allows knowing where goods are located at any time, so that transfers between supply chain actors are accurate and up to date
Improving cybersecurity	Cybersecurity is the application of technologies, processes and controls to protect systems, networks, programs, devices and data from cyber-attacks

Source: JRC's own elaboration

The category "Process type" is described in **Table 4**. It includes the main governance process type in which public sector organisations are and could potentially apply emerging technologies. The classification relies on the one proposed by Freeman Engstrom et al., 2020.

Table 4. Governance process types descriptions

Process type*	**Description**
Enforcement	Tasks that identify or prioritise targets of agency enforcement action
Analysis, monitoring and regulatory research	Tasks that collect or analyse information that shapes agency policymaking
Adjudication	Tasks that support formal or informal agency adjudication of benefits or rights
Public services and engagement	Tasks that support the direct provision of services to the public or facilitate communication with the public for regulatory or other purposes
Internal management	Tasks that support agency management of resources, including employee management, procurement and maintenance of technology systems

Source: Engstrom, Ho, Sharkey, & Cuéllar, (2020)

4.2 Limitations

Before getting into the main subject of the report, this section introduces several limitations that need to be kept in mind. First, despite the width and depth of this exercise, the information gathered from public information was clearly limited by its availability in the public domain and the research team's search capacity. For this reason, we do not claim the completeness or representativeness of our landscape. The results presented here can give an indication about where blockchain is used in the public sector in Europe, but the results do not aim at being representative of the situation regarding the maturity of blockchain adoption in Europe or in any specific Member State.

Second, the correct interpretation, assessment and subsequent categorisation of the data collected strongly depend on the intelligibility of the information. Sometimes, the information available is vague, limited or not accessible in English; with the necessity of it having to be translated. Hence, this process must be done thoroughly under the discretion and expertise of the authors and, despite the best attempts of the research team, there can be misinterpretations or wrong categorisations. However, it is assumed that the overall statistics are slightly affected by individual inaccuracies.

Third, our research does not consider the evolution of a concrete case over time, as normally the information is collected in a snapshot taken at a specific moment. Consequently, it is possible that a case, for example, collected in 2020 might be in a different status today, and this information is not publicly available. This can be relevant for the cases that have been publicly announced, and later discontinued in the pilot phase without publishing this information.

Fourth, issues regarding the interpretation of what blockchain is and what it is not can arise. For example, one of the most common misunderstandings is to think that blockchain and DLTs are one and the same, when in fact not all DLTs are blockchain. Another example is the case of X-Road – a centrally managed distributed Data Exchange Layer (DXL) between information systems – that was developed and launched by Estonia's Information System Authority (RIA). By April 2018, several articles erroneously stated that X-Road is a

"blockchain-based technology or it utilises blockchain internally"; this was denied by an article[25] regarding the underlying technology of X-Road, published by the Nordic Institute for Interoperability Solutions (NIIS).

Furthermore, the definition of public sector varies among countries depending on the legislation that governs the state-owned organisations. This fact can also lead to confusion as it is not always clear if an organisation is public or private. This is especially frequent in domains like health, agriculture, energy and transport, as well as others, since they are often included in the discourse on the public sector. Moreover, there is always a grey area or mix of private-public organisations, such as private organisations partially or totally owned by the government. This might result in incorrect categorisation or an incorrect decision for the inclusion or exclusion of a certain case.

Despite the aforementioned limitations, some relevant considerations arise from the case collection as this represents a unique attempt at the European level to offer an overview of blockchain development and use in public services in EU countries.

[25] https://www.niis.org/blog/2018/4/26/there-is-no-blockchain-technology-in-the-x-road

5 Blockchain-based public services trends

The following section describes the overall blockchain-based public services trends, based on an analysis of cases collected. These are the specific relevant questions to answer with this analysis:

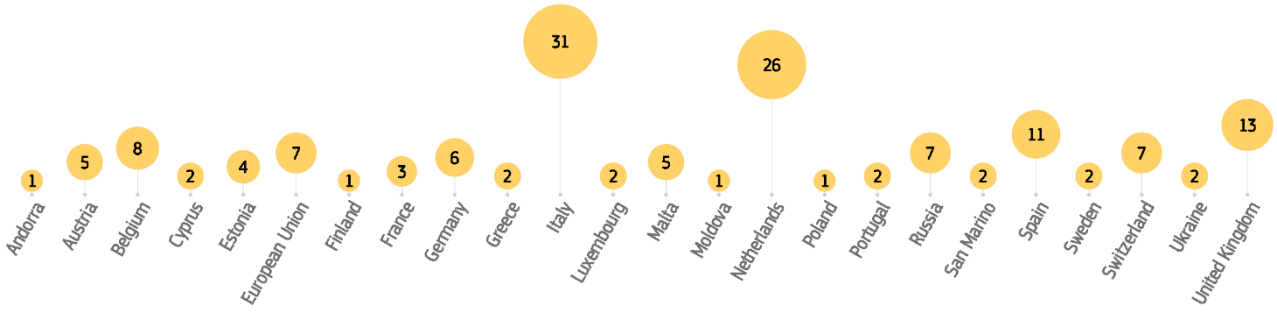
- What is the distribution of blockchain-based use cases in terms of sectors of public administration?
- What is the distribution of blockchain-based use cases in terms of activity performed and types of services?
- What is the status of the development and implementation of blockchain-based solutions in the public sector?
- How much are blockchain-based use cases used in cross-sector and cross-border cases?
- How much are blockchain-based cases used at different levels of government (local, regional, national, international)?
- What are the public values where blockchain-based use cases contribute the most?
- How has the overall landscape evolved over the years?

5.1 General overview

Our research identified 167 blockchain-based use cases in the public sector. **Figure 2** shows the distribution of the cases across 23 countries. The largest number of detected cases are found in Italy, followed by the Netherlands and the UK. There are seven cases that we labelled "European Union cases" as they are either led by an EU institution and body or co-led by a consortium of EU Member States.

It is important to note that the landscape represents the research results, and we do not claim completeness or representativeness of our landscape. As such, the results presented here indicate where blockchain is occurring in the public sector in Europe. However, the results are not suitable for creating a benchmarking between different countries or any statement about the maturity of countries regarding using blockchain.

Figure 2. Mapping the blockchain-based use cases in the public sector in Europe



Source: JRC's own elaboration

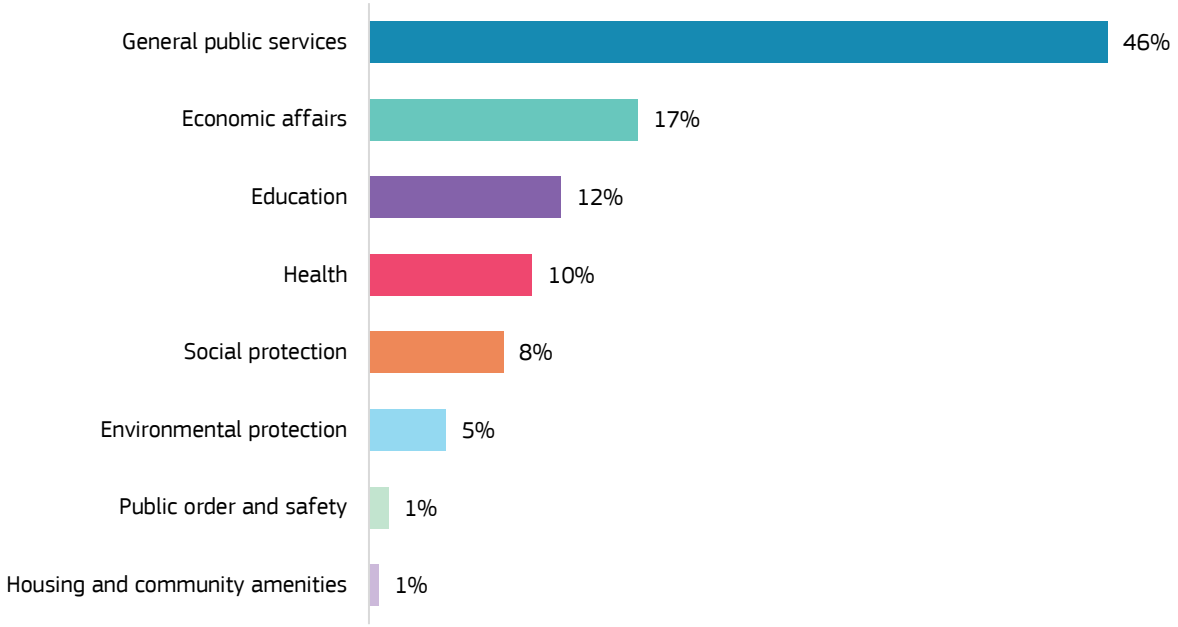
5.2 Main sectors of blockchain-based public services (COFOG)

A key aspect is identifying the main sectors of public administration where blockchain-based services are developed and tested. For this purpose, we use the COFOG classification.[26] This classification has three levels of detail: divisions, groups and classes. The research maps cases for the first level – the public sector division. **Figure 3** shows the distribution of cases. Most cases fall under the broad COFOG category of **General Public Services (46%)**. The following categories, ranked by share of the total collection, are **Economic affairs (17%)**, **Education (12%)**, **Health (10%)**, **Social Protection (8%) and Environmental protection (5%)**.

[26] COFOG Classification: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Classification_of_the_functions_of_government_(COFOG)

Only **1%** of all cases collected fall under **Public Order and Safety** and **Housing and Community Amenities**, respectively. The research did not find cases in the categories of Defence, Recreation, Culture or Religion. This absence might be because public administrations are not the leading implementing organisations in these policy areas (due to historical outsourcing and/or increased involvement of private sector organisations). In the case of Defence, there is a lack of transparency surrounding these technologies due to safety/security concerns.

Figure 3. Public administration main sectors with blockchain-based use cases (COFOG Level I)



Source: JRC's own elaboration

A more in-depth view of the General Public Services is helpful to understand examples within this extensive and comprehensive category. The category includes:

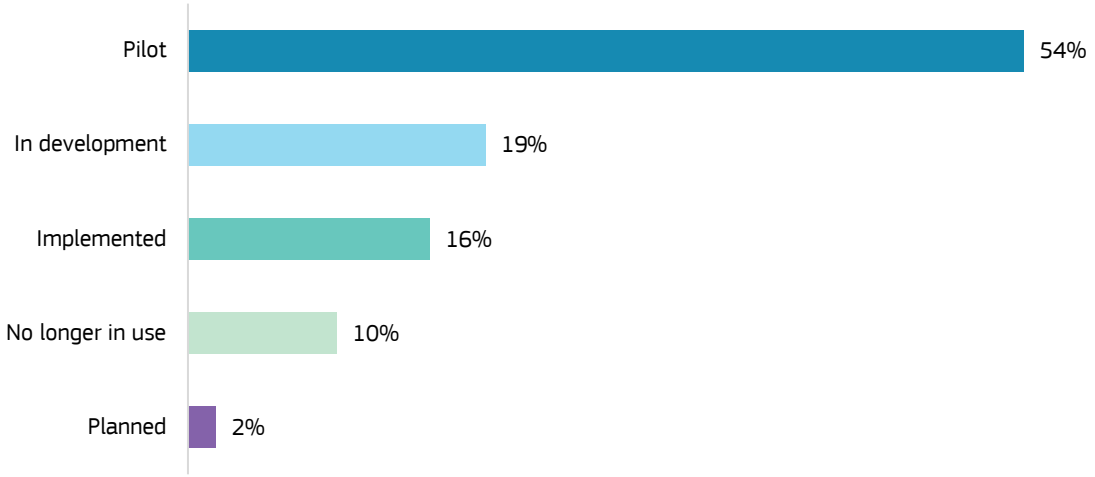
- Cases related to privacy and data sharing, for example, putting citizens in control of their personal data and allowing them to decide how it is shared
- Certification and validation cases, such as certification of skills for public employees or digital signature processes
- Decentralised digital ID cases to access e-government services or many public applications related to education, e-health or mobility
- Improvements in the internal processes of public administration, such as recruitment or competency management, data sharing between public organisations using secure cloud federations, and procurement management
- Governance and voting systems

5.3 Development and implementation of blockchain solutions

The implementation status of the cases was categorised. In some cases, it is difficult to determine a project's actual status with the public information available. **Figure 4** shows the distribution of cases: 54% are pilots, proof of concepts or experimentations made by public administrations or consortia (e.g., with the support of a funded EU project). These cases explore possible innovative uses of blockchain in the public sector through pilots that are not an integrated part of the organisation's digital infrastructure. Only 16% of cases are in the implemented category, meaning that the solution is fully developed and used in daily operations within the

public administration. 19% are in development, meaning the blockchain solution collected is under development but not yet implemented.

Figure 4. Development level of blockchain cases



Source: JRC's own elaboration

Some cases are planned (2%), and most target concrete implementation. Of course, the limited number of scheduled cases also depends on the limited number of administrations that already promote and make public cases in this initial phase. However, it remains challenging to assess the real-time status of these blockchain cases with the limited public information available and due to the rather novel status of most of these technologies. It is not uncommon for blockchain projects to stop entirely after a pilot or come back after a period where management has solved any issues, for instance, technical or legal-related. The status of implementing the blockchain use cases is indicative.

10% of the collected cases are no longer in use because the pilot experimentation ended, there is no information about the effective adoption of the solution, or it terminated for some other reason.

5.4 Application types

To understand the actual purposes of using these technologies, we complemented the COFOG classification with the application type of the collected cases (e.g., procurement management, digital identity). For classifying application types, we developed an ad hoc taxonomy, building upon and extending existing ones (such as those used in the European Blockchain Observatory and Forum[27] and the Catalogue of Services Action of the EU ISA² Programme[28]).

5.4.1 Application types by sectors

In this analysis, the application types are crossed with the public administration main sectors (**Figure 5**), highlighting some interesting points.

The application type **Certification and validation processes** is the application with the highest number of use cases and is especially relevant (more than 50% of the cases) in the education sector, more concretely with the certification of academic credentials. Many states such as Italy, the UK, Malta, Belgium, Cyprus, Andorra, Germany, Greece or the Netherlands carry out pilot use cases. Certification and validation is one of the most interesting applications of blockchain technology. Thanks to decentralisation, it can quickly solve the problem

[27] https://www.eublockchainforum.eu/
[28] https://joinup.ec.europa.eu/sites/default/files/news/2019-09/ISA2_European%20taxonomy%20for%20public%20services.pdf

of counterfeiting diplomas and reduce resources required to store records, increasing the efficiency of the service and speeding-up academic diploma issuance and verification. The next sector where we find more certification and validation use cases is in the General public services sector, covering aspects like providing evidence with legal value or e-signatures. Other sectors where certification and validation use cases are applied are Health (COVID-19 certificates) or Social Protection (blockchain-based union card).

Figure 5. Application type by public administration sectors

Source: JRC's own elaboration

The second application with more use cases is **Data sharing management**. This activity is especially relevant in the General public services sector, for example, giving citizens control of their data (Spain, the Netherlands and Italy) or in open data applications (UK, Spain). In this category, we also find all of the healthcare-related use cases regarding a sensitive topic: the transparent exchange of medical records by patients, doctors or researchers (UK, Italy). Blockchain has the potential to transform healthcare, particularly by integrating existing data silos, and at the same time, enabling patients to have control over accessing their health records. In Estonia, for example, the government is building a nationwide system integrating data from Estonia's different healthcare providers to create a common record that every patient can access online.

The other categories of application types for blockchain-based use cases are also interesting. One is the **Registration and data notarisation processes** (e.g., property, vehicle and other documents such as contracts). It is one of the most mature applications of blockchain technology as it responds to clear administration needs. Moreover, blockchain provides transparency across the system with a trusted mechanism for transferring and storing data, solving potential fraud and significantly reducing the time and cost of the registration process, for example, in property transactions. Several European states such as Sweden, the

Netherlands, Malta, the UK and Germany are exploring blockchain-based solutions for digitalising the registration of land, vehicle and property transactions. The sectors where this application is more often used include General public services (e.g., land or vehicle registration), Economic affairs (e.g., business registration) or Health (e.g., medical instruments registration).

Financial management and support is another application with many use cases. Most in this category focus on a complete digitalisation and high automation of the processes for providing social protection or financial support to citizens (e.g., digital vouchers, subsidies or pension infrastructure), for example, cases in the Netherlands, Belgium, Austria and the UK. Financial support application is also part of the Economic affairs sector (e.g., loans for public administration employees, interbank settlement services, or multi-stakeholder financial arrangements) in the UK, Italy and the Netherlands. Finally, there is a use case in the Netherlands related to the healthcare sector to make the financial and administrative processes in subsidised public healthcare services more efficient.

Internal management processes is another type of application that refers to internal procedures that can be linked to the provision of services or internal operations. These use cases are mostly related to the General public services sector (e.g., blockchain infrastructure services, human resources management and multi-stakeholder authorisation processes). Some of the use cases in Italy, Portugal or Greece are part of broader European research projects such as QualiChain or Sunfish. Furthermore, in the Netherlands, we find other interesting blockchain use cases for internal processes in the environmental protection sector, specifically waste management. The main idea is to avoid paper-intensive processes that require all parts to participate in its administrative management. In these cases, smart contracts can help automate the approvals for transport in a joint administration where the blockchain provides absolute certainty about the integrity of the data.

Authentication of self-sovereign digital ID services is one of the most important applications of blockchain technology as it allows users to manage directly and autonomously their own digital ID. Most of the cases found with this application fall in the General public services sector and offer safe and easy-to-use access to a range of electronic government services without the need for additional logins and passwords. There are several use cases in the Netherlands, Switzerland and Germany.

The blockchain application that covers the **Tracking of goods, supply chain and IoT** is the category with a more significant number of cases, with most of them included in the Economic affairs sector (e.g., food traceability systems). Tracking of goods is another straightforward application of blockchain, potentially improving supply chain transparency and traceability and reducing administrative costs. There are several use cases in Italy regarding blockchain application in the agri-food industry, with products such as meat, milk and wine. We also find instances in the UK with the Food Standards Agency regarding the traceability of meat and securing IoT systems with blockchain on the Isle of Man.

The following application type is **payments and international transactions**. We find use cases in the environmental protection sector, specifically in projects that reward citizens for best practices to encourage behavioural models aimed at sustainability and reducing CO2 emissions. We find examples in Austria, Italy or San Marino. Another sector with several use cases is social protection, with blockchain-based payment solutions, for example, for welfare payments (UK) or asylum seekers payments (Finland).

Governance and voting is a critical government function that has been an important application of blockchain in public services. Electronic voting systems have the potential to engage citizens in the governance processes. States like Switzerland, Estonia, Ukraine, Russia and Italy are testing potential solutions. In this category, all cases are part of the General public services sector.

Another application type with fewer cases is **public procurement management**. In this sector, blockchain can enhance the reliability and transparency of each step of the procurement process, supporting disintermediation. Some examples are a decentralised blockchain e-auction system in Ukraine or an implemented blockchain technology in an electricity trading platform in Germany. With fewer use cases, we find **Copyright and IPR management** applications, with cases addressing the protection of intellectual property of authors and publishers in Italy or to combat intellectual property infringement in the space industry in Russia. Finally, other application types with only one case found are **Improving cybersecurity**, **Prediction and planning** and **Monitoring policy implementation**.

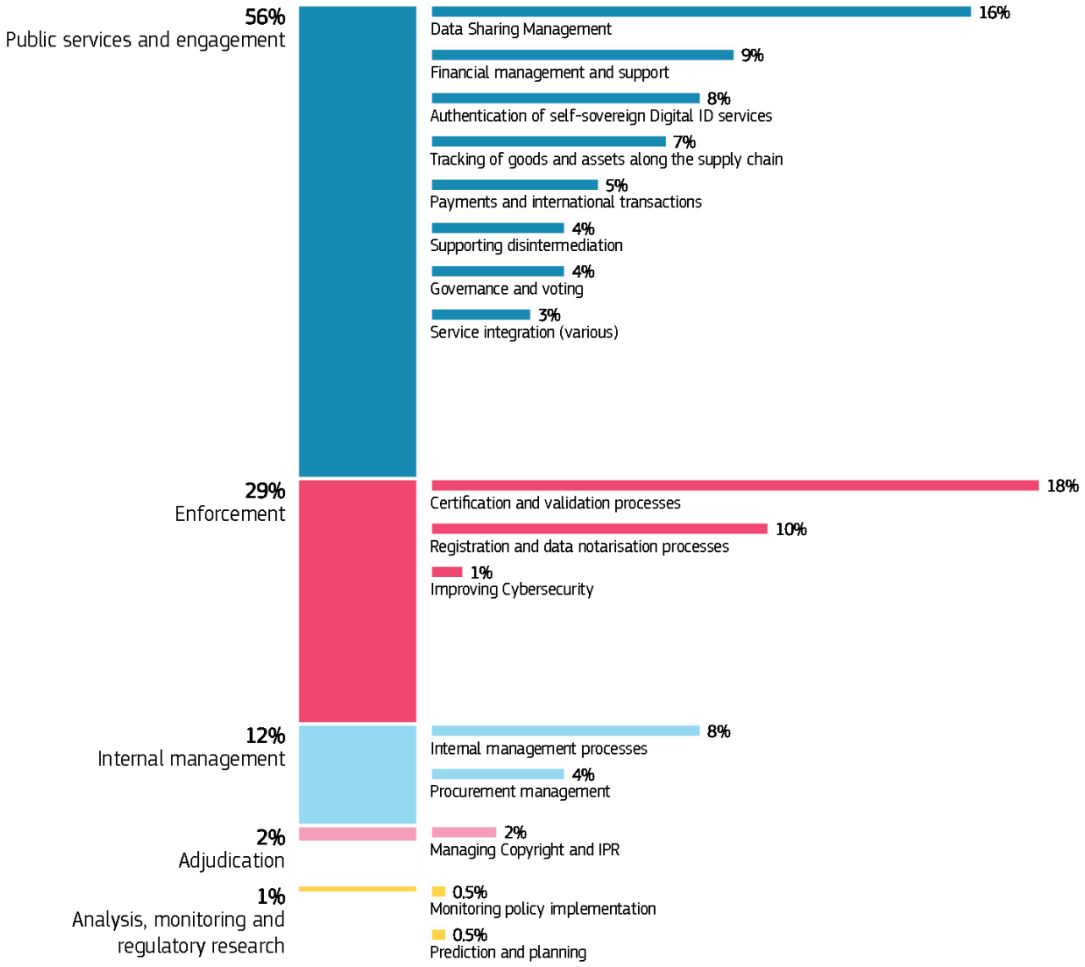
5.4.2 Processes and application types

The process type indicator[29] aims to measure with a coarse granularity the type of governance process inside the public sector for each specific case (**Figure 6**). Considerations regarding the results are:

- Data Sharing Management i**s the largest application type** within the generic Public Services and Engagement process. This category indicates that blockchain is mainly used for sharing data between organisations or between organisations and citizens, respecting at the same time data protection (compliance with the requirements of the GDPR) and providing an overall solution that improves communication and collaboration.
- Two other large application types are found in the **Enforcement process**. They are Certification and Validation processes and Registration and Data Notarisation processes – both crucial processes in public administration. Blockchain is also used for fraud prevention processes, which guarantee to the parties of a transaction that a document is genuine and can be trusted. The capacity of blockchain to keep records in this way makes them uneditable and undeletable.
- More significant cases belong to **Public Services and Engagement (56%)**. In other words, the government functions directly to provide services or support communication activities to external actors – mainly citizens and firms. Among these cases, the majority are related to the improvement or creation of new services through application types such as data sharing management (16%), financial management and support services (9%), tracking goods and assets along the supply chain (8%), and authentication of self-sovereign digital ID services (7%). A smaller portion concerns payments and international transactions (5%).

[29] https://www-cdn.law.stanford.edu/wp-content/uploads/2020/02/ACUS-AI-Report.pdf

Figure 6. Cases by process and application type



Source: JRC's own elaboration

The second process type, Enforcement (29%), is the government demand related to enforcing regulatory mandates. The application types classified in this category involve Certification and validation processes (18%) and Registration and data notarisation processes (10%). Fewer are found in the Internal management process type (12%), where most of the cases support various types of internal management processes (8%) and procurement management (4%).

Other process types have fewer cases, such as Adjudication (2%). Fewer cases are related to copyright and IPR management applications (2%), indicating that there are not many use cases in the public sector for adjudicating benefits or rights such as patent applications. A similar case is the Analysis, monitoring and regulatory research process type (1%), with fewer cases in prediction and planning applications (0,5%) and monitoring policy implementation (0,5%).

5.5 Recipients of blockchain-based public services

The implementation of blockchain solutions implies an interaction among different actors. The public sector is mainly involved in three types of relations:

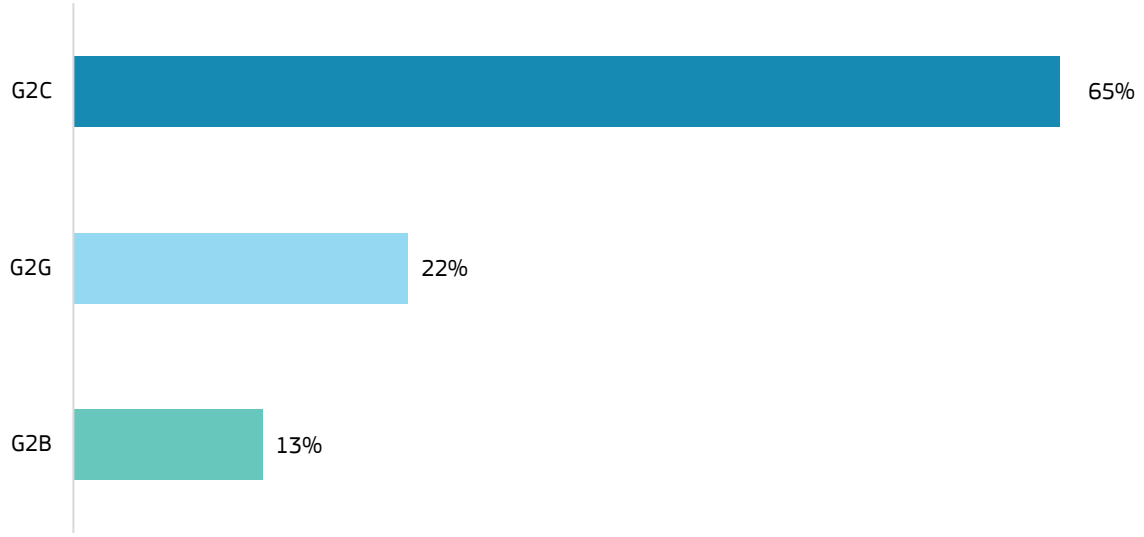
- **Government-to-Government (G2G)**: are the processes between and within public organisations, such as services and information transactions between the central-state government, state-local governments, and between department-level and attached agencies and bureaus.

- **Government-to-Citizen (G2C)**: refers to services and information transactions by the government interacting with private users (citizens).
- **Government-to-Business (G2B)**: relies on services and information transactions by the government with private organisations and other economic activities.

It is interesting to note that blockchain-based public services support direct interaction with users and the governmental backend interaction within and among public organisations. In this sense, as shown in **Figure 7**, about 65% of the cases focus on services targeting citizens (G2C). In this group, we find all of the services related to Health, Education or General Public Services such as voting systems or identity management applications where there is an interaction between government and citizens.

On the other hand, 22% target internal government recipients (G2G), for example, for procurement management solutions or to track policy implementations and 13% target private sector organisations (G2B), for example, to record changes in in legal status of companies.

Figure 7. Recipients of blockchain-based services

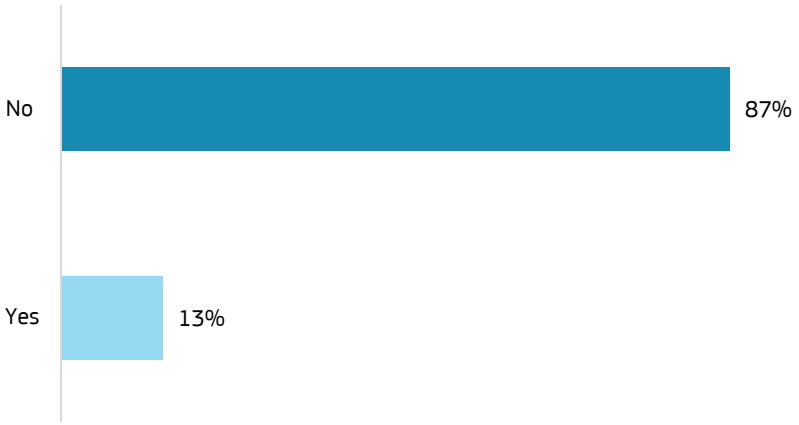


Source: JRC's own elaboration

5.6 Cross-sector and cross-border cases

Another relevant aspect of the use cases is whether they are cross-sector and/or cross-border. This aspect is helpful as an indicator of the actual level of interoperability of blockchain-based public services. Regarding blockchain interoperability, we refer to the ability of a blockchain network to share, see and access information across existing data management systems in the public and private domain without the need for an intermediary to carry out the exchange (Tan, Mahula, and Crompvoets, 2022). The results show that 13% of the collected cases are across public administration sectors, whereas cross-border examples cover 12% of the collected cases, indicating that the level of interoperable services is currently low. Most of the cross-border and cross-sector cases are extracted from the European Blockchain Service Infrastructure (EBSI). This cross-sector and cross-border initiative enables service integration and interoperability and is a potential trendsetter in facing interoperability challenges.

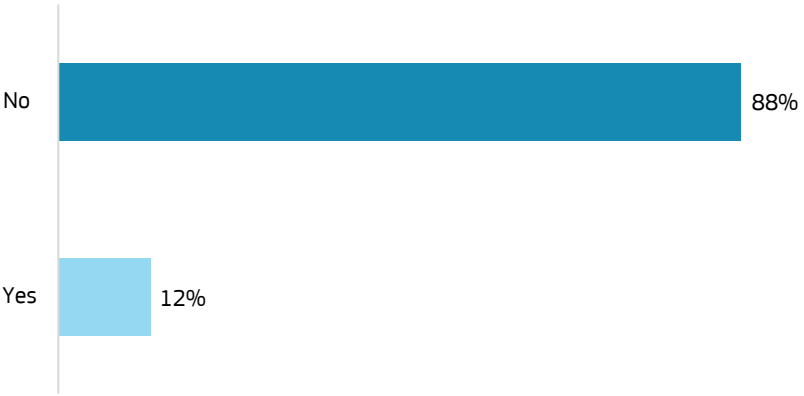
Figure 8. Cross-sector cases



Source: JRC's own elaboration

The general picture of **cross-sector** cases is composed mainly of data access and sharing cases, for example, an open data portal where data is accountable by logging all changes on a distributed, immutable database (Valls City Council, Spain). Other examples concern services that require data and services across sectors. Public procurement is one of the most prominent activities in these cases, followed by financial management cases.

Figure 9. Cross-border cases



Source: JRC's own elaboration

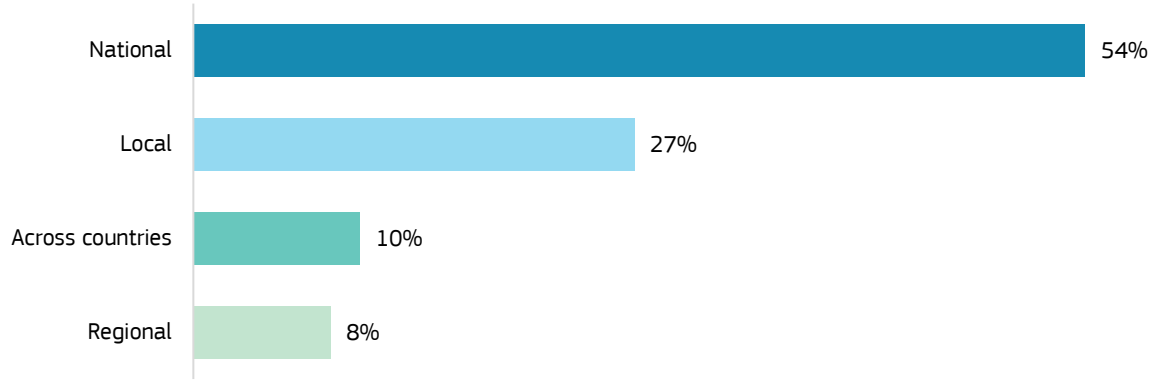
We find many cases regarding cross-border examples, especially those related to data exchange. Some of these cases are in the education sector – more concretely, academic credentials use cases supported by EBSI. For instance, universities across the EU can easily exchange academic information in a cross-border Erasmus exchange scenario. Another example of a cross-border data exchange use case is the accessibility of national archives and digital government records. A trial in the UK, Estonia and Norway focused on leveraging blockchain to tackle the long-term future of digital video archives, securing the system using a proof-of-authority blockchain distributed across multiple independent archives.

5.7 Geographical extent and types of organisations

Another important aspect to understand is the scope, in terms of geographical extent, of the innovation of public services using blockchain. This indicator follows the administrative tiers identified by Nomenclature of Territorial

Units for Statistics (NUTS).[30] This information helps determine where resources should be distributed to promote innovation, in this case, related to blockchain-based public services.

Figure 10. Geographical extent



Source: JRC's own elaboration

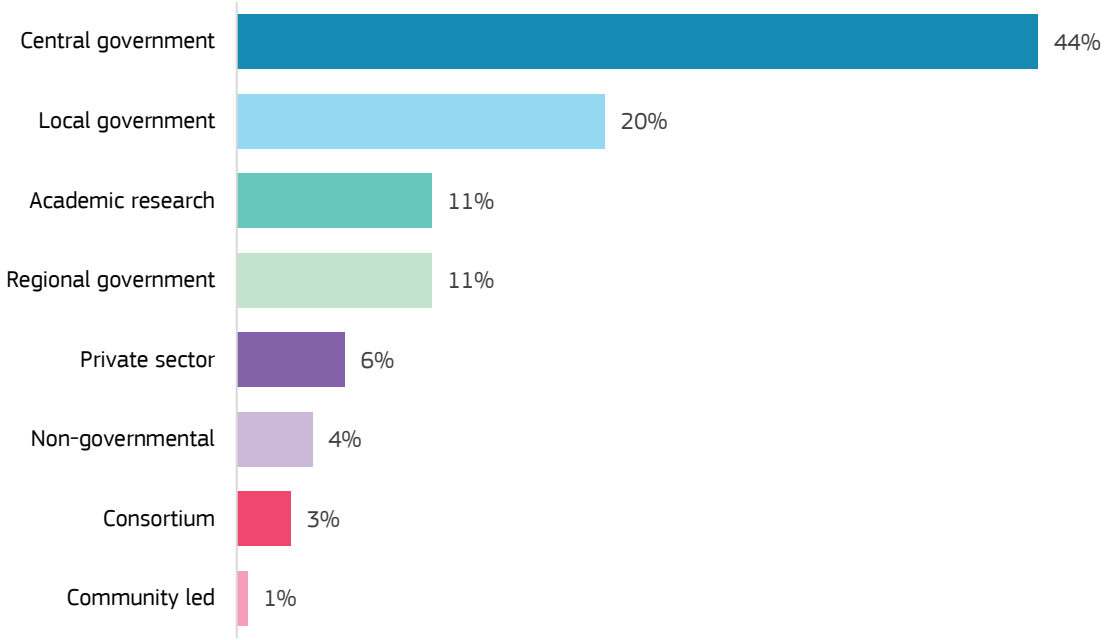
Figure 10 shows the distribution of the collected cases across local, regional, national and multi-national levels. More than half of the cases (54%) are initiatives launched at the national level, followed by local (27%) and regional ones (8%). Finally, cases across countries (10%) are initiatives involving multiple countries that aim to drive experimentation and the adoption of blockchain-based public services through piloting.

The results show how blockchain-based public services development seems to be driven mainly by national governments, which might have the necessary human and financial capacity to sustain it. However, several initiatives have been developed by regional and local administrations, demonstrating that regions, cities and municipalities, even small ones, can benefit from developing blockchain-based public services.

Furthermore, as shown in **Figure 11**, in almost half of the cases the type of organisation responsible for the ownership of a case is the central government (44%), followed by local governments (20%), regional governments (11%), academic research institutions (11%), and in fewer cases, the private sector (6%) and non-governmental organisations (4%).

[30] https://ec.europa.eu/eurostat/web/regions-and-cities/overview

Figure 11. Responsible organisation type

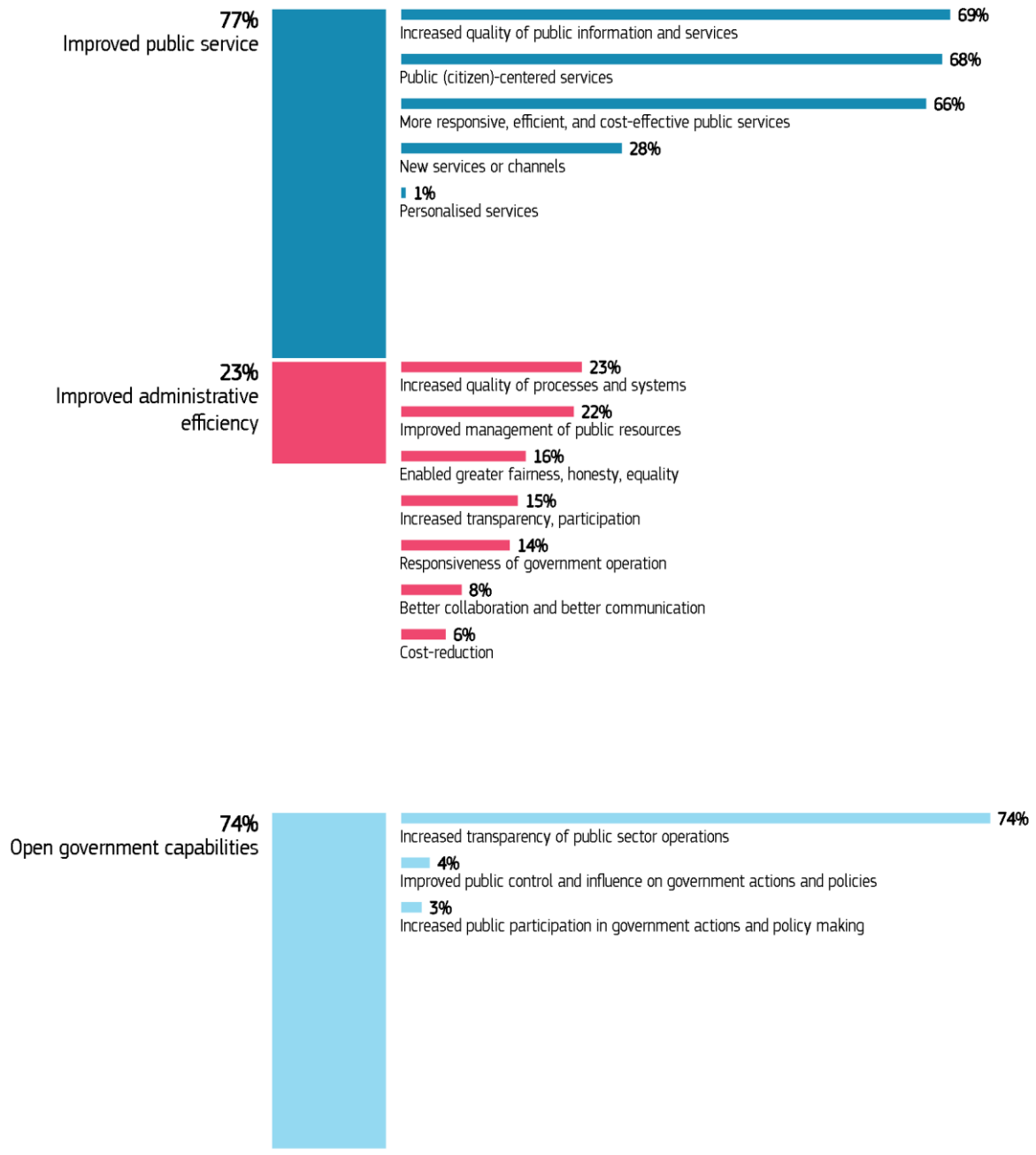


Source: JRC's own elaboration

5.8 Value drivers

Furthermore, we categorised the cases along the taxonomy of public value proposed by Twizeyimana and Andersson, 2019. It shows which public value the cases most contribute to. The public value categories in this taxonomy are Improved public service, Improved administrative efficiency and Open government capabilities.

Figure 12. Public value of e-government blockchain services (level I)



Source: JRC's own elaboration

This classification focuses on different value areas for public services. Our research considers three aspects of value improvement that cover various aspects of the service:

- **Improved Public Service**: This public value refers to different service improvements offered by e-government. Our research measured that 77% of the cases include service improvements. The main values identified are an increase in the quality of public administration and services (69%); more citizen-centred services (68%); more responsiveness, efficiency and cost-effectiveness (66%); and new services or channels (28%). It is remarkable that only in 1% of the cases, we identified personalised services as a value driver.
- **Improved Administrative Efficiency**: This aspect refers to the internal point of view of the administration and includes purposes of: efficiency, effectiveness, increasing quality and lower cost for administrative processes, systems and services, keeping government operations

systematic, sustainable, flexible, robust, lean and agile, and better management of public resources and the economy. Our research measured that 23% of the cases improve the administration's efficiency. Other values identified are an increased quality of processes (23%), increased management of public resources (22%), enabling of greater fairness, honesty and equality (16%), and an increase in transparency and participation (15%).

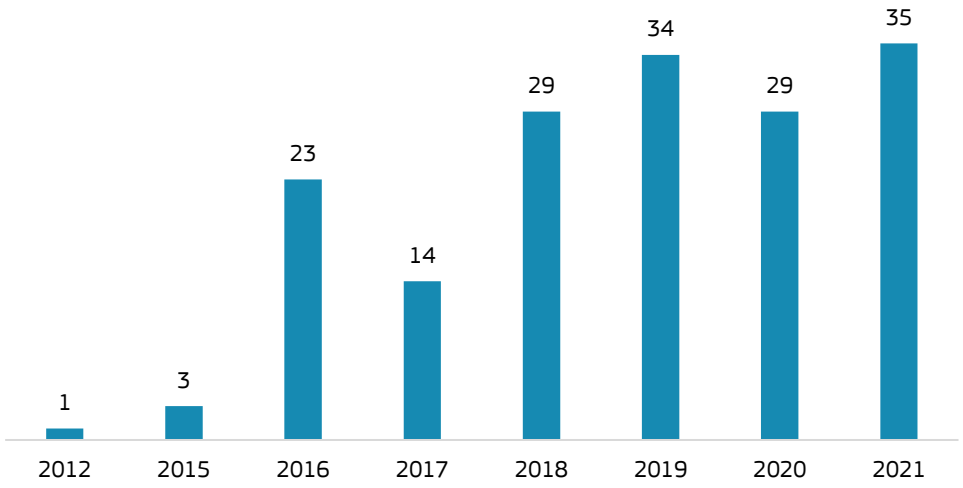
- **Open government capabilities:** This category refers to impacts on openness, transparency, participation, communication and collaboration to provide personal or corporate influence and control of government actions or policy. Our research measured that 74% of the cases contribute to open government capabilities. The primary value identified is increased transparency of public sector operations (74%). It is remarkable that only in 4% of cases, is there an improvement of public control and influence over the government's actions and policies, and in only 3% of the cases, is there an increased public participation in government actions and policymaking. These are the cases normally related to the governance and voting application type as they have the potential to engage citizens in the governance processes.

5.9 The evolution over the years

The previous sections have provided an overview of the current European blockchain landscape in the public sector. However, our dataset also indicates that this landscape has changed over the years. Firstly, it needs to be kept in mind that, despite this representing a significant sample of cases, we cannot claim completeness. Secondly, the starting date of a project for implementing a blockchain solution may not always be precise and may vary for a few months from the actual starting of activities.

The number of cases per year shown in **Figure 13** indicates an **overall positive trend** regarding the number of initiatives, starting from 2012. During 2017-2020, the growth rate decreased, which could be related to how the data was collected.

Figure 13. Historical progression of blockchain cases in the public sector



Source: JRC's own elaboration

In reading these data, it is essential to consider that the starting date is simply the earliest date available in the information at our disposal. This date can be the effective starting date if declared, or an approximation, the date of publication of the news article, or a hypothesis that relies on the interpretation of the information available.

6 Policy implications and recommendations

This section aims to draw some policy implications and propose recommendations based on the analysis conducted and reported in the previous sections. The evidence collected is mainly based on the quantitative analysis made in the previous section and on observations of the research team on concrete examples and cases. Hence, the drafted recommendations primarily focus on which elements public organisations should consider when approaching blockchain implementation in the public sector. The following paragraphs will report the research team's main insights from this research.

The research team was able to detect 167 blockchain-based cases in the public sector in Europe. Among these cases, 126 were collected after 2018, ranging between 28 and 35 cases collected annually between 2018 and 2021. It suggests that **the number of cases, increasing since 2018, continued the overall positive trend but decreased in growth rate**. Besides this, here are some other aspects worthy of note:

- Only 13% of the cases are cross-sector, and 12% are cross-border.
- The cases embrace various application types, sectors and governmental functions of public administration, from certification and validation in the education sector to financial management for social protection, tracking of goods and assets in the supply chain or governance and voting.
- 20% of the cases are at the local level, and 11% are at the regional level, meaning that blockchain is not only accessible to large national governmental agencies.
- More than half of the use cases (54%) are pilot projects, and only 16% are fully developed and used in daily operations within public administration.

While acknowledging the study's limitations, it is possible to state that although blockchain technology is still in its early stages in technology and adoption, there is widespread interest in understanding the technology better. **All levels of public administration and many other sectors are interested in embracing its benefits** to accelerate the digital transformation of processes, services and organisations.

At the same time, we see considerable hype in wider society, where ads for blockchain, NFTs and cryptocurrencies such as Bitcoin seem everywhere. Behind this hype, in some cases, an ideology about social change consists of seeing blockchain as a technology that could empower citizens more, making them less dependent on governments and corporations.

However, the reality shows that public administration **must face many steps** before blockchain can solve real-life problems. In addition, if we compare the numbers of two emerging technologies in the public sector, blockchain and AI, in terms of the number of cases or amount of implemented projects in the daily operations of administrations, we see that the adoption of AI is far ahead when compared to blockchain. Hence, it is possible to state that public administrations must raise internal awareness regarding blockchain's potential for better delivery of public services, educating and engaging on all levels. Secondly, public administrations should consider blockchain a possibility for experimenting, despite its complexities. Once public employees understand its potential benefits, a blockchain-based solution can better solve many existing administration problems than traditional approaches. This analysis extracts the first recommendation:

Recommendation 1

Public administration should raise internal awareness regarding the possibilities of blockchain by considering blockchain-based solutions as a real option and experimenting and discovering the benefits and potential to be exploited.

Once the decision is taken, and the suitability of a blockchain-based solution is going to be evaluated, it is important to design a project with a clear roadmap for implementation. Our research indicates that 54% of the use cases are pilot projects that are not integrated into the organisation's digital infrastructure. Only 16% are implemented, fully developed and used in daily operations. Several factors can cause the discontinuation, for example, lack of structural funding and legal or governance issues. The risk of failure in implementing a blockchain project is high. The implementation roadmap must include a plan incorporating all the aspects to consider if the project succeeds and is taken into production, for example, who will provide funding for the

service, who will do the system maintenance or who will manage it. With respect to the latter, it is important to highlight that one of the most important aspects to assess before starting a blockchain project are related to the technical challenges, as they are still the major issues, and more specifically the scalability and the performance requirements of the system.

Moreover, the evaluation must provide impact assessments to understand whether a blockchain-based solution is really solving the initial problem versus traditional solutions. An evaluation would give more evidence to policymakers to better understand benefits, risks and costs.

Recommendation 2

Blockchain adoption should be treated as a complex project, which needs to include: an evaluation of suitability, scalability and feasibility with a pilot, a clear roadmap for implementation, and risk and impact assessment analyses.

One main challenge is attracting adequate partners to think creatively about building and delivering innovative blockchain-based solutions. Creating collaborations is not easy; it takes time to build collaborative networks, and public services often choose classical solutions as they are faster to implement than an emerging technology like blockchain. This level of complexity cannot be faced only by the internal workforce of the public administration. Hence, partnerships between the public, private organisations and academia can assure that the required talent is onboard when building a blockchain-based solution for the public sector and facilitate a successful implementation. Moreover, such a collaboration encourages the co-creation of new ideas and more innovative public services.

In addition, implementing a blockchain-based public service requires the cooperation and commitment of all the participating members of the existing processes. They may have complex economic and business relationships among themselves. An example of this complexity is the case of the German asylum procedure, which involves many federal and state authorities. The proof of concept carried out by the Federal Office for Migration and Refugees (BAMF) demonstrated the suitability of blockchain technology to support cross-organisational communication and procedures, requiring a collaborative context between the organisations involved. In this regard, best practices are fundamental in implementing a decentralised technology like blockchain. Involving many organisations requires coordination at several levels while minimising the complexity of the coordination.

Recommendation 3

Public administrations should increase and strengthen the collaboration with other public organisations and the private sector to experiment and implement new blockchain use cases. At European level, it is important to leverage the cooperation framework and infrastructure created through the European Blockchain Service Infrastructure (EBSI).

The European Blockchain Services Infrastructure (EBSI) is leading the creation of an interoperable and common blockchain infrastructure that enables cross-border public services using blockchain technology. A standard infrastructure is an appropriate technical, organizational and, to some extent, legal step in supporting cross-border use cases. Despite a more complex governance than for actions at local level, it is the way forward to ensure interoperability; to reach critical mass for moving into operation; to avoid fragmentation; to propose implementation at scale; to address cross border use cases, while leveraging on the experience of pilots and actions undertaken at national or other levels, and to reinforce the cooperation between public authorities across Europe.

Moreover, it is complemented by another European initiative that will foster the creation of reusable and interoperable by default services in public administrations, the GovTech Incubator.[31] This initiative has the purpose of proposing a favourable environment for the development of cross-border experimentation with emerging technologies such as blockchain that will lead to innovative services.

However, there are still challenges. From the findings, only 12% of the cases are cross-border, indicating that the level of interoperable services is currently low. Moreover, interoperability and scalability are still one of the main technical challenges in deploying blockchain use cases for public services. Existing blockchain solutions face technical constraints when managing many users and transactions, like high energy consumption or transaction costs. Although the recent progress, blockchain technology is still in an early stage regarding its adoption for large-scale applications by the public services. In this respect, public administrations must cooperate, promote interoperable standards and define the technical requirements and best practices to deploy feasible cross-border large-scale applications across Europe. In this regard, the EBSI aims specifically to foster this cooperation through a joint approach that can be then exploited and used at National or local level, in addition, the deployment of these new public services through EBSI can avoid above technical constraints.

Recommendation 4

Public administrations should avoid the creation of digital silos by promoting interoperability and facilitating international collaboration with cross-border use cases deploying large-scale applications.

Furthermore, legal issues are one of the main aspects to be considered before implementing a blockchain-based service. In this regard, the legality is often uncertain. In some pilot projects, the implementation of daily operations within the public administration stopped after a successful proof-of-concept development. There can be many reasons for this. In many cases, a lack of legal framework poses obstacles for implementation. For example, the legal recognition of data notarised in a blockchain, or digital signatures is still unclear or not permissible in certain contexts, such as in property transfers; therefore, it is still mandatory to use paper documents. Public administrations must address the legal aspects before integrating blockchain into their services.

Regulations can have both positive and negative effects on the innovation process. The policymaking process must consider the impact of regulation on innovation. Conversely, innovation and technological evolution influence the rationale and design of regulations. Hence, it is relevant to recognise the legal value of data registered in a blockchain and to adapt regulations according to new insights from technology and societal preferences. Along this line, the EU regulatory sandbox which is going to be launched by the EC is an important initiative.

Recommendation 5

Public administrations should consider legal aspects at the early stages of the experimentation and implementation process to become aware of the possible obstacles the project will face when moving into production after a successful proof of concept.

In summary, the implementation of a blockchain-based solution is complex and slow. A blockchain solution is not a typical IT project, and technical, legal and organisational aspects need to be addressed in different phases from the beginning of experimentation through to implementation.

[31] https://joinup.ec.europa.eu/collection/interoperable-europe/news/call-digital-govtech-incubator-open

7 Conclusions

The report offers an overview of the adoption of blockchain by the public sector, collecting and analysing data from an inventory of use cases. In addition, the report does not aim to give an opinion regarding the pros and cons of the adoption of blockchain in concrete fields; it simply tries to show a reality in the European landscape. Moreover, it offers a novel and fresh view, adding new insights to the existing body of knowledge on the topic. It contributes to a systematic analysis of blockchain in the public sector from a more theoretical and anecdotal outlook. The 167 cases collected and analysed in a database are available in open data. It represents one of the legacies of the research for any researcher or policymaker that wishes to undertake a deep-dive, refine or integrate the analysis. In fact, more than a result, the database aims at being the starting point that can foster further research on the topic.

Blockchain technology is an innovative technology with a clear disruptive potential that is still in the early stages in terms of adoption in the public sector. The analysis highlights the growing evidence of early-adoption projects showing that public administration can use this technology in creative and interesting new approaches to providing services while fulfilling its requirements. Moreover, it provides a glimpse of some trends on where this technology can be more disruptive and transformative. For example, it provides a picture of application types and the public administration sectors which are experimenting more with this technology, and the public value where the use cases can contribute more. In addition, based on the evidence collected, the research team can draw some recommendations mainly addressed to public officials that aim at developing and using blockchain-based solutions within the public administration.

However, public administration must take many steps before blockchain can solve real-life challenges. Implementing a blockchain-based solution is more complex than a typical IT project due to the many technical, organisational and legal challenges. Moreover, there is still a lack of empirical evidence to better understand the suitability of blockchain technology's ability to solve the problems of public administration. Creating awareness within public administration regarding the potentialities of this technology along with experimentation seems to be the way forward. In this **direction, researchers must keep collecting and analysing quantitative and qualitative data on blockchain use cases**. Providing impact assessments of blockchain-based solutions will increase the empirical evidence and improve the understanding of the solution's suitability to solve a concrete problem of the public administration. Other important future steps to accelerate the adoption of blockchain-based solutions include the establishment of legal certainty to facilitate the deployment of new innovative public services. On the one hand, the empirical evidence created by evaluating blockchain's suitability to solve real-life problems can better understand the benefits, costs and risks associated with implementing these solutions in the public sector. On the other hand, the lack of a legal framework can negatively affect the innovation processes. In this direction, some possible future actions could start by analysing the existing legal framework to better understand where the present situation is **hindering and not fostering the adoption** of blockchain-based solutions.

Finally, the launch of EBSI, in cooperation with the European Blockchain Partnership, to create an interoperable and standard blockchain infrastructure that enables cross-border public services **is fundamental** for addressing the above challenges and for promoting, developing, piloting and deploying operational blockchain-based services across Europe. Despite a more complex governance than for actions at local level, it is the way forward to ensure interoperability; to reach critical mass for moving into operation; to avoid fragmentation; to propose implementation at scale; to address cross border use cases, while leveraging on the experience of pilots and actions undertaken at national or other levels, and to reinforce the cooperation between public authorities across Europe.

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List of abbreviations and definitions

AI	Artificial Intelligence
AOC	Open Government of Catalonia
BAMF	German Federal Office for Migration and Refugees
BLING	Blockchain in Government
Blockchain	Secure peer-to-peer distributed ledger used to record transactions across many computers ensuring data integrity, immutability, and consistency.
CBDCs	Central Bank Digital Currencies
COFOG	Classification of the functions of government
DLT	Distributed Ledger Technology
DXL	Data Exchange Layer
EBP	European Blockchain Partnership
EBSI	European Blockchain Services Infrastructure
EDIHs	European Digital Innovation Hubs
eIDAS2	Electronic Identification and trust Services
EU	European Union
ESSP	European Social Security Pass
G2B	Government to Business
G2C	Government to Citizen
G2G	Government to Government
GDPR	General Data Protection Regulation
Govtech	Engagement of the public sector organisations with start-ups and small and medium-sized enterprises (SMEs), in their innovation activities, for the design and provision of tech-base products and services.
Hash values	Hash values are returned by a hash function being a cryptographically secure and collision free function that allows the verification of the integrity of data.
ID	Identity Document
INATBA	International Association of Trusted Blockchain Applications
IOS	Inter-Organisational Systems
IoT	Internet of Things
IPR	Intellectual Property Rights
ISA^2	Interoperability solutions for public administrations, businesses and citizens
IT	Information Technology
JRC	Joint Research Centre
NIIS	Nordic Institute for Interoperability Solutions
NUTS	Nomenclature of Territorial Units for Statistics
MiCA	Markets in Crypto Assets
OECD	Organisation for Economic Co-operation and Development
PCP	Pre-Commercial Procurement

PPPs	Public-Private Partnerships
PS	Public Service
P2P	Peer-to-peer network
QR Code	Quick Response Code
RIA	Estonia's Information System Authority
SME	Small and medium-sized enterprise
TOE	Technology Organisation Environment framework
UK	United Kingdom

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