Understanding the Use of Emerging Technologies in the Public Sector: A Review of Horizon 2020 Projects

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The main purpose of this article is to provide an up-to-date understanding of the utilization and deployment of emerging technologies in the public sector, as this is reflected through 19 recently funded Horizon 2020 research projects. For the needs of this study, we have adopted a well-known literature review method that enables a concept-centric analysis of the accumulated knowledge in the field under consideration, and accordingly proposed a conceptual framework that facilitates such an analysis. Through a detailed consideration of these projects and their pilot case implementations, a series of insights about recent research development and applications in the public sector are extracted and discussed. To the best of our knowledge, this is the first attempt to gain such insights from a research projects perspective, which may reveal useful information about the utilization and deployment of these technologies in real-life pilots. The findings of this study are also justified or challenged by referring to recent review articles that investigate the use of emerging technologies in the public sector.

CCS Concepts: • **Applied computing** → **E-government**; • **Information systems** → **Information systems applications;**

Additional Key Words and Phrases: Public sector, emerging technologies, e-Government, H2020, blockchain, artificial intelligence, machine learning, review

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1 INTRODUCTION

Electronic government (e-Government) refers to government's use of **Information and Communication Technologies (ICTs)**, which is usually combined with modernization and reform of the traditional organizational structures and business processes of government. Although many definitions of e-Government combine

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ICTs with issues related to private sector management [71], organizational change and sophistication [51, 83], and socio-economic and public administrative aspects [74], it is widely accepted that ICTs constitute the core element of e-Government [34, 52]. At the same time, the potential of ICTs for government reform becomes bigger when organizational boundaries subside [32]. Admittedly, the implementation of e-Government has enabled a greater access to and delivery of governmental information [38, 42], streamlined the provision of public services [53], and facilitated citizens' engagement in diverse decision- and policy-making processes [4, 26, 46].

In any case, it has been early recognized that e-Government is neither a homogeneous nor a static phenomenon [33]. Various stage and maturity models have been proposed to describe the dynamics of e-Government, as well as to facilitate the comparison and evaluation of the progress of relevant initiatives [3, 51, 77]. Advanced stages of e-Government implementation were characterized by personalized Web interfaces for citizens, data mobility across public agencies, application mobility across vendors, and transfer of data ownership to the citizens [3]. The descriptions of these advanced implementations had foreseen the rapid progress of the capabilities of the ICTs [54]. Indeed, during the past decade, various emerging technologies were adopted by e-Government to facilitate the achievement as well as the advancement of its goals [84].

Generally speaking, emerging technologies is a dynamic concept comprising an evolving list of ICTs that continuously reshape human action and interaction. Representative examples of such technologies that have been applied and tested in the public sector include blockchain [12, 16, 40, 93], **Artificial Intelligence (AI)** [5, 13, 21, 40, 48, 69, 90, 92], semantic technologies [15, 41, 61], and Internet of Things [24, 91]. From an organization science point of view, emerging technologies do much more than automate and inform, thus posing a series of challenges that distinguish them from prior technologies [81]. This is mainly due to the following key factors: (i) emerging technologies become increasingly "intelligent" in that they lead to developments that could someday mimic or possibly outperform humans in a great diversity of skilled and cognitive acts; (ii) they enable new forms of data analytics that significantly enhance the public sector's ability in tracking, deciphering, and influencing the behaviors of individuals and groups; (iii) they enable new approaches to innovation and collaboration within and across organizations, which foster the co-creation of new knowledge and accelerate the development of novel services and processes [47]; and (iv) they demonstrate a rapid diffusion and adoption rate, which in turn transforms the way things get done and leads to the creation of novel business models [9].

As a consequence, a series of recently published research articles and working papers elaborate diverse issues related to the implementation and adoption of emerging technologies in the public sector. For instance, Gil-Garcia et al. [32] discuss the deployment of a creative mix of emerging technologies and innovation in the public sector and provide perspectives on the nature of smart governments; Kankanhalli et al. [45] identify the challenges involved in implementing and adopting Internet of Things and AI in the public sector, and accordingly propose a comprehensive research framework for smart government transformation; McKenna [60] aims to provide an understanding of the awareness aspect of emerging technologies; Giusti et al. [35] discuss how the use of emerging information technologies can support participatory urbanism, particularly among low-income and underserved populations; Gil-Garcia and Flores-Zúñiga [31] propose a comprehensive digital government success model that attempts to integrate implementation and adoption perspectives; Milić et al. [61] present an overview of applied Semantic Web technologies in the open government data domain that increase openness and transparency of government; Tan et al. [82] elucidate the implications of various governance choices in each level of governance and provides a primer for researchers and policy practitioners on the design of blockchain-based systems in the public sector; and finally, based on the analysis of data collected in 20 countries, Ubaldi et al. [85] offer insights on the state of the art on the strategies and practical examples on how governments are attempting to integrate AI and blockchain technologies in the public sector.

In this context, the objective of this article is to gain an up-to-date understanding of the utilization and deployment of emerging technologies in the public sector, as this is reflected through recently funded **Horizon 2020 (H2020)** research projects. In particular, we focus on projects that were funded during the 2018–2020 H2020 work program, thus being active from 2019 to 2024. The systematic analysis of research projects, which is not

only based on scientific publications, has recently emerged as an important method to address a set of research questions or getting the state of the art of a particular topic [27, 29, 37]. In particular, the exploitation of competitive H2020 research projects, which have been thoroughly evaluated and reviewed by experts, ensures access to high-quality information before it appears in scientific literature. To the best of our knowledge, this is the first attempt to gain such insights from a research projects perspective, which may reveal useful information about the utilization and deployment of these technologies in real-life pilots. More specific objectives of this article, formulated as research questions (RQ1–RQ3), include the following:

- *RQ1: What are the prominent emerging technologies exploited in the public sector through these projects?*
- *RQ2: How do these technologies contribute toward the achievement of the e-Government vision and objectives set by the EU?*
- *RQ3: Which novel e-Government pilot cases do these technologies enable?*

The rest of the article is organized as follows. Section 2 presents the research approach that was followed to achieve the objectives of this article. Section 3 sketches the conceptual framework for understanding the use of emerging technologies in the public sector, as created through the analysis of the identified projects. Aiming to derive meaningful implications and insights, as well as to identify potential research gaps, Section 4 first provides a descriptive overview on the concepts and projects identified, then synthesizes and interprets these findings. The results from the application of the proposed framework are further justified or challenged in Section 5, by referring to research results from the related literature on the use of each emerging technology in the public sector. Finally, Section 6 outlines concluding remarks, comments on the boundaries and limitations of this review, and sketches future research directions.

2 RESEARCH APPROACH

The work reported in this article is based on a research method for performing Systematic Research Projects Reviews [29]. Moreover, it adopts and adapts valuable guidelines that appear in scientific methods for conducting systematic literature reviews [79, 87]. These methods provide guidelines on (i) setting the boundaries of the work, (ii) identifying the source material, (iii) structuring the review, and (iv) identifying critical gaps.

2.1 Setting the Boundaries

e-Government has been part of the European Agenda since the beginning of the century [80]. The European Commission started to systematically fund e-Government research within the fifth (1998–2002), the sixth (2003–2006), and the seventh (2007–2013) framework programs. This trend continued in the latest framework program, namely H2020, which was active for 7 years, from 2014 to 2020. In particular, three distinct work programs were published, covering three periods inside H2020, namely 2014–2015, 2016–2017 and 2018–2020.

Several topics in the preceding work programmes aimed at addressing challenges related to the objectives and principles of the European e-Government Action Plan, such as the *once-only principle* (e.g., CO-CREATION-05-2016: "Co-creation between public administrations: once-only principle"), the *inclusiveness and accessibility principle* (e.g., DT-GOVERNANCE-05-2018-2019-2020: "New forms of delivering public goods and inclusive public services"), and the *openness and transparency principle* (e.g., CO-CREATION-04-2017: "Applied co-creation to deliver public services"). Moreover, several topics focused on ICTs and—explicitly or implicitly—encouraged the exploration of applying emerging technologies in the public sector (e.g., EURO-6-2015: "Meeting new societal needs by using emerging technologies in the public sector" and DT-TRANSFORMATIONS-02-2018-2019-2020: "Transformative impact of disruptive technologies in public services").

In this study, we have thoroughly considered 19 research projects that are related to the use of ICTs in the public sector and were funded through the calls of the 2018–2020 period of the H2020 framework programme. The corresponding calls were included in Societal Challenge 6: "Europe in a changing world—inclusive, innovative and reflective societies." Two out of the three Societal Challenge 6 calls were related to the public sector, namely

"Socioeconomic and cultural transformations in the context of the fourth industrial revolution" and "Governance for the future." The research projects considered in this study were funded through the following three topics, under which eight calls for proposals were issued between 2018 and 2020:

- DT-TRANSFORMATIONS-02-2018-2019-2020: Transformative impact of disruptive technologies in public services. This topic focuses on public administrations' and policy makers' "use of distruptive technologies (such as artificial intelligence and big data analytics, block chain, Internet of Things, virtual and augmented reality, simulations or gamification)."
- DT-GOVERNANCE-05-2018-2019-2020: New forms of delivering public goods and inclusive public services. This topic refers to "the transformative impact of new technologies" in the public sector.
- DT-GOVERNANCE-12-2019-2020: Pilot on using the European cloud infrastructure for public administrations. This topic refers to public administrations' use of "open and big data, in particular as facilitated by high-performance computing (HPC) capabilities offered by the European Cloud Initiative."

The study described in this article adopts a twofold level of analysis, namely research projects and pilot cases. First, the vision, the overall objectives, and the characteristics of each research project are investigated. Then, at a more detailed level, the cases of applying and piloting the ICTs in a specific context are investigated. This may include the use of ICTs to streamline digital public service provision in a specific country or to augment the quality of decision making in a specific citizen group.

2.2 Identifying the Source Material

Literature reviews ensure the accumulation of a relatively complete census of relevant literature. In our study, this requires the identification of the research projects along with the elicitation of details about the use of ICTs in the pilot cases for each specific project. Initially, the **Community Research and Development Information Service (CORDIS)**, which is the European Commission's primary portal for disseminating information about EU-funded research projects and their results, was searched for projects that have been funded under the preceding calls. The 19 research projects identified officially started within the 2018–2021 period and, as of the time of writing this article, most of them are active.

The websites of the projects were then scrutinized to (i) gather additional information about each project's objectives, pilot cases, and overall approach, and (ii) identify deliverables that describe the application and exploitation of emerging technologies (in pilot cases). It is noted that for projects that are still in their early implementation stages, only limited content was available in the CORDIS portal; in these cases, additional information was sought and collected by directly contacting the project coordinators and/or associated partners. Table 12 in the appendix provides a detailed list of the projects investigated in this study, with information about their websites and the particular deliverables considered.

2.3 Structuring the Review

In our method, we adopt a concept-centric analysis. A concept-centric analysis, in contrast to the author-centric approach, helps others make sense of the accumulated knowledge in the field under consideration. As a result, the most important concepts that will facilitate the analysis and synthesis of the identified content need to be specified. In this study, for each research question we aim to answer, the relevant concepts were extracted and meaningfully combined into a framework for understanding the use of emerging technologies in the public sector.

To provide a complete and scientifically sound analysis framework at both levels of analysis (i.e., research project and pilot case implementations), two core e-Government-related EU artifacts were also considered. Specifically, at the research project level, the e-Government Action Plan 2016–2020 was consulted. This action plan illustrates the main principles that need to be taken into account in relevant initiatives in Europe; it also delineates reusable solutions and services (key digital enablers) based on agreed standards and technical specifications

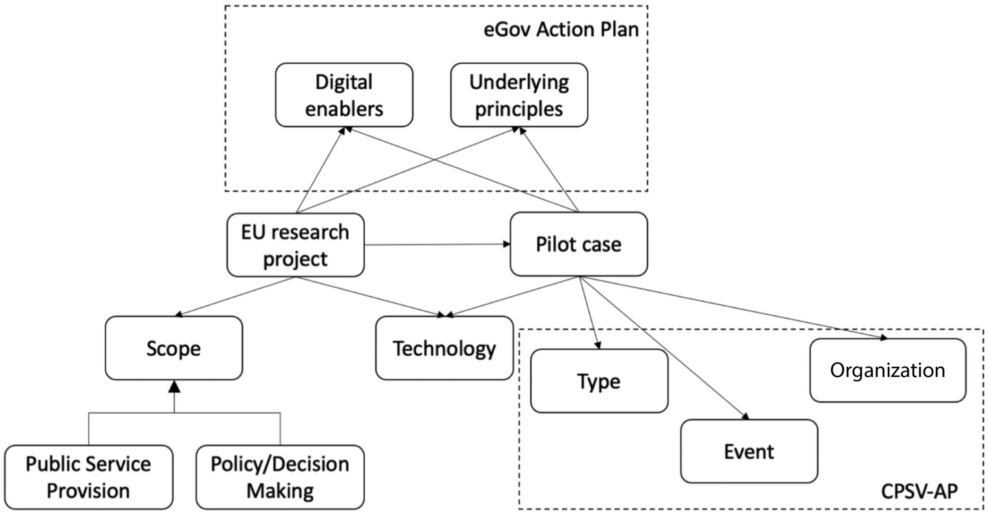


Fig. 1. The concept-centric analysis framework.

to facilitate the development of digital public services. Subsequently, at the pilot case level, the **Core Public Service Vocabulary Application Profile (CPSV-AP)**[1] was utilized to rigorously describe the pilot case implementations. The CPSV-AP, which is developed under the responsibility of the European Commission's ISA[2] Programme,[2] is a first step toward creating a model for describing public services related to business and life events.

2.4 Identifying Critical Gaps

The last step of the our method involves the identification of critical knowledge gaps in the literature, which will thereafter motivate researchers to close this breach. In our case, these knowledge gaps refer to topics that are under- or over-represented in current EU-funded projects. For instance, these topics may particularly refer to the employed technologies, the underlying e-Government principles, the adopted digital enablers, and the involved government activity. Knowledge gaps will emerge by combining and comparatively analyzing these topics (e.g., by analyzing the use of technologies per type of governmental activity). The concept-centric analysis framework presented in Section 3 will guide the identification of the critical knowledge gaps. Finally, these gaps could motivate both the research community and the European Commission to shape and/or refine their future research objectives.

3 CONCEPT-CENTRIC ANALYSIS FRAMEWORK

This section describes the concept-centric analysis framework used in our study (Figure 1). An *EU research project* and the respective *pilot cases* are in the center of this framework. The research projects considered include a set of pilot cases that aim to demonstrate the applicability of the proposed solutions in real-world settings and evaluate their results. Moreover, a research project has a scope that could be either *public service provision* or *policy/decision making*.

[1]Core Public Service Vocabulary Application Profile 2.2.1: https://joinup.ec.europa.eu/collection/semantic-interoperability-community-semic/solution/core-public-service-vocabulary-application-profile/releases.
[2]ISA[2]—Interoperability solutions for public administrations, businesses and citizens: https://ec.europa.eu/isa2.

As far as the e-Government Action Plan 2016–2020 is concerned, it describes a set of underlying principles that relevant e-Government initiatives need to take into account. The pilot cases of the research projects aim at contributing toward one or more of these principles. According to the e-Government Action Plan 2016–2020, the underlying principles include the following:

- *Digital by default* (i.e., public administrations should preferably deliver services digitally and provide information in a machine readable manner),
- *Once-only principle* (i.e., public administrations should ensure that citizens and businesses have to provide certain standard information to the authorities and administrations only once),
- *Inclusiveness and accessibility* (i.e., digital public services should address different needs such as those of the elderly and people with disabilities),
- *Openness and transparency* (i.e., public administrations should be open and transparent, accessible to anyone, anytime, anywhere, and responsive to new ideas and demands; this includes sharing information and data and engaging with stakeholders in the co-creation of services),
- *Cross-border by default* (i.e., public administrations should make relevant digital public services available across borders),
- *Interoperability by default* (i.e., public services should be designed to work seamlessly across organizational silos), and
- *Trustworthiness and security* (involving personal data protection, privacy, and IT security).

In addition, research projects and their pilot cases exploit various *key digital enablers* to achieve their objectives. As introduced in the e-Government Action Plan 2016–2020, the modernization of the public sector should rely on "shared and reusable solutions and services based on agreed standards and technical specifications in order to reduce their cost of development, their time to deployment and increase interoperability." These key digital enablers include open services and technical building blocks, which were funded through the Connecting Europe Facility programme. The Connecting Europe Facility building blocks offer basic capabilities that can be used in any European project to facilitate the delivery of digital public services across borders. Examples of key digital enablers include the following:

- *eID*, which enables the mutual recognition of national electronic identification schemes across borders;
- *eDelivery*, which facilitates public and private organizations to transfer documents and data among each other over a public or private network;
- *eSignature*, which facilitates the creation and verification of electronic signatures across public administrations and businesses;
- *eArchiving*, which facilitates the preservation and reuse of information in the long term; and
- *eInvoicing*, which enables public sector contractors and companies to receive and process electronic invoices, according to the European standards.

Finally, we consider each pilot case being involved with a government activity. By adopting CPSV-AP, the proposed concept-centric analysis framework classifies these activities according to the *Type* property of a public service, which refers to the purpose of a government activity. According to CPSV-AP v.2.2, the *Type* property is populated using the **Classification of the Functions of Government (COFOG)** glossary,[3] which was developed by the Organization for Economic Co-operation and Development and published by the United Nations Statistical Division as a standard for the classification of the purposes of government activities. COFOG includes the following classes:

- *General public services* (i.e., executive and legislative organs, financial and fiscal affairs, external affairs, foreign economic aid, etc.),

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

- *Defense* (i.e., military and civil defense, foreign military aid, etc.),
- *Public order and safety* (i.e., police and fire-protection services, law courts and prisons, public order and safety, etc.),
- *Economic affairs* (i.e., general economic, commercial, and labor affairs; agriculture; fuel and energy; manufacturing and construction; transport, communication; etc.),
- *Environmental protection* (i.e., waste management, water waste management, pollution abatement, protection of biodiversity and landscape, etc.),
- *Housing and community amenities* (i.e., housing development, community development, water supply, street lighting),
- *Health* (i.e., medical products, appliances, and equipment; outpatient and hospital services; public health services; etc.),
- *Recreation, culture, and religion* (i.e., recreational and sporting services, cultural services, broadcasting and publishing services, religious and other community services, etc.),
- *Education* (i.e., pre-primary, primary, secondary, and tertiary education; post-secondary non-tertiary education), and
- *Social protection* (i.e., sickness and disability, old age, family and children, unemployment, housing, etc.).

4 RESULTS

The concept-centric analysis framework described in the previous section was employed to further analyze the identified projects and extract a series of insights about recent research developments and their applications in the public sector. The results of this analysis are included and commented on in this section. The two levels of analysis (i.e., research projects and pilot case implementations) are presented in the next two distinct sections.

4.1 Research Projects

Initially, the objectives of the projects, as stated at the CORDIS portal, were analyzed to identify whether they explicitly aim at exploring a specific technology or contributing toward a specific action plan principle or digital key enabler. According to the proposed conceptual framework, the projects were classified into two broad categories upon their scope, namely the ones that develop solutions for *policy or decision making* and those that focus on *public service provision*.

As made clear in Table 1, 11 out of 19 projects focus on public service provision, whereas the remaining eight on policy/decision-making issues. The former were funded through the topics *DT-TRANSFORMATION-02* and *DT-GOVERNANCE-05*, whereas the latter were funded through *DT-TRANSFORMATION-02* and *DT-GOVERNANCE-12*.

In terms of emerging technologies, Table 2 presents the most prominent technologies that are included in the description of the objectives of each project. The technologies identified were grouped into broader categories that correspond to a well-established research field. It should be noted here that the projects might have exploited more technologies during the course of their operation. In any case, the technologies included in the table are the ones that the projects highlight and focus on. As shown in Table 2, the most prominent category of technologies is AI. In this category, we included not only mentions to "artificial intelligence" *per se* but also mentions to machine learning/deep learning (DE4A and AI4PublicPolicy), predictive algorithms (URBANITE and HECAT), and algorithmic techniques (Qualichain). Blockchain and Distributed Ledger technologies along with Cloud Computing and **High Performance Computing (HPC)** are the two following categories of technologies in the list.

The next more frequent category of technologies is Semantic Technologies, which includes semantics (ACROSS), ontologies (DE4A), and linked data and knowledge graphs (inGov), as well as tools for data aggregation and linking (PolicyCLOUD). **Natural Language Processing (NLP)** technologies including virtual

Table 1. H2020 Projects Reviewed in This Study

Acronym (CORDIS link)	Title	Topic	Duration	Scope
Qualichain	Decentralised Qualifications' Verification and Management for Learner Empowerment, Education Reengineering and Public Sector Transformation	TRANS-02	2019–21	PSP
URBANAGE	Enhanced urban planning for age-friendly cities through disruptive technologies	TRANS-02	2021–24	PDM
ETAPAS	Ethical Technology Adoption in Public Administration Services	TRANS-02	2020–23	PSP
IMPULSE	Identity Management in Public Services	TRANS-02	2021–24	PSP
URBANITE	Supporting the decision-making in urban transformation with the use of disruptive technologies	TRANS-02	2020–23	PDM
HECAT	Disruptive Technologies Supporting Labour Market Decision Making	TRANS-02	2020–23	PDM
TOKEN	Transformative Impact of Blockchain Technologies in Public Services	TRANS-02	2020–22	PSP
CO3	Digital Disruptive Technologies to Co-Create, Co-Produce and Co-Manage Open Public Services Along with Citizens	TRANS-02	2019–21	PSP
ACROSS	Towards user journeys for the delivery of cross-border services ensuring data sovereignty	GOV-05	2021–24	PSP
inGov	Inclusive Governance Models and ICT Tools for Integrated Public Service Co-Creation and Provision	GOV-05	2021–23	PSP
GLASS	Single sign-on eGovernance paradigm based on a distributed file exchange network for security, transparency, cost effectiveness, and trust	GOV-05	2021–23	PSP
INTERLINK	Innovating government and citizen co-delivery for the digital single market	GOV-05	2021–23	PSP
mGov4EU	Mobile Cross-Border Government Services for Europe	GOV-05	2021–23	PSP
DE4A	Digital Europe for All	GOV-05	2020–22	PSP
DUET	Digital Urban European Twins for smarter decision making	GOV-12	2019–22	PDM
PolicyCLOUD	Policy Management through technologies across the complete data lifecycle on cloud environments	GOV-12	2019–22	PDM
IntelComp	A Competitive Intelligence Cloud/HPC Platform for AI-Based STI Policy Making	GOV-12	2021–23	PDM
AI4PublicPolicy	Automated, Transparent Citizen-Centric Public Policy Making Based on Trusted Artificial Intelligence	GOV-12	2021–23	PDM
DECIDO	Evidence and Cloud for more informed and effective policies	GOV-12	2021–23	PDM

PSP, public service provision; PDM, policy/decision making.

Table 2. Emerging Technologies Explicitly Mentioned in the Objectives of a Research Project

Emerging Technology	Total Count	Public Service Provision Projects	Policy-Making Projects
Artificial Intelligence	8	IMPULSE, DE4A, Qualichain	IntelComp, URBANAGE, HECAT, AI4PublicPolicy, URBANITE
Cloud Computing/High Performance Computing	6	ACROSS	AI4PublicPolicy, DECIDO, DUET, IntelComp, PolicyCLOUD
Blockchain and Distributed Ledgers	6	DE4A, Qualichain, IMPULSE, CO3, GLASS, TOKEN	
Semantic Technologies	4	ACROSS, DE4A, inGov	PolicyCLOUD
Natural Language Processing	4	inGov	AI4PublicPolicy, IntelComp, PolicyCLOUD
Mobile Technologies	3	inGov, ACROSS, mGov4EU	
Gamification	3	URBANAGE, CO3	HECAT
Digital Twins	2		DUET, URBANAGE
VAR and 3D Interfaces	2	CO3	DUET

assistants, chatbots (inGov), and sentiment analysis and opinion mining (PolicyCLOUD) are in the same place in the list with Semantic Technologies. Mobile apps (inGov and ACROSS) and mobile devices (mGov4EU) are aggregated in the category Mobile Technologies, which is the next most frequent category, along with that of Gamification. Finally, the two less frequent categories are Digital Twins and **Virtual and Augmented Reality (VAR)** and 3D interfaces.

We mention here that UX (HECAT), geolocated social networks (CO3), privacy preserving technologies (ACROSS), and zero-knowledge proofs (DE4A) are mentioned only in one project each, and thus they are not included in Table 2. Finally, it is noted that two projects, namely INTERLINK and ETAPAS, do not explicitly mention any technology in the description of their objectives.

An interesting exercise is to explore the allocation of the identified emerging technologies in projects dealing with policy/decision making or public service provision. The last two columns of Table 2 depict this allocation. As shown, blockchain and mobile technologies are mentioned only in public service provision projects, and Digital Twins only in policy/decision-making ones. Moreover, semantic technologies are mainly employed (three out of four projects) in public service provision projectsand in policy/decision-making ones (three out of four projects). Another interesting observation is that AI, although present in both categories of projects, prevails in policy/decision making. Finally, cloud computing and HPC technologies are mainly mentioned (five out of six projects) in policy/decision-making projects.

The objectives of the projects were also analyzed to identify whether the projects explicitly aim at contributing to or exploiting a specific principle or key enabler that has been proposed by the EU. Table 3 presents these projects along with the specific EU e-Government principles or enablers. As shown, the Single Digital Gateway along with the regulation that brings the gateway into effect were explicitly mentioned in the objectives of three projects. The EU's Single Digital Gateway facilitates online access to the information, administrative procedures, and assistance services that citizens and businesses need to get active in another EU country. Similarly, the European Open Science Cloud is explicitly mentioned in three projects and is part of the European Cloud Initiative. Thereafter, the ISA^2 core vocabularies, including the Core Public Service Vocabulary (inGov), are explicitly mentioned in the objectives of two projects. Core vocabularies are data models that capture the fundamental

Table 3. EU e-Government Principles and Enablers

EU e-Government Principles/Enablers	Projects
Single Digital Gateway (SDG) and Single Digital Gateway Regulation (SDGR)	ACROSS, DE4A, mGov4EU
European Open Science Cloud (EOSC)	AI4PublicPolicy, DECIDO, IntelComp
ISA^2 core vocabularies	inGov, DECIDO
eID and eIDAS regulation	IMPULSE, mGov4EU
Once-only principle	DE4A, mGov4EU

characteristics of an entity such as a person, a business, a location, a public organization, or a public service. Two projects refer to the electronic identification schemes (eIDs) and the European regulation eIDAS regarding the electronic identification and trust services for electronic transactions in the internal market. Finally, two projects explicitly mention the "once-only" principle. Finally, we note that the European Interoperability Framework (inGov), the relevant-only principle (DE4A), and the digital by default principle (mGov4EU) are mentioned only in one project each, and thus they are not included in Table 3.

4.2 Pilot Cases

At a more detailed level of granularity, our analysis focused on pilot cases, which constitute an essential instrument to demonstrate the applicability and facilitate the evaluation of the results of a research project. In total, we identified 74 pilot cases, resulting in an average of 4.4 pilots per project. This average value is similar in both public service provision and policy/decision-making categories. It is worth mentioning that 47 pilots are included in public service provision projects and 27 in policy/decision-making ones. In addition, it is mentioned that although most of the projects comprise several pilot cases addressing different problem areas, four projects focus on a single problem area. These include *public education* (Qualichain), *urban planning* (URBANAGE), *urban mobility* (URBANITE), and *labor market* (HECAT). Figure 2 in the appendix provides a detailed list of pilot cases identified in our work with references to the associated countries.

4.2.1 Pilot Cases in Public Service Provision Projects. The objectives of the pilots included in the public service provision projects range significantly. The pilots focus on either a specific public service or a life/business event comprising more than one public service. Studying abroad (DE4A, ACROSS), getting a job abroad (GLASS, DE4A, ACROSS), moving to or visiting for a short period another country (GLASS, DE4A), staffing the public sector (Qualichain), and supporting lifelong learning (Qualichain) are examples of life/business events in these projects. It is also mentioned that several pilots aim at developing technical infrastructures that support citizens, businesses, and public authorities. Representative examples include the mobile signature infrastructure and the mobile voting infrastructure of the mGov4EU project.

We first focus on the public services that are implemented in the identified projects. Table 4 presents these services classified according to the *Type* concept of the proposed analysis framework (Section 3). It includes not only typical public services, such as the issuance of a social security number or a certificate of residence, but also public services with a wider scope. These include the social distribution of quality food excess, the dynamic access to a city's services, the rehabilitation services to patients, the misinformation handling, and the publication of government data. In the social distribution of quality food excess service, for example, the role of the public sector is to facilitate the distribution of food from donors to beneficiaries. An important remark is that environmental protection and defense, which are present at the COFOG glossary, do not concern any of the identified cases, and thus they do not appear in the table.

We thereafter examine the reasons for employing the emerging technologies of Table 2 in the identified public services. A specific technology can be employed in multiple public services for the same reason. Table 5 depicts

Table 4. Public Services Classified upon the *Type* Concept of the Proposed Framework

Public Service	Projects
General public service	
Public organizations publish government data in a responsible and ethical manner	ETAPAS
Citizens issue social security number	GLASS
Citizens request certificate of residence	mGov4EU
Citizens request a copy of civil state certificate	DE4A
Citizens request change of address	DE4A
Citizens request pension claim	DE4A
Citizens get information on public service execution	inGov, ETAPAS
Citizens apply for a job in the public sector	Qualichain
Issuance of eID	Impulse
Public order and safety	
Public authorities handle misinformation online	ETAPAS
Economic affairs	
Register a company in another country	DE4A
Update company data in another country	DE4A
Local authorities collect tourism city tax	inGov
SMEs apply for public funding	Token
Suppliers of data trace the use of data made by third parties	Token
Companies participate in a public procurement process	Token
Housing and community amenities	
Local authorities dynamically grant access to the city and the parking services	Token
Health	
Robot-mediated rehabilitation services to patients	ETAPAS
Recreation, culture, and religion	
Creation and visualization of different types of content, (e.g., artistic content)	CO3
Education	
Education institutions issue qualification component to citizens	Qualichain, GLASS
Students gets personalized recommendation on courses	Qualichain
Citizens apply for admission to public higher education abroad	DE4A
Citizens apply for a study grant abroad	DE4A
Citizens request a diploma recognition	DE4A
Social protection	
Issuance of a public transport discount card for disabled	inGov
Provision of benefits to household units	inGov
Social distribution of quality food excess	CO3
Use subsidized taxi rides in rural regions	mGov4EU

the different uses of AI in public service provision. The specific tasks supported by the use of the technology are presented along with the respective public services. These include the provision of personalized recommendations, the verification of copies or mobile photos of official documents through image recognition, and citizens' authentication through facial recognition.

Table 6 summarizes the use of blockchain in public service provision. The validation of evidence (official documents, information, etc.) requested during the execution of a public service is the most common reason

Table 5. AI in Public Services

Aim of the Technology Use	Public Services
Provision of personalized recommendations	Students gets personalized recommendation on courses
Verification of photos/copies of official documents	Issuance of eID
Facial recognition to authenticate citizens	Issuance of eID

Table 6. Blockchain Use in Public Services

Aim of the Technology Use	**Public Services**
Validation of evidence (official documents, information, etc.)	Citizens apply for a job in the public sector
	Companies participate in a public procurement process
	Citizens issue social security number
	Citizens request a diploma recognition
	SMEs apply for public funding
	Education institutions issue qualification component to citizens
Creation of immutable timestamps	Companies participate in a public procurement process
Distribution of social benefits	Social distribution of quality food excess
Document transactions	Suppliers of data trace the use of data made by third parties
Trusted distributed ownership of information	Local authorities dynamically grant access to a city
Trusted and verified parties can manage their identities	Local authorities dynamically grant access to a city

for using blockchain technologies. In this case, a public agency issues an evidence as a verifiable credential in a digital form, which is cryptographically signed by the issuer agency. The citizen stores the verifiable credential along with a cryptographic proof in a digital wallet. If the citizen, at a later stage, invokes the execution of a public service that requires the specific evidence as an input, she shares the digital verifiable credential with the responsible public agency, which then verifies and uses the evidence.

Other reasons for using blockchain technologies include the creation of immutable timestamps, the development of a digital wallet that could replace the transfer of social benefits, the trusted distributed ownership of information, the recording of transactions, and user authentication. In particular, recording the date and time of an event, known as timestamping, is important in many scenarios in the public sector, such as to leave proof of the moment when a citizen or a business triggers the execution of a public service. In the case of competitive processes, such as public procurement, trust and transparency are also important for all parties involved; blockchain provides the means to create immutable and trustful timestamps.

The public sector provides numerous benefits to people in need. Many of these benefits are focused on specific citizens' needs such as food, health, and housing, and thus they can be only exchanged in specific authorized locations. For example, food stamps can be used only with authorized retailers. Blockchain enables the public to create tokens, whereas digital wallets enable users to exchange these tokens easily. Tokens can be used to distribute social benefits to citizens in need, and citizens can exchange these tokens with actual products or services from authorized providers.

Table 7. Semantic Technologies Use in Public Services

Aim of the Technology Use	Public Services
Data integration from multiple public registries	Provision of benefits to household units
Transfer of evidence and information between public agencies	Citizens apply for admission to public higher education abroad
	Citizens apply for a study grant abroad
	Register a company in another country
	Update company data in another country
	Local authorities collect tourism city tax

Table 8. NLP Use in Public Services

Aim of the Technology Use	Public Services
Question & answering	Citizens get information on public service execution
	Robot-mediated rehabilitation services to patients
Opinion mining	Public authorities handle misinformation online

Table 7 presents the identified uses of semantic technologies in public service provision. The main aim of usage of this technology is the creation of a common semantic data model that enables the transfer of evidence and information between public authorities in the same or across multiple countries. The transfer of evidence facilitates the execution of a public service that involves multiple public agencies and contributes toward the implementation of the once-only principle. Moreover, semantic technologies have been used in one pilot for the integration of data coming from multiple sources (specifically, from multiple registries in Malta).

Finally, NLP is used in public service provision to facilitate the development of question and answering applications, as well as the incorporation of opinion mining procedures (including sentiment analysis) in user-generated online texts (Table 8).

4.2.2 Pilot Cases in Policy/Decision-Making Projects. The pilots included in the policy/decision-making projects aim at addressing one or more policy objectives in various policy areas such as public order and safety and environmental protection. Table 9 presents the policy objectives that are described in the eight policy/decision-making projects considered in this study. The objectives are grouped based on their policy area using the *Type* concept of our analysis framework.

As shown in Table 10, the most prominent uses of AI technologies in policy/decision making include predictive analytics, computational simulation models, explainable AI, risk factor prediction, and clustering. In particular, predictive analytics scenarios include the forecasting of energy consumption in the "Energy management and optimization" pilot in AI4PublicPolicy. Examples of computational simulation models include (i) the transport planning case in URBANITE, which exploits an agent-based modeling approach for trip chains analysis to discover the outcomes of interventions with the traffic network, such as by building a tunnel, and (ii) the models and algorithms of the traffic assignment problem of the digital twin developed in DUET. Risk factor prediction cases include the calculation of predictive risk of fires during evacuation procedures in the "Prevention and protection against forest fires" pilot in DECIDO, or the calculation of the traffic jam factor of a road in a specific time slot in URBANITE. Finally, clustering cases include the grouping of clients upon similar energy usage in the "Energy management and optimization" pilot in AI4PublicPolicy.

NLP technologies such as opinion mining and sentiment analysis, named entity recognition, and topic modeling are employed to analyze user-generated content in social media (Table 11). In particular, in a pilot case of the PolicyCLOUD project, opinion mining techniques were applied on Twitter data to identify radicalization efforts and link those efforts to particular terrorist groups or attacks.

Table 9. Policy Objectives Categorised upon the *Type* Concept of the Framework

Policy Objective	Projects
Public order and safety	
Emergency policies related to floods and weather alerts	DECIDO
Improve citizens' safety	DUET
Policies against radicalization	PolicyCLOUD
Economic affairs	
Improve investments in agri-food promotion	PolicyCLOUD
AI capabilities in industry	IntelComp
Energy management and optimization	AI4PublicPolicy
Housing and community amenities	
Power outage management of public infrastructure	DECIDO
City planning including more functional spaces and services for older people	URBANAGE
Organize the operations of the various citizen-facing services and department of the municipality	AI4PublicPolicy
Water infrastructure planning and maintenance	AI4PublicPolicy
Health	
Improve quality of life in cities	PolicyCLOUD, URBANAGE
Prevention, diagnosis, and treatment of cancer	IntelComp
Social protection	
Address unemployment	PolicyCLOUD, HECAT
Environmental protection	
Prevention and protection against forest fires	DECIDO
Emergency policies related to wildfires	DECIDO
Improve the living environment of citizens	DUET
Pollution reduction and urban environment protection	DUET
Support and improve sustainable mobility (including bike mobility, public transport, etc.)	URBANITE, AI4PublicPolicy
Help traffic planners to control congestion	URBANITE
Mobility impact on citizens' lives	DUET
Sustainable Blue Growth under climate change	IntelComp

Moreover, the exploitation of visualizations and business intelligence offered through dashboards has been reported in many cases. These dashboards aim at aggregating diverse data from multiple sources and enable policy makers to monitor the real-time picture of a situation, thus gaining a complete understanding of a certain topic. Example cases include the visualization of signals received via a municipality call center regarding numerous topics (PolicyCLOUD); a dashboard that monitors wine sales price on specialized websites and generates alarm systems when prices fall below a minimum price (PolicyCLOUD); a dashboard regarding the forest fire risk management that exploits data provided by the Finnish Meteorological Institute; the European Forest Fire Information System and meteorological data from Copernicus climate data (DECIDO); and a dashboard offering map layers, charts, and graphs that summarize the status of bike mobility in the city (URBANITE). These dashboards allow decision makers and policy makers to have, in a single view, the overall and relevant information they need to gain insights about a specific topic.

Digital Twins technologies have also been proposed to facilitate policy and decision making in an urban environment. The idea is to create a digital replica of the city that facilitates the understanding of the complex

Table 10. AI Use in Policy Making

Aim of the Technology Use	Policy Objective
Predictive analytics	Prevention and protection against forest fires
	Emergency policies related to floods and weather alerts
	Address unemployment
	Energy management and optimization
Simulation computational models	Support and improve sustainable mobility (including bike mobility, public transport, etc.)
Risk factors prediction	Support and improve sustainable mobility (including bike mobility, public transport, etc.)
	Prevention and protection against forest fires
Clustering	Energy management and optimization

interrelation between various urban factors such as traffic, air quality, and noise. Computational models in Digital Twins need to be able to use each other's outputs. For example, an air-quality model that predicts air quality at certain locations and at certain times can greatly benefit from accessing the output of a traffic model that predicts the number and type of vehicles. DUET cases aim at interconnecting such models and standardize their communication.

4.2.3 Framework Conditions for the Effective Use of Emerging Technologies. Generally speaking, there are numerous institutional and socio-economic factors that may affect the effective use of the emerging technologies being elaborated and utilized in the pilots under consideration in this study. Such factors shape the context in which these pilots operate and are commonly referred to as the framework conditions for digital government ecosystems. A detailed exploration of these conditions in the context of emerging technologies goes outside the scope of this article. However, according to related empirical studies [8, 58, 78], we argue that such conditions usually comprise the following domains: culture and norms, public sector commitment, human capital and the digital divide, formal institutions, market conditions, finance and regulations, and infrastructure and amenities. In addition, taking into account that most of these domains are affected by or regulated within territorial boundaries, digital government ecosystems are geographically bounded. In any case, since new challenges emerge and framework conditions change, public service providers should often assess their service portfolio and critically review their delivery model.

5 DISCUSSION

In this section, we attempt to justify (or challenge) the results reported previously. To this aim, we refer to research results pointed out in the related literature, focusing on recent review articles elaborating and commenting on the use of the technologies under consideration in the public sector. In addition, we sketch a research agenda based on the results of our study.

5.1 Artificial Intelligence

With respect to AI technologies, a systematic literature review of 26 papers focusing on the implications of their use in public governance appears in the work of Zuiderwijk et al. [92]. As identified, the potential benefits of AI use in government span nine categories, namely (i) efficiency and performance benefits, (ii) risk identification and monitoring benefits, (iii) economic benefits, (iv) data and information processing benefits, (v) service benefits, (vi) benefits for society at large, (vii) decision-making benefits, (viii) engagement and interaction benefits, and (ix) sustainability benefits. In particular, for the decision-making benefits category, it is argued that machine learning could support government decision makers and lead to better and more accurate decision making; AI

Table 11. NLP Use in Policy Making

Aim of the Technology Use	Policy Objective
Keyword extraction/named entity recognition	Policies against radicalization
Opinion mining/sentiment analysis	Policies against radicalization
	Improve investments in agri-food promotion

is expected to reduce administrative burden, and Big Data Algorithmic Systems can enable automatic decision making within public institutions [50, 56]. Undoubtedly, the preceding nine categories cover both the public service provision and the policy-making/decision-making scopes distinguished in our study, and justify the balanced allocation of projects in the corresponding categories. Moreover, the diverse list of challenges identified in the work of Zuiderwijk et al. [92], covering (i) data challenges, (ii) organizational and managerial challenges, (iii) skills challenges, (iv) interpretation challenges, (v) ethical and legitimacy challenges, (vi) political, legal, and policy challenges, (vii) social and societal challenges, and (viii) economic challenges, as well as the broad and inclusive use of the term *AI* given in the projects elaborated in our study, justify why the most prominent category of technologies in Table 2 is AI.

The aforementioned diversity in terms of benefits of AI use and challenges is also reported in the work of de Sousa et al. [21] and Dreyling et al. [23], where it is clearly highlighted that the public sector is increasing the use of AI in its services. In addition, it is noted that very interesting results that are in full accordance with the findings of our work are discussed in the work of Wirtz et al. [89], a study that is based on a quantitative and qualitative analysis of 189 articles to review the current literature on AI in the public sector. As reported, the current state of research is heterogeneous and thematically and methodologically unbalanced; many studies focus on governance and administration, whereas more specific application areas receive less attention; and studies to date focus in detail on changes to existing government structures, whereas the creation of entirely new structures due to new AI technologies is given less consideration.

A series of research gaps identified in extant reviews of AI technologies in the public sector have been consolidated in the work of Sharma et al. [76] and Wirtz et al. [89]. A major research gap concerns the little focus given on the development, implementation, and usage of AI-based services within the domains of healthcare, public mobility and society, education, environment, and culture; the pilots reported in Section 4.2 address this very gap by developing public services and shaping innovative policies in these sectors. Another important gap concerns the elaboration of the underlying factors influencing the adoption of AI technologies in the public sector and the associated risks—be they technological, ethical, social, legal, or regulatory—within different public sector domains; the ETAPAS project focuses on these very issues by assessing ethical technology adoption in public administration services.

5.2 Blockchain and Distributed Ledgers

As far as blockchain technologies are concerned, two perspectives for the related architectures and applications in the public sector have been distinguished in the work of Ølnes et al. [93], namely the perspective of *governance by BC*, in which public organizations adopt blockchain technologies for their own processes (like service provisioning), and that of *governance of BC*, which determines what blockchain technologies should look like and how to adapt to changes, and should ensure that public values and societal needs are fulfilled. All projects considered in our study fall within the former perspective. The fact that blockchain technologies are mentioned only in public service provision projects is justified by the primary expectation of blockchain, which is to facilitate direct interaction between citizens, providing administration without a governmental administrator and tailoring services provided by governments; all these fall outside of the policy/decision-making scope.

The preceding fact is also justified by a systematic literature review of blockchain-based applications [12], arguing that the adoption of blockchain technology in the public sector concerns particularly the utilization

of a secure, distributed, open, and inexpensive database technology to reduce cost and bureaucracy, increase efficiency, and authenticate many types of persistent documents, whereas blockchain applications in the public sector include document verification, e-residency approaches, development of more reliable and transparent taxation mechanisms, development of more robust regulatory compliance frameworks, and land management. All these fall within the public service provision scope. Similar results and indications are reported in the work of Sarantis et al. [72], concluding that most of the current cases of blockchain technologies in the public domain have been applied to services, improving transactional and registry functionality, whereas in all cases, interoperability can be enhanced.

The majority of the pilot cases of the projects considered in our study deal with the aforementioned verification-related issues and applications. However, there are also cases that build on blockchain technology to develop public services for "not well explored so far" purposes; these concern the immutable timestamping, the development of digital wallets, the distributed ownership of information, and the distribution of social benefits related to food, health, and housing, as well as the user identification and authentication. In turn, this justifies the ever-increasing adoption and applicability of blockchain technology today; it is also in accordance with the research presented in the work of Brinkmann [11], which aimed to identify the relevance of the new public governance paradigm to the design of public blockchain solutions, and concluded that blockchain-based public service delivery has so far only partly met the various expectations associated with new public governance.

A recent survey on blockchain-enabled digital government and public sector services has identified two significant research gaps [20]. One of them concerns the study of the strong entanglement between the blockchain applications and the underlying IT infrastructure, calling for additional research about whether this is an inherent behavior of blockchain-based systems or an artifact of current deployments; the six projects focusing on blockchain and distributed ledgers, and especially Qualichain, CO3, DE4A, and GLASS, are committed to thoroughly address this issue. For instance, GLASS considers the use of the InterPlanetary File System (IPFS) as the backbone file storage solution [14, 22]. The second gap concerns the need to complement the technological opportunities with institutional readjustments, including the associated legal frameworks; a particular GLASS deliverable, titled "GLASS EU Legal Framework," elaborates the relevant legal frameworks and their characteristics, assesses their applicability to the foreseen project solution at the infrastructural level and for the specific use cases, and concludes with a summary of resulting legal requirements.

5.3 Natural Language Processing

NLP techniques employed in the public sector translate textual structures or commands into a format that intelligent applications (e.g., chatbots or virtual assistants) can understand and process to generate responses to be sent back to citizens [5], group citizens by interests so that they can better interact with each other, and assist citizens in aggregating and developing proposals [7]. Taking as input queries expressed by citizens in natural language, NLP is usually combined with data mining for extracting citizens' sentiment from text or multimedia content. State-of-the-art chatbots go beyond a typical FAQ logic; they can self-improve by learning from every new dialogue and every new phrase they analyze. As argued in the work of Kowalski et al. [49], the systematic and exhaustive inclusion of citizen voices, processed using machine learning and NLP techniques, represents a substantial and desirable improvement over other prominent methods of incorporating citizen views into political and public policy decision making. An interesting study about the integration of chatbots with knowledge graphs from both a technical and a public administration view to build a "getting a passport" public service is reported in the work of Patsoulis et al. [68]; as argued, such an integration is technically feasible and provides potential benefits to citizens.

According to the preceding, NLP techniques may cover both the public service provision and the policy/decision-making scopes distinguished in our study, in that they make it easier to include direct public participation in decisions that relate to complex policy areas, and they also enable the development of

innovative public services [6]. However, emphasis is lately given to the second scope [49, 65, 70]. This remark is fully justified by the number and type of pilot cases considered in this study. Specifically, these cases exploit NLP techniques to offer diverse services, including provision of information about the execution of public services, robot-mediated rehabilitation to patients, and handling of misinformation by public authorities, as well as to facilitate policy making in issues including radicalization and promotion of agri-food investments. In the cases considered, NLP techniques aim to serve typical purposes such as question and answering, keyword/feature extraction, named entity recognition, opinion mining, and sentiment analysis.

Two major research gaps concerning NLP models and techniques for public services are stressed in a very recent report written in the context of the Catalogue of Services action part of the former ISA[2] (now Interoperable Europe[4]) initiative [10]. The first one is that most NLP models today are built for broadly spoken languages such as English, Spanish, or French, and many resources are available for their training purposes, whereas languages spoken by small populations or groups with little access to the Internet or technology often go overlooked. This issue has been partly addressed by new technologies such as multilingual sentence embeddings that can identify and leverage shared characteristics between languages. In any case, the pilots discussed in Section 4.2 do not address this gap, which remains a research topic to be addressed in future NLP improvements. The second gap concerns the lack of unifying ontologies and semantic repositories that describe the physical world with the precision needed in practical applications, such as those of public services. Standards such as the **Resource Definition Framework (RDF)** have improved the automated processing of Web resources, but more development regarding these issues is needed toward large-scale deployment of NLP models and techniques. It is noted that this second gap is not addressed in the pilots considered in this work.

5.4 Mobile Technologies

Mobile technologies already provide governments with significant opportunities to achieve improved communication and data exchange, expanded service delivery, and stronger digital equality [75]. The increasing use and penetration of mobile phones extends outreach and access to groups that are traditionally difficult to reach, such as citizens living in rural areas, and expands governments' accountability and transparency to a higher number of citizens [63]. With respect to their adoption toward improving government performance and strengthening public good governance, it is broadly admitted that emphasis should not be placed on the mobility features *per se*; instead, focus should be placed on the needs of both the public sector and the end users, be these citizens or businesses, to ensure that mobile technologies are properly utilized to reorganize the way civil servants work and meet the needs of citizens through improved service delivery [62]. The preceding advocate the use of these technologies toward primarily fulfilling the public service provision scope distinguished in our study, by enabling the development of innovative public services, and not the policy/decision-making scope. This remark is also justified by the allocation of related projects mentioned in Table 2 and the type of pilot applications reported in Table 4.

As concluded in a recent survey on **Mobile Government (m-Government)** research development and perspectives [88], "mobile government is a very young and open-ended field of research, which provides various opportunities for further researchers." As also identified, research opportunities go beyond adoption and intention to use, to cover key topics such as (i) acceptance-based attitude toward m-Government, (ii) use-based attitude concerning the user's attitude after or during the usage of m-Government services, and (iii) usage behavior (e.g., the frequency of m-Government services being queried by citizens). As mentioned in Section 4, two projects considered in this study aim to develop diverse mobile applications (inGov and ACROSS), whereas a third one deals with issues related to the use of mobile devices (mGov4EU). These projects and their corresponding pilots partially address the preceding key topics, paying particular attention to the first two.

[4]https://joinup.ec.europa.eu/collection/interoperable-europe/interoperable-europe.

5.5 Cloud Computing and HPC

Admittedly, cloud computing and HPC have the potential to offer significant benefits in the public sector. These benefits are often distinguished in three levels, namely those concerning the citizens, the society, and the government [2]. The related technologies are expected to be a fundamental part of e-Government strategy in the upcoming years, since they enable the digital transformation of public authorities through the use of innovative and cost-effective models and services [64, 66]. At the same time, they enable the deployment of a platform that is more scalable, reliable, high performance, and relatively low cost as compared to other distributed computing infrastructures [19].

According to the preceding, these technologies may serve both the public service provision and the policy/decision-making scopes distinguished in this work, in that they enable the development and, especially, the easy deployment of innovative public services and policy/decision-making procedures. In any case, the allocation of related projects shown in Table 2 indicates that the majority of the projects considered in this study focus on the policy/decision-making scope.

5.6 Gamification

As far as gamification is concerned, its value for governments and agencies to motivate citizens and retain their engagement has been broadly acknowledged [17]. By meaningfully integrating gamification techniques, e-Government services may move from their traditional form to one that serves citizens through enjoyable Web and mobile technologies; at the same time, gamification in e-Government may encourage new types of users to participate (e.g., young people) by augmenting their interest, awareness, and loyalty to diverse e-Government issues while rendering a feeling of active participation and empowerment [1]. As such, gamification techniques may cover both the public service provision and the policy/decision-making scopes distinguished in our study; they make it more enjoyable and engaging to include direct public participation in decisions that relate to complex policy areas, and they also enable the development and extended utilization of novel public services. Finally, with respect to the three levels of citizen engagement outlined by Macintosh [57], namely empowering, engaging, and enabling, it has been argued that research remains scarce with regard to the levels of empowering and enabling, thus encouraging researchers to focus their investigation on them [36]. The preceding remarks are fully justified by the number and type of pilot applications considered in this study.

According to the research gaps identified in a recent review on e-Government services with gamification elements, gamification element selection does not depend on the user profile, the impact of gamification is not evaluated based on whether the usage is maintained over time, and, finally, no sort of interaction among citizens is enabled [18]. The identified pilots do not address any of these research gaps.

5.7 Semantic Technologies

With respect to semantic technologies, they generally build on the synergy of human and machine reasoning to interpret data, elaborating a high level of structure and well-defined semantics of content and links. Technologies such as RDF, RDF with attributes (RDFa), Web Ontology Language (OWL), SPARQL Protocol, and RDF Query Language (SPARQL) may enable a formal description of concepts, terms, and relationships within a knowledge domain [28]. In the context of e-Government, these technologies make open government data a part of the Web, where it can be interlinked to other data that provide documentation, additional context, and necessary background information [61]. As stated in the work of Kalampokis et al. [43], the real value of open government data is enhanced with application of semantic technologies to link data, and provide unexpected and unexplored insights into different domains and problem areas.

Due to their broad application in any knowledge domain, semantic technologies may cover both the public service provision and the policy/decision-making scopes distinguished in our study. They may augment the quality of policy/decision making by informing the process with publicly available data while also enabling the

integration of machine reasoning functionalities [39]. At the same time, they also enable the development of smart and efficient public services that may increase openness and transparency of government, and improve the accessibility to and re-usability of government data. The preceding remarks are justified by the number and type of pilot cases considered in this study. Specifically, the pilot cases of the projects considered exploit semantic technologies to offer diverse services including provision of benefits to household units, admission to public higher education and study grants abroad, and registration of a company in another country. Beyond data integration purposes, these technologies aim to also serve the transfer of evidence between public agencies.

It has been early recognized that semantic technologies in the public sector support either process integration involving integration of systems and services through service discovery, composition, mediation and invocation, or data interoperability [86]. Our analysis demonstrates that most of the identified pilots fall into the latter category, as they aim at addressing semantic interoperability challenges to enable transferring evidence and information between public authorities. The European Commission works on the development of relevant standards to facilitate technical and semantic interoperability in the public sector [44].

5.8 Digital Twins

Digital Twins provides an exact digital counterpart of an object, process, or system, and has recently started being used by the public sector to deliver benefits to government and citizens. Digital Twins' overarching benefit is enabling experimentation with no physical repercussions or real-world costs. Public sector applications include city planning [73], government-run energy projects [67], and public healthcare [55]. Due to its nature, this technology primarily suits to the policy/decision-making scope distinguished in our study, in that it enables an easy and inexpensive assessment of alternatives decisions and policies, and not to the public service provision scope. This remark is justified by the allocation of related projects mentioned in Table 2 and the number and type of pilots considered in this study.

5.9 VAR and 3D Interfaces

Finally, as far as **Virtual Reality (VR)**, **Augmented Reality (AR)**, and 3D interfaces are concerned, it is broadly admitted that the related technologies become more and more affordable and user friendly, enabling the public sector to explore and build innovative approaches that may range from field operations to personnel training to service delivery [25, 59]. Similar to what happens with gamification technologies, they could provide end users with a higher level of realism and immersion. In any case, state and local governments are still in the early stages of AR and VR adoption. These technologies may cover both the public service provision and the policy-making/decision-making scopes distinguished in our study. The allocation of related projects and the number and type of pilot applications considered in this study justify this remark.

5.10 Research Agenda

According to the preceding discussion, there are several research directions calling for further investigation toward addressing the identified research gaps. These include the following:

- The elaboration of the factors that influence the adoption of AI technologies within diverse public sector domains, together with the associated technological, ethical, social, legal, or regulatory risks;
- Actions toward complementing the technological opportunities raised from the adoption of blockchain-enabled digital government and public sector services with institutional readjustments, including the associated legal frameworks;
- With respect to NLP models and techniques for public services, attention should be also paid to languages spoken by small populations or groups with little access to the Internet or technology;
- Work toward developing unifying ontologies and semantic repositories that offer the precision needed in public services while also supporting large-scale deployment of NLP models and techniques;

- With respect to mobile technologies, research should go beyond their adoption and intention to use in the public sector, and elaborate topics related to the acceptance-based and use-based attitude of citizens, as well as to the corresponding usage behavior;
- With respect to semantic technologies, research should focus on the application and wide adoption of standard vocabularies, architectures, and building blocks, which were developed and suggested by the European Commission to facilitate semantic interoperability (an indicative work toward this direction is the Core Public Service Vocabulary [30]);
- With respect to gamification, attention should be paid to the issues of element selection upon the user profile, evaluation of its impact based on whether the usage of its elements is maintained over time, and development of gamification services that enable interaction among citizens;
- The development of applications based on Digital Twins and the investigation of its adoption within diverse public sector domains; and
- The elaboration of AR and VR adoption in solutions concerning state and local governments for both public service provision and decision/policy making.

6 CONCLUSION

Given the lack of a comprehensive overview of applications of emerging technologies in the public sector, the concept-centric approach proposed in this article aims to analyze and compile relevant findings from 19 recently funded H2020 research projects to provide an integrative overview of the utilization and deployment of such applications in real-life pilots. To the best of our knowledge, this work is the first attempt to contribute to the theoretical body of knowledge on the use of emerging technologies in the public sector from a research projects perspective. Specifically, the particular study contributes by identifying the prominent emerging technologies exploited in the public sector through a series of currently active projects, how these technologies contribute toward the achievement of the e-Government vision and objectives set by the EU, and which e-Government pilot cases these technologies enable.

The main limitation of our study is that it covers only the research projects funded by H2020 resources from 2018 to 2020. H2020 was certainly the EU's primary research and innovation funding program; admittedly, it has produced significant research and innovation outcomes and large-scale demonstration activities with high-quality technological value. However, the findings of our study may not be reflective of similar research initiatives funded by national or private resources. For instance, our findings regarding the allocation of projects and type of pilot cases involving blockchain and distributed ledger technologies may not apply to other contexts. Future research could adopt the analysis framework proposed in this study to investigate whether its findings can be generalized.

A second limitation concerns the source material used in our study. As noted in a previous section, we mainly retrieved the information sought from the projects' websites, whereas for projects still in their early implementation stages, additional information was found by directly contacting the project coordinators and/or associated partners. Generally speaking, the preceding websites are quite informative from the early stages of a research project; however, they are in most cases regularly updated to reflect in more detail the ongoing advancements. Future research could reassess whether the evolution of the projects considered in this study has modified the way that emerging technologies are utilized and deployed in their foreseen applications.

In any case, we argue that the analysis of research projects and their pilot cases reported in this article constitutes a first step toward a systematic investigation of the applications of emerging technologies in the public sector. Beyond revealing useful information about the utilization and deployment of these technologies in real-life pilots, the proposed approach is able to derive meaningful implications and insights, and accordingly identify possible directions and opportunities for future research investment with respect to the increasing diffusion of these technologies in the public sector and its complex implications.

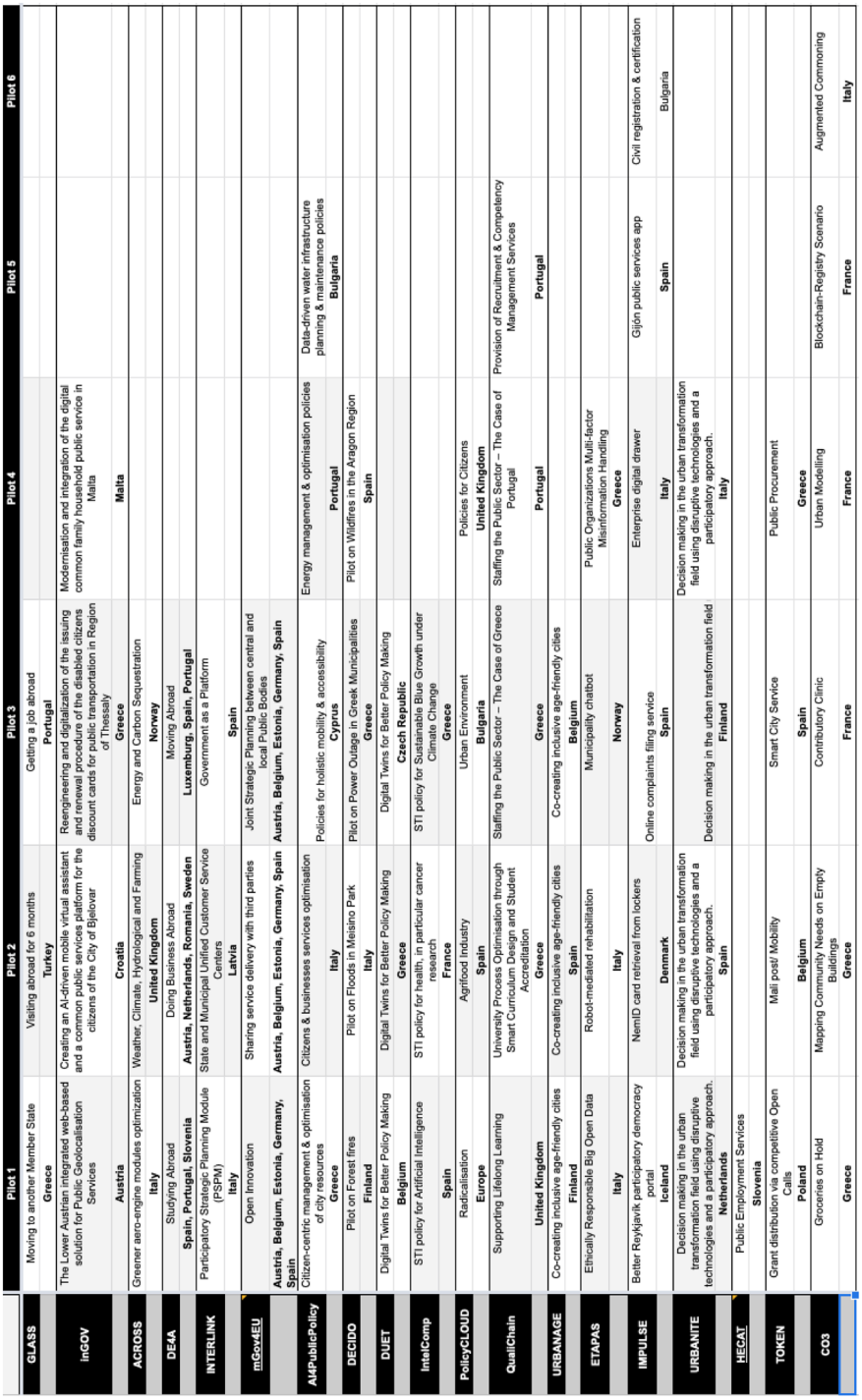
A APPENDIX

Table 12 summarizes the public deliverables per project that were considered in this study. This source material complements the information extracted from CORDIS, the projects' websites, as well as the information collected through direct communication with the projects' coordinators and/or associate partners.

Table 12. Source Material Per Project That Were Used in this Study

Acronym	Website	Public Deliverables
Qualichain	qualichain-project.eu	D7.5: Qualichain Pilots Execution Documentation, Final Release
URBANAGE	urbanage.eu	Stakeholder mapping and engagement roadmap; Challenges, user requirements and solutions CO-C
IMPULSE	impulse-h2020.eu	D2.1: Stakeholder analysis and evaluation criteria; D2.5: IMPULSE piloting roadmap V1
ETAPAS	etapasproject.eu	
URBANITE	urbanite-project.eu	D2.2: Mapping of stakeholders; D5.1: Detailed requirements specification
HECAT	hecat.eu	D1.4: HECAT User Vision Statement
TOKEN	token-project.eu	
CO3	projectco3.eu	D3.2: Pilot Requirements; D3.3: Pilots Report I
ACROSS	across-h2020.eu	D6.1: Use case scenarios & roadmap; D5.1: System Architecture & Implementation Plan - initial
inGov	ingov-project.eu	D1.1: IPS Enhanced Models and Needs Elicitation
GLASS	glass-h2020.eu	D2.3: Government to all specification list
INTERLINK	interlink-project.eu	D5.1: Use-case plans and guidelines v1
mGov4EU	mgov4.eu	D1.3: Specification of System Requirements
DE4A	de4a.eu	D4.1: Studying abroad - Use cases Definition and Requirements; D4.5: Doing Business Abroad - Use cases definition and requirements; D4.9: Moving Abroad - Use cases definition and requirements
DUET	digitalurbantwins.com	D2.2: Scenario specifications of the DUET solution; D6.1:Pilot Operations Plan;
PolicyCLOUD	policycloud.eu	D6.10: Use Case Scenarios Definition & Design; D2.5: State of the art & Requirements Analysis
IntelComp	intelcomp.eu	D1.1: Report on the domain-specific needs and Public Administrations and stakeholder assessment in the three pilot domains; D1.4: Policy brief on the use of AI and data-driven tools for STI policy design
AI4PublicPolicy	ai4publicpolicy.eu	D2.8: Plan and report on cocreation activities V1
DECIDO	decido-project.eu	D2.3: Pilot evaluation and impact assessment framework, methodology and instruments; D4.4: Mapping of stakeholders

Figure 2 provides a detailed list of pilot cases identified in our work with references to the associated countries.



	Pilot 1	Pilot 2	Pilot 3	Pilot 4	Pilot 5	Pilot 6
GLASS	Moving to another Member State **Greece**	Visiting abroad for 6 months **Turkey**	Getting a job abroad **Portugal**			
inGOV	The Lower Austrian integrated web-based solution for Public Geolocalisation Services **Austria**	Creating an AI-driven mobile virtual assistant and a common public services platform for the citizens of the City of Bjelovar **Croatia**	Reengineering and digitalization of the issuing and renewal procedure of the disabled citizens discount cards for public transportation in Region of Thessaly **Greece**	Modernisation and integration of the digital common family household public service in Malta **Malta**		
ACROSS	Greener aero-engine modules optimization **Italy**	Weather, Climate, Hydrological and Farming **United Kingdom**	Energy and Carbon Sequestration **Norway**			
DE4A	Studying Abroad **Spain, Portugal, Slovenia**	Doing Business Abroad **Austria, Netherlands, Romania, Sweden**	Moving Abroad **Luxemburg, Spain, Portugal**			
INTERLINK	Participatory Strategic Planning Module (PSPM) **Italy**	State and Municipal Unified Customer Service Centers **Latvia**	Government as a Platform **Spain**			
mGov4EU	Open Innovation **Austria, Belgium, Estonia, Germany, Spain**	Sharing service delivery with third parties **Austria, Belgium, Estonia, Germany, Spain**	Joint Strategic Planning between central and local Public Bodies **Austria, Belgium, Estonia, Germany, Spain**			
AI4PublicPolicy	Citizen-centric management & optimisation of city resources **Greece**	Citizens & businesses services optimisation **Italy**	Policies for holistic mobility & accessibility **Cyprus**	Energy management & optimisation policies **Portugal**	Data-driven water infrastructure planning & maintenance policies **Bulgaria**	
DECIDO	Pilot on Forest fires **Finland**	Pilot on Floods in Meisino Park **Italy**	Pilot on Power Outage in Greek Municipalities **Greece**	Pilot on Wildfires in the Aragon Region **Spain**		
DUET	Digital Twins for Better Policy Making **Belgium**	Digital Twins for Better Policy Making **Greece**	Digital Twins for Better Policy Making **Czech Republic**			
IntelComp	STI policy for Artificial Intelligence **Spain**	STI policy for health, in particular cancer research **France**	STI policy for Sustainable Blue Growth under Climate Change **Greece**			
PolicyCLOUD	Radicalisation **Europe**	Agrifood Industry **Spain**	Urban Environment **Bulgaria**	Policies for Citizens **United Kingdom**		
QualiChain	Supporting Lifelong Learning **United Kingdom**	University Process Optimisation through Smart Curriculum Design and Student Accreditation **Greece**	Staffing the Public Sector – The Case of Greece **Greece**	Staffing the Public Sector – The Case of Portugal **Portugal**	Provision of Recruitment & Competency Management Services **Portugal**	
URBANAGE	Co-creating inclusive age-friendly cities **Finland**	Co-creating inclusive age-friendly cities **Spain**	Co-creating inclusive age-friendly cities **Belgium**			
ETAPAS	Ethically Responsible Big Open Data **Italy**	Robot-mediated rehabilitation **Italy**	Municipality chatbot **Norway**	Public Organizations Multi-factor Misinformation Handling **Greece**		
IMPULSE	Better Reykjavik participatory democracy portal **Iceland**	NemID card retrieval from lockers **Denmark**	Online complaints filing service **Spain**	Enterprise digital drawer **Italy**	Gijón public services app **Spain**	Civil registration & certification **Bulgaria**
URBANITE	Decision making in the urban transformation field using disruptive technologies and a participatory approach. **Netherlands**	Decision making in the urban transformation field using disruptive technologies and a participatory approach. **Spain**	Decision making in the urban transformation field **Finland**	Decision making in the urban transformation field using disruptive technologies and a participatory approach. **Italy**		
HECAT	Public Employment Services **Slovenia**					
TOKEN	Grant distribution via competitive Open Calls **Poland**	Mail post/ Mobility **Belgium**	Smart City Service **Spain**	Public Procurement **Greece**		
CO3	Groceries on Hold **Greece**	Mapping Community Needs on Empty Buildings **Greece**	Contributory Clinic **France**	Urban Modelling **France**	Blockchain-Registry Scenario **France**	Augmented Commoning **Italy**

Fig. 2. List of project pilots and associated countries.

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