STUDY

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Challenges and limits of an open source approach to Artificial Intelligence

Policy Department for Economic, Scientific and Quality of Life Policies
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Challenges and limits of an open source approach to Artificial Intelligence

Abstract

Coupled with the numerous opportunities emerging from the use of artificial intelligence (AI), open source comes with the potential for innovation capacity in both the public and private sector. Advantages include the ability to enhance transparency, facilitate the auditing of AI and thereby enhance citizen trust, while stimulating economic activities and domain-specific expertise. Disadvantages and limits include legal, technical, data, risk management, societal and ethical challenges. This analysis examines all main open source artificial intelligence pro and cons and proposes seven recommendations to boost its uptake.

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CONTENTS

LIST OF ABBREVIATIONS

API	Application Programming Interface
AI	Artificial Intelligence
CivicTech	Civic Technology
DEP	Digital Europe Programme
EC	European Commission
EP	European Parliament
EU	European Union
EU-FOSSA	European Union – Free and Open Source Software Auditing
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GovTech	Government Technology
GPL	General Public License
GPT	Generative Pre-Trained Transformers
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technologies
IPAs	Intelligent Personal Assistants
IT	Information Technology
ML	Machine learning
MS	Member State
OS	Open source
OSI	Open Source Initiative
OSOR	Open Source Observatory

OSS	Open-source software
OSS AI	Open Source Artificial Intelligence
RRF	Recovery and Resilience Facility
SME	Small and Medium Enterprises

EXECUTIVE SUMMARY

Background

The aim of the in-depth analysis is to provide an analysis of the potential of adopting an open-source software (OSS) approach to deploying artificial intelligence (AI), with the aim of facilitating evidence-based decisions and synthesize current state of knowledge to tackle challenges and limitations related to such combined approach. The analysis discusses the role that open-source could play in accelerating the use and exploitation of AI, in particular in the public sector, providing a critical assessment of the key research and data published on the subject.

Methodology

The analysis is based on existing available data, studies and analysis from various sources, complemented by own independent analysis and expertise as well as a targeted stakeholder consultation performed in the period of March and April 2021. The analysis includes a **literature review** and desk research of academic and non-academic sources including market reports, legal and policy documents and online sources such as expert blogs. Seven **semi-structured expert interviews** with representatives from regulatory authorities, academia, and the private sector to enrich the findings from the review of available secondary sources with stakeholder opinions and exclusive insights on the subject matter. Lastly, an **online survey** disseminated via expert networks and other channels targeting key stakeholders to enrich and validate results.

Findings

The convergence of OSS and artificial intelligence (AI) is driving rapid advancements in a number of different sectors. This open source AI (OSS AI) approach comes with high innovation potential, in both the public and private sector, thanks to the capacity and uptake of individuals and organisations to freely reuse the software under open source licences. In the EU, AI has a high opportunity to bring digital transformation in sectors such as commerce: currently, only 1 out of 5 companies in the EU are highly digitalised, while 60% of large industries and more than 90% of Small and Medium Enterprises (SMEs) lag behind in digital innovation. OSS AI can support companies to leverage the best innovations in models and platforms that have already been created, and hence focus on innovating their domain-specific expertise. In the public sector, OSS has the benefits of enhancing transparency, by opening the "black box", and ultimately, citizen trust in public administration and decision-making. Furthermore, governments can stimulate economic activities by providing open government software to national and local companies. Across the public sector in European MS, OSS policies and legislation are most commonly embedded in the broader digitalisation initiatives within the policy and legal framework of these countries. However, a clear link to the AI policies and strategies are missing for most countries (Czech Republic and Finland being the only countries with overlapping policy documents). Furthermore, despite the advances and power of OSS AI, many governments are still tethered to traditional ways of providing services due to a number of challenges, such as their current, legacy IT systems, shrinking public budget dedicated to digital innovation, or lack of AI expertise in their workforce. A particular aspect to consider is also linked to the public procurement processes for acquiring IT systems, which are often not inducive to enabling digital innovation and partnership models typical of the OSS community, and the emerging Gov Tech and Civic Tech ecosystems. This is not the least due to the fact that the current policy environment does not invest enough into the increased uptake of OSS AI solutions, which will be necessary in order to reach the goal of digital sovereignty of the EU.

Conclusions and policy recommendations

Open source holds vast potential to contribute towards digital sovereignty of Europe. However, more has to be done to boost uptake of open source in order to tap into the vast potential it can bring. Based on the results of this analysis, the following policy recommendations can be drawn:

- **Defining an OSS AI assessment policy / methodology to determine which public services are appropriate for the (experimental) use of OSS AI systems.** A clear lack of economic research has been conducted so far to clearly distil the costs and benefits of using open source AI in public administration across the EU.
- **Promoting Government Technology (GovTech) and Civic Technology (CivicTech) ecosystems**. It is crucial to engage experts such as local entrepreneurs, social innovators and SMEs. Special attention should be made to align strategies for the deployment and scale-up of AI-powered Local Digital Twins and the creation of AI algorithm registries.
- **Facilitating good quality data access for public institutions.** European data spaces should consider the promotion of OSS AI. This could be done by supporting voluntary data sharing by individuals and communities of developers, and setting up structures to enable key public and private sector organisations to share data.
- **Supporting public organisations as potential open source AI producers.** Third-party intermediaries could be used to identify and manage open source AI projects across the EU in alignment with the digital transformation goals of the EU. Close collaborations with universities could be a way to introduce, maintain, and monitor open source AI solutions in government in a sustainable way and promote technology transfer.
- **Using public procurement to encourage OSS AI digital solutions in the public and private sector.** As part of the Adopt AI programme to support public procurement of AI systems and transforming procurement processes themselves, a special effort should be dedicated to developing OS approaches to AI, also within the context of the new public procurement data space proposed in the AI Coordinated Plan.
- **Stimulating the OSS innovation ecosystems to accelerate AI development and use.** This could be done through incentives to OSS collaborators, especially SMEs, and increasing the transparency of the source of software underpinning the digital infrastructure and functionalities deployed along the entire value chain.
- **Creating opportunities for strengthening the sharing of OS data and analytical tools across communities of research and practice,** promoting the creation of repositories to support developing AI applications, and the transfer of specific AI components to be used "on demand", following the approach the European Commission (EC) initiated with the "AI4EU platform"[1], to develop an AI resources catalogue, which includes reusable AI datasets, models, libraries and other resources.

[1] See the AI4EU Platform available at: https://www.ai4eu.eu/ai4eu-platform.

1. INTRODUCTION

Open-source software (OSS) is a sub-set of free software that is made available under specific type of copyright licenses. Coupled with the numerous opportunities emerging from the use of artificial intelligence (AI), advancements could be unprecedented in breadth and depth, in a number of different sectors, to automate processes, build transparency, and innovate services. An open source approach comes with much potential for innovation capacity and uptake, in both the public and private sector thanks to the ability of individuals and organisations to freely reuse the software under open source licences. The capability to deploy existing technology facilitates innovation by leveraging on innovative service and organisational models and digital platforms, while the evolution of OSS communities that support software developments increase the diversity of potential AI expert sources and help to create a level playing field against "technological giants" that so far played a key role in software development and usage.

However, despite an abundance of opportunities that are made readily available to individuals and companies to exploit, open source AI (OSS AI) can also bring about new risks or negative consequences for individuals or the society. Particularly, in the public sector, there are costs and benefits that must be taken into consideration when deploying OSS AI. Digitising administrative procedures can be regarded as inevitable for the government amid rapid digital technological changes, in particular those building on vast datasets that need the support of AI technologies. The importance of open source in the public sector across Europe is affirmed by governments increasingly incorporating open source as part of their country's political and legal framework. OSS AI is currently used in the public sector in a few Member States (MS) to automate government services and enhance the transparency of administrative procedures between governments and citizens. In general, digitalising services, and in particular adopting advanced AI solutions, has the potential to deliver cost savings in public sector organizations, as well as other downstream political, economic, social and technical benefits for the country by leveraging on the enormous quantities of data that are being generated on a daily basis, as well as the capacity to deliver proactive and personalised services.

In particular, OSS AI has the potential to enhance transparency by opening "black boxes", and ultimately, citizen trust in public administration and decision-making, while the government can stimulate economic activities by providing open government software to national and local companies. Despite the advances and power of an open source approach to AI, many governments are still tethered to traditional ways of providing services due to a number of challenges, such as their current, legacy IT systems, shrinking public budget dedicated to digital innovation, or lack of AI experts in their workforce. A particular aspect to consider is also linked to the public procurement processes for acquiring IT systems, which are often not inducive to enabling digital innovation and partnership models typical of the OSS community, and the emerging Gov Tech and Civic Tech ecosystems.

This is not the least due to the fact that the current policy environment does not invest enough into the increased uptake of OSS AI solutions, which will be necessary in order to reach the goal of digital sovereignty of the EU in the future.

2. EXISTING TYPES OF OPEN-SOURCE SOFTWARE

2.1. Origins

In this age of increasing digitalisation, more and more software is made available to the public with the purpose of open collaboration and peer production. This "open" and collaboratively built software is present in our every-day lives and is used for a diverse range of applications, including from power popular Internet browsers and mobile operating systems to blockchain and digital infrastructures. **Open source is a widely-used term describing software that comes with all necessary permissions granted in advance to facilitate its use, improvement, and redistribution (modified or unmodified) by anyone and for any purpose**[2]. These permissions are often called "the four freedoms[3]"of software users:

- The freedom to run the program as you wish, for any purpose.
- The freedom to study how the program works and change it so it does your computing as you wish. Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help others.
- The freedom to distribute copies of your modified versions to others.

It stands in contrast to proprietary software, where only the original authors of proprietary software can legally copy, inspect and alter that software[4]. According to the Open Source Initiative (OSI), a global non-profit that advances the use and awareness of **open-source software (OSS)** is characterised by[5]: (1) free redistribution; (2) source code distribution; (3) derived works permission; (4) integrity of the authors source code; (5) no discrimination against persons or groups; (6) no discrimination against fields of endeavour; (7) distribution of license; (8) license must not be specified to a product; (9) license must not restrict other software; and (10) license must be technology neutral. The origins of open source can be traced back to the GNU (GNU's Not Unix) Operating System in 1983[6]. The operating system Linux was quietly released in 1991, incorporating many of the GNU project elements and primarily used as an alternative to MacOS and Windows. This system is often credited with kick-starting momentum of open source use and by the early 2000s large companies were taking advantage of OSS. Today, Linux boasts impressive hosting statistics; it runs 100% of the world's top 500 super computers, operates 90% of all cloud infrastructure, and with Android phones based on Linux, 85% of all smartphones run on this system[7].

2.2. Licensing

Licensing in OSS is crucial because it allows project originators to adjust the copyrights so the software can be freely used, modified, and shared, while at the same time establishing guidelines and maintaining copyright. It does not necessarily mean that executable software is given away for free, but rather that the source code is available for free; converting that source code into runnable code requires expertise, time, and capacity[8]. Licenses vary in restrictiveness and distribution terms and for

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2 European Commission (2020) *Managing licence compatibility issues in free and open-source software*. European Union Publications Office.

3 GNU Operating System (2021) *What is free software?* Free Software Foundation.

4 Ibidem.

5 Opensource.org (2007) The Open Source Definition | Open Source Initiative.

6 GNU Operating System (2017) *Overview of the GNU System - GNU Project - Free Software Foundation*.

7 Galov, N. (2021) *111+ Linux Statistics and Facts – Linux Rocks!* Hosting Tribunal.

8 Ibidem.

those that are considered open source license types, they are approved by a Board of Directors of the OSI, through a **License Review Process**. To this day, this board has a list[9] comprising of more than 80 open source licenses that are available and approved for use. These categories differ in how the software can be used, how it protects the users, originators, and defines other limitations around the software. While the **Copyleft license** used to be the most common open source license in use, over the past few years there has been a decline in the use of this type of license and a rise in **Permissive licenses**, which in 2020 accounted or 76% of all open source licenses worldwide[10]. The OSI also classifies the licenses by popularity and use, such as the **"Special purpose licenses"** category which are licenses used by institutions, that have specialised concerns or rules, such as government copyrights[11].

2.3. Open source components

Open source comprises a diverse range of software components. **Operating systems** tie hardware resources together and manage them from a machine level with examples of this including Linux and FreeBSD. **Web servers** are computer systems that deliver data from web pages to end users over the Internet using a method called Hyper Text Transfer Protocol (HTTP). **Data systems** are databases (structured and not structured), storing key data or information, that are distributed and shared with the source code included. **Development models** are programming languages that are not proprietary and fall within the parameters of open-source protocols. These software components can be layered or "stacked" together to create platforms that run on different operating systems. The most popular of these is defined as LAMP, a model of service stacks that undergird much of the web[12]. The **LAMP** acronym stands for:

- **Linux:** an open source operating system (OS) and the largest open source project in the world;
- **Apache**: an open source cross-platform web server that played a key role in the early web;
- **MySQL:** an open source relational database management system used by many database-driven web apps; and
- **PHP:** a general purpose scripting language used in software development (Perl or Python languages are sometimes substituted).

This open source development model has resulted in some of the most important open source web applications today such as WordPress and Drupal.

2.4. Existing types of Open Source Artificial Intelligence

The convergence of OSS and artificial intelligence (AI) is driving rapid advancements in a number of different sectors. Following the European Commission (EC) proposal for laying down harmonised rules on AI[13], an **artificial intelligence system** (AI system) means software that is developed with **machine learning** (ML), logic- and knowledge-based, and or statistical approaches. It can, for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments they interact with. Generally speaking, the term "AI", has been mainly associated with ML algorithms or rather software containing one or several ML algorithms[14]. ML

[9] Open Source Initiative (2021) Licenses and standards.

[10] Johnson, P. (2021) *Open source licenses in 2021: trends and predictions*. White Source Software.

[11] Open source licenses by category (2021) Open source Initiative. Opensource.org website.

[12] Red Hat (2021) *What is open source software?* Red Hat website.

[13] COM(2021) 206 final.

[14] Annex I of COM(2021) 206 final.

is an approach to data analysis that involves building and adapting models, which allow programs to "learn" through experience by typically using huge amounts of data to train and improve their results. The main difference between a ML and AI is that the former is created by a process of automated iterative improvements which can be supervised or unsupervised. As part of the convergence of OSS and AI, **AI-based systems** have emerged to provide tools to assist developers in designing algorithms or creating intelligent applications[15]. The most prominent examples include TensorFlow and Apache SystemDS. **ML based libraries** comprise a set of predefined, reusable functions typically written in Python or R readily available for use[16]. Libraries save developers from writing redundant lines of code since typically they comprise a compilation of functions and routines readily available for use.

[15] Predictive Analytics (2021) *Top 18 Artificial Intelligence Platforms*. Predicted Analytics Today.

[16] Bhadwal, A. (2021) *15 Best Machine Learning Libraries You Should Know in 2021*. Hackr.io Blog.

3. CHALLENGES OF OPEN SOURCE ARTIFICIAL INTELLIGENCE

While OSS AI offers a unique opportunity to make a high impact for most businesses, challenges need to be properly identified and addressed. The following subsections will describe general challenges, with some written specifically in the context of public sector. It is important to note that, due to its slower adoption as compared to the private sector, there is less knowledge concerning AI challenges specifically associated with the public sector[17]. Furthermore, AI practices and digital transformation strategies from the private sector cannot directly be transferred to the public sector because of the government's need to maximise public value[18].

3.1. Legal challenges

Selecting the legal model for licensing software is a pivotal decision in the context of OSS AI and when chosen correctly, it has the potential to encourage innovation while providing a safeguard to intellectual property rights. As a copyright holder, the owner of a piece of software has broad latitude in determining how that software can be licensed. With **dual licensing**, a software component is released under two licenses simultaneously: a proprietary license and an open source license, typically the General Public License (GPL). This licensing method has become a popular means by which licensors gain the economic benefits associated with commercial licensing while leveraging the community benefits associated with open source licensing. The dual license approach, however, comes with its own challenges. Open source community members have pointed out that dual licensing might not benefit the community, but rather result in less contributions to an open source project, because contributors are reluctant to contribute to projects with severe licensing limitations, like the GPL that requires they re-assign their copyrights[19]. With both OSS and open source data, there is a risk that the information will be accessed by organizations or individuals who will misappropriate or perform another violation within the field for which the licence has been granted for. Additional measures should be sought to prevent these risks from occurring. For example, most licenses do not include any indemnification for **third-party infringement** claims, which is customary in commercial software licenses[20]. **Purpose-limitations** constitute another challenge. Entities must be clear with why they are collecting personal data or code and what they intend to do with it. There is always a risk, if the copyright laws are not written properly, that data or code is used for something different than its original intent. The impacts of EU General Data Protection Regulation (GDPR) in the EU are only finding their concrete form, and, as yet there is no joint concept or interoperable open ecosystem for the exchange of personal data based on consumer consent[21]. Entities must clarify where **responsibility for AI implementation** rests with regard to consequences of the decisions made by an automated decision-making system or any other consequence of the implementation of an AI solution. In the case of algorithmic decision-making for the allocation of benefits, no specific cohort of the population should feel discriminated by these decisions while they should also be able to check the basis of the decision. The principle of **technology neutrality** implies that governments cannot unfairly favour one

[17] Desouza, K.; Dawson, G.; & Chenok, D. (2019) "Designing, developing, and deploying where is artificial intelligence systems: lessons from and forin public sector". *Business Horizons*, 63(2), p205-213.

[18] Fatima, S.; Desouza, K.C.; & Dawson, G.S. (2020) "National strategic artificial intelligence plans: A multi-dimensional analysis". *Economic analysis and Policy*, 67(C), p178-194.

[19] Goldstein, A. (2018) *Dual Licensing for Open Source Components: Yeah or Meh?* White Source Blog.

[20] Lee, V.; & Radcliffe, M. (2021) *Intellectual Property basics for Startups: open-source software*. DLA Piper.

[21] AI Finland (2019) *3 Eleven key actions ushering Finland into the age of artificial intelligence.* AI Finland.

technology over another[22]. EU promotion of OSS in the public sector is currently based on non-legally binding recommendatory initiatives[23] which might not be regarded as sufficient to promote the development of the software industry.

3.2. Technical challenges

Legacy or traditional database systems used in the public or private sector are not always well equipped to manage and store data from unstructured sources. Governments and other organisations need to adopt the **appropriate technical infrastructure** to manage Big Data and this comes with the challenge of investing and modernising IT infrastructures of public administrations. Since there are many technical solutions available, deciding on the individual systems as well as the combinations to adopt is becoming increasingly complex[24]. The compatibility of the OSS system to the current system must be considered, as well as the availability for support of the technology once it is deployed. The integration of the vast amount of data and the **interoperability** between different IT systems is important for a successful digital transformation[25]. In fact, a recent report by the World Bank stressed the fact that the lack of interoperability could lead to disruptions in the network, poor data exchange, and suboptimal performance. Hence, interoperability is a top priority today as governments try to integrate services across departments to improve effectiveness and efficiency[26]. The public sector's management including **IT management** may not be familiar with open source solutions, its deployment, features, and availability. OSS AI, particularly the code, is often not polished to facilitate engagement and a large amount of effort and expertise is required to learn how the software works. A combination of public technical challenges can be evidenced in the case of the municipality of Munich which switched all public administration computers to open software in 2006, then switched back to Windows in 2020, and now is currently in negotiations to implement Linux again[27].

3.3. Data challenges

Open source embeds particular challenges in terms of data quality and quantity. Open source systems do not directly translate into transparent and high-quality datasets. To grasp the concept of **transparency**, the entire open-source system must be considered. OSS AI software can also be used on "closed data", in this sense there is still no complete transparency and how the assessment of AI quality can be done. This, in turn, hinders the potential benefits of having open source as not all of the elements that are related to AI are open source. In this context, the adoption of open standards is crucial to obtain an effective transparency. Due to the amount of data that is required for AI, having access to **high-quality big data** sets is also a challenge. Furthermore, OSS projects rely on continuous engagement of developers for quality and productivity; if these developers are volunteers, they are free to leave the project at any time, potentially jeopardizing the advancement of the project. Open data can offset some of these challenges since it can drive transparency and accountability in

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22 Lee, J. (2006) "Government policy toward open-source software: The puzzles of neutrality and competition". *Knowledge, Technology, & Policy*, 18, p113-141.

23 Devenyi, V.; Di Giacomo, D.; & O'Donohoe, C. (2020) "Status of Open-source software Policies in 28 European Countries – 2020". European Commission.

24 Hashem, I.A.T.; Chang, V.; Anuar, N. B.; et al. (2016) "The role of big data in smart city". *International Journal of Information Management*, 36(5), p748–758.

25 Desouza, K. (2018) "Delivering Artificial Intelligence in Government: Challenges and Opportunities". *IBM Center for The Business of Government Delivering.*

26 Barcevičius, E.; Cibaitė, G.; Codagnone, C.; Gineikytė, V.; Klimavičiūtė, L.; Liva, G.; Matulevič, L.; Misuraca, G.; & Vanini, I. (2019) "Exploring Digital Government transformation in the EU - Analysis of the state of the art and review of literature", EUR 29987 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-13299-8, JRC118857.

27 Schaer, C. (2020) *Linux not Windows: Why Munich is shifting back from Microsoft to open source – again.* ZDNet.

governments by improving how government resources are used and how misconduct is detected. On the other hand, to tackle concerns on data privacy and vulnerability while keeping open sources, a potential solution is also exemplified by the Decentralized AI[28] strategic program which aims to transfer information instead of raw data in an efficient and secure way.

3.4. Risk management challenges

AI open source should consider a well-defined risk-based approach in line with the proposal of AI regulation advanced by the EC. The accuracy of AI systems is also domain-sensitive in which security vulnerabilities arise when training data is not representative of the given environment[29]. Risk challenges are addressed in the recently published 2021 Proposal for the Artificial Intelligence Act[30]. The proposal sets harmonised rules for the development, placement on the market and use of AI systems in the Union following a proportionate risk-based approach. It further sets a methodology to define "high-risk" AI systems that pose significant risks to the health and safety or fundamental rights of persons. If individuals or enterprises do not secure or manage their open source systems well, there is an increased **risk of a security breach**. This was seen in the Apache Struts system in which a vulnerability was discovered that impacted government and business entities that were connected to the system. System breachers in this case were able to manipulate the impacted application as if they had full user rights: view, change, delete data, or create new accounts[31]. Most OSS does not have dedicated **technical support** and without a support team, updates and security patches may not be available. If vulnerabilities are discovered in the software, cyber threat actors can exploit these vulnerabilities to gain access to an organization's network, systems, and information[32]. Due to the public nature of open-source AI, **cybersecurity** is also a challenge; the systems that public and private institutions choose to deploy may be vulnerable and prone to attacks from other AI applications[33]. In fact, AI is likely to be used by both attackers and defenders in cyber defensive scenarios. For example, when considering government AI systems that are built to identify management and access control, adversaries could compromise many techniques simply by stealing authorization tokens. AI monitoring of behavioural patterns could also lead to privacy violations, and for this reason should be prohibited if aims at manipulating user behaviours, according to the proposal of AI regulation and unless required for public security.

3.5. Society and ethics challenges

From a societal and ethical point of view, open source may bring about challenges, which have been identified as especially prone in the public sector. The first of the challenges is gaining social **acceptance and trust** in the technology from both citizens and civil servants. If citizens feel discriminated by AI or that it threatens their safety, privacy, or employment, thus contradicting their expectations with regard to AI, they will be very unlikely to accept or trust it. Once trust is established, it is fragile and must be maintained by performance reliability, collaboration, and communication[34]. While open codes increase transparency, the difficult comprehension of these algorithms will demand

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28 AI Sweden (2021) Decentralized AI. AI Sweden.

29 Coglianese, C.; & Lehr, D. (2019) Transparency and Algorithmic Governance. *Administrative Law Review*, 71, p1.

30 COM(2021) 206 final.

31 National Vulnerability Database (2021) Homepage.

32 Canadian Centre for Cybersecurity (2020) *Security Considerations When Using Open-source software* [Online].

33 National Vulnerability Database (2021) Homepage.

34 Wirtz, B.; Weyerer, J.C.; & Geyer, C. (2019) Artificial Intelligence and the Public Sector— Applications and Challenges, *International Journal of Public Administration*, Vol. 42(7): 596-615.

for a specific supervision through a humans-in-the-loop[35], society-in-the-loop[36] or a framework model[37]. Furthermore, the accuracy in data analysis has improved to a point, where it is – in general and for not complex tasks - better than the human ability[38]. As OSS AII will take over a great number of tasks, the challenge lies in how to help workers gain the skills required through **workforce transformation** to take advantage of the new work opportunities that OSS AI entails[39]. While there are opportunities for open source maintainers to receive **financial support** for their contributions, it is essential that governments take into consideration a clear financing structure for OSS AI. Exclusive dependence on volunteers could lead to risk management issues. Governments should ensure an adequate retribution for the work provided by OSS AI developers and need to give additional support such as investing in reviewing comments, questions and suggestions for OSS AI improvement[40].

[35] Zalnieriute, M.; Moses, L. B.; & Williams, G. (2019) "The Rule of Law and Automation of Government Decision-Making". *Modern Law Review*, 82(3).

[36] Rahwan, I. (2018) "Society-in-the-loop: programming the algorithmic social contract". *Ethics and Information Technology*, 20.

[37] Gasser, U.; & Almeida, V. (2017) "A Layered Model for AI Governance". *IEEE Internet Computing*, 21(6), p58-62.

[38] Esteva, A.; Kuprel, B.; Novoa, R. A.; Ko, J.; Swetter, S. M.; Blau, H. M.; & Thrun, S. (2017) "Dermatologist-level classification of skin cancer with deep neural networks". *Nature*, 542: p115-118.

[39] Susar, D.; & Aquaro, V. (2019) "Artificial Intelligence: Opportunities and Challenges for the Public Sector". *ICEGOV2019: Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, p418-426.

[40] Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2017) *Onderzoek publiceren Open-source software*. Gartner.

4. OPPORTUNITIES OF OPEN SOURCE ARTIFICIAL INTELLIGENCE

4.1. Mitigating AI-related challenges

When considering the challenges of AI, OSS has the potential to address or mitigate some of the risks that are inherent to AI use. An example of this is that OSS AI could **mitigate discrimination and bias in ML models** as compared to traditional AI or software due to the convergence of AI and transparency of code[41]. Open source toolkits have been developed, such as the IBM AI Fairness 360[42], which allow the user to examine, report, and mitigate discrimination and bias in ML models throughout the AI application lifecycle. In particular, experts in the field have emphasised that open source solutions **facilitate the auditability of AI** because it is often the most transparent option. In addition, as AI is currently dominated by an oligopoly of centralised mega-corporations, this type of technologies is thus spoken for by a small, biased minority[43]. An OSS approach to AI can help tackle this issue in two distinct manners. Firstly, it can help **develop a local software industry which is able to compete with technological giants** and **increase the diversity of AI expert sources**- provided that there is government support for it to thrive[44,45]. For instance, Dutch administrations showed higher odds of OSS adoption in the presence of high political commitment[46] Additionally, as it has been illustrated in the literature: if governments' software is run on something other than Windows, then the market for these alternative platforms would be wildly expanded[47]. Secondly, open source could increase transparency if supported by a team which makes the complex algorithms "readable" for citizens, and therefore, giving them the tools to identify any potential AI bias. The open source community also offers an **extra layer of security** by continually monitoring software code for flaws and vulnerabilities which is especially beneficial during the development stage of new and emerging technologies like AI[48]. In fact, the cybersecurity sector uses open source tools to perform risk management and prevent algorithms from being manipulated by external hackers.

OSS drives innovation due to the decentralized quality of code contributions, which means that developers from a multitude of organizations, industry verticals, and geographies can contribute. As OSS inherently embraces contributions from large and diverse groups of developers, an open source community of developers is more likely to make **innovative code contributions** than a closed source community of developers such as those within a specific enterprise[49]. This is important also when considering the commercial sector. Businesses that can explain and trust AI, can **increase the number and accuracy of models in production** — resulting in measurable economic value. Open source is a key part of this effort[50]. OSS, as a public resource based on non-rival use rights, allows for lower entry

41 Angell, R.; Johnson, B.; Brun, Y.; & Meliou, A. (2018) "Themis: automatically testing software for discrimination". In *Proceedings of the 2018 26th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering* (ESEC/FSE 2018). Association for Computing Machinery, New York, NY, USA, 871–875.

42 IBM Research Trusted AI (2021) AI Fairness 360. IBM Research Trusted AI.

43 Montes, G. A.; & Goertzel, B. (2019) "Distributed, decentralized, and democratized artificial intelligence". *Technological Forecasting and Social Change* 141, p354-358.

44 Botelho, A. J.; Stefanuto, G.; & Veloso, F. (2003) "The Brazilian Software Industry". In Arora, A. & Gambardella, A. (2005) From Underdogs to Tigers: The Rise and Growth of the Software Industry in Brazil, China, India, Ireland and Israel. Oxford University Press.

45 Li, M.; Lin, Z.; & Xia, M. (2005) Leveraging the Open Source Software Movement for Development of China's Software Industry. *Information Technologies and International Development*, 6(2), p45-63.

46 Van Loon, A.; & Toshkov, D. (2015) "Adopting open-source software in public administration: the importance of boundary spanners and political commitment". *Government Information Quarterly*, 32(2), p207–215.

47 Lessig, L. (2002) The Future of Ideas: the Fate of the Commons in a Connected World. Random House.

48 Rimi, C. (2019) Artificial intelligence: an open source future. IT Pro Portal.

49 Dayaratna, A. (2019) *How Open Source Is the Key to Innovation, Productivity, Collaboration, and Transparency Within the Digital Enterprise*. IDC TECHNOLOGY SPOTLIGHT.

50 Chen, P. (2020) *IBM's open source strategy champions AI trust and transparency*. IBM.

barriers in software development and offers public stakeholders a set of cost-effective, re-usable tools and resources that can give impetus to innovation, entrepreneurship and economic growth[51]. An OSS AI can also **facilitate interoperability and avoid lock-in issues** if it is based on open standards. As specifications are known and open, it is always possible to get another party to put into operation the same solution adhering to the standards being followed[52]. In addition, the use of open standards ensures that data and systems can be interpreted independently of the tool which generated it and increase the control by supporting migration, thereby reducing an organisation's reliance on a single product or supplier[53]. They can create value by promoting competition between implementations, which leads to lower prices and improved product quality[54].

4.2. AI uptake and innovation in private sector

The widespread and pervasive use of technology is changing the every-day functions of society. Further advancement of these technologies has been cited as bringing society to the dawn of the Fourth Industrial Revolution, also known as Industry 4.0[55,]. At the heart of the Industry 4.0 is AI, which continues to advance hyper-automation and hyper-connectivity. Industry 4.0 is being further complemented by Industry 5.0 which captures the value of new technologies, providing prosperity beyond jobs and growth, while respecting planetary boundaries, and placing the wellbeing of the industry worker at the centre of the production process[56]. Recent advances in AI have been extraordinary, with many technologies already achieving or surpassing human-level performance in tasks such as data analytics, transcription, and image recognition. The combination of OSS and AI is considered a **catalyst to transform and revolutionize services** in a multitude of areas in the private and public sector. In the EU, AI has a high opportunity to bring digital transformation in sectors such as commerce: currently, only 1 out of 5 companies in the EU are highly digitalised, while 60% of large industries and more than 90% of Small and Medium Enterprises (SMEs) lag behind in digital innovation[57]. An open-source approach to AI can support companies to leverage the best innovations in models and platforms that have already been created, and hence focus on innovating their domain-specific expertise, which will eventually **accelerate technological advancements** further.

Open source could further **help to create a level playing field** and balance issues that small organizations face by using the open source community as a foundation and feedback loop for their own technologies. Furthermore, studies on the world-wide economic developments and implications brought about by AI reveal that by 2035, AI could increase labour productivity by up to 40 percent and double economic growth rates in at least 12 developed countries[58]. The benefits are expected to present new levels of service, increased profit, expansion of businesses, improved efficiency, and cost structures[59]. The potential of OSS AI uptake can be identified in a variety of sectors due to its low costs and potential for innovative capacity. The **financial sector** uses OSS AI systems to analyse data,

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51 Rexhepi, G.; Hisrich, R. D.; & Ramadani, V. (2020) Open Innovation and Entrepreneurship: Impetus of Growth and Competitive Advantages (1st ed. 2019 ed.). Springer.

52 Almeida, F.; Oliveira, J.; & Cruz, J. (2011) "Open Standards and Open Source: Enabling Interoperability". *International Journal of Software Engineering & Applications,* 2(1).

53 Balaguer, F.; Di Como, R.; Garrido, A.; Kon, F.; Robles, G.; & Zacchiroli, S. (2017) "Open source systems: Towards Robust Practices". *13th International Conference OSS 2017*.

54 Simcoe, T. (2005) "Open Standards and Intellectual Property Rights". In (Oxford University Press) *Open Innovation: Researching a New Paradigm*.

55 Park, S. (2017) "The Fourth Industrial Revolution and implications for innovative cluster policies". *AI & Society*, Vol. 33(3).

56 European Commission (2021) *Industry 5.0 Towards a sustainable, human-centric and resilient European industry*.

57 European Commission (2021) *Digital Innovation Hubs (DIHs) in Europe*. European Commission.

58 Accenture (2017) *Why is Artificial Intelligence Important?* Accenture.

59 Park, S. (2017) The Fourth Industrial Revolution and implications for innovative cluster policies. *AI & Society*, 33(3), p.433-445.

strengthen security systems, and make forecasts for banking systems. Open source systems such as H2O.ai are being used to identify money laundering, perform credit risk scoring, and churn predictive analysts[60]. In **healthcare**, AI is becoming used more frequently as a tool for diagnostics and medical image analysis tasks due to its accuracy compatible to expert clinicians. Computer assisted detection and diagnosis, and image segmentation and registration have significantly benefited from AI[61]. OSS AI systems such as the Tesseract-Medical Imaging[62] are used in the medical field to provide standard image viewing and reporting schemes. Additionally, OSS AI is considered the future in the **cybersecurity sector**[63] in which open source tools, such as Adversarial Robustness Toolbox, are currently used in risk management to prevent algorithms from being manipulated by external hackers. In addition to the potential for uptake, there is further opportunities for innovation and business. The open source setting is truly effective because it **can attract tremendous technical talent**, since many more people can become innovators than could be possible in a proprietary model. Talented programmers at small institutions can gain higher visibility[64], while the main aim of developers will be to obtain recognition and be highly valued in open source communities to further advance their careers[65]. When considering innovation through AI, open source creates a valuable, global network of feedback that **increases the speed at which AI algorithms are created and improved**. From the business perspective, OSS AI stimulates economic activity, sustainability and innovation power by allowing companies to make use of existing source code and develop services on it. They also offer significant benefits for businesses and economies by contributing to productivity growth, decreasing operational costs, producing revenue, enhancing efficiency and improving customer experience[66].When considering AI models, they are both often expensive to develop, and require a large amount of data to build and train algorithms. In the context of government and innovation capacity, **reuse prevents partial solutions, waste and realises synergy within the government**[67]**.** If an open source solution is devised in one municipality or country, then another community could also benefit from that.

As a matter of fact, a large majority of the AI ecosystem used in many applications is already open source. For instance, Python is the language behind a majority of AI applications, and the same applies to AI systems powered by software such as TensorFlow, IBM Watson, Apache Mahout, and others. What changes is whether the code is made publicly available or not. And this may be even if most underlying "components" are OS. An example is the case of the Generative Pre-Trained Transformers (GPT), an innovation in the Natural Language Processing space developed by OpenAI[68], an AI research and deployment company. The GPT-2 version is an unsupervised deep learning transformer-based language model created in 2019 for the single purpose of predicting the next word(s) in a sentence. GPT-3 is instead the 3rd version release and upgraded version of GPT-2. It takes the GPT model to a whole new level as it is trained on a massive number of parameters (i.e. 175 billions, which is over 10x the size of its predecessor) on an open source dataset called 'Common Crawl,' and other texts from OpenAI such as Wikipedia entries. What is important for this argumentation, however, is the fact that

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60 H2O (2021) H2O website: financial services.

61 Sedghi, A.; Hamidi, S.; Mehrtash, A.; Ziegler, E.; Tempany, C.; Pieper, S.; Kapur, T.; & Mousavi, P. (2019) "Tesseract-medical imaging: open-source browser-based platform for artificial intelligence deployment in medical imaging". *SPIE Medical Imaging 10951, Medical Imaging 2019: Image-Guided Procedures, Robotic Interventions, and Modelling*.

62 GitHub link to Tesseract-Medical Imaging with all available open content: https://github.com/Tesseract-MI/Tesseract-MI.

63 Columbus, L. (2019) *Why AI Is the Future of Cybersecurity*. Forbes.

64 Lerner, J.; & Tirole, J. (2003) "Some Simple Economics of Open Source". *The Journal of Industrial Economics*, 50(2), p197-234.

65 Riehle, D. (2007) "The Economic Motivation of Open-source software: Stakeholder Perspectives". *Computer,* 40(4), p25-32.

66 Hernandez, A. (2019) *The Best 7 Free and Open-Source Artificial Intelligence Software*. Good Firms Blog.

67 Senate of the Netherlands (Eerste Kamer der Staten-Generaal) (2020) *Considerations for "open, unless" and an open source 2020–2021 approach*.

68 OpenAI website (2021) Homepage.

Microsoft announced in September 2020 that it had licensed 'exclusive' use of GPT-3; others can still use the public API to receive output, but only Microsoft has control of the source code. Due to this, EleutherAI developed its own transformer-based language models styled around the GPT architecture so to use their own GPT-Neo to replicate a GPT-3 sized model and open source it to the public, for free.

4.3. Leveraging on a community of experts

From the commercial perspective, open-source is often considered as an **option by businesses to reduce costs and to leverage the ideas of the open-source community**. For businesses that have less expertise in programming, open-source offers visibility into how developers manage datasets and software. Due to the accessibility to a myriad of AI tools, libraries, and documentation, open-source facilitates access for businesses to develop in their sectors using AI techniques and feedback from experts within the community. Highly innovative software organizations are exemplary of development-related innovation, transparency, speed, and efficiency because of their ability to integrate open source technologies and culture into their practices and methodologies[69]. Due to the volunteer nature of participation, developers may join/leave a project according to their desire and need. In this sense, engineers from tech giants as well as independent developers, who routinely contribute to the open-source AI community, help deliver AI tools that characterize high-speed innovation. In fact, open source solutions released by **tech giants**, such as TensorFlow, are essential to innovation as they act as an essential foundation to many open source projects. TensorFlow is now used by some of the world's largest brands including Airbnb, Coca-Cola, and PayPal[70] and is prevalent in a variety of sectors.

4.4. Relevance of open data

The capacity of AI-based systems to develop is possible thanks to the use of large datasets to train the algorithms. While making open data available alone could favour larger companies as they have access to proprietary datasets to combine with open data sources – which smaller companies do not have access to, the creation of **open data portals** such as Kaggle.com[71], open data repositories on GitHub[72], or on official public websites can play a big role for AI projects. The business value, however, would come mainly by integrating such open data with specific data – such as those coming from the enterprise itself or gathered from internal processes of the organizations or networks, depending on the purpose of the data analysis and AI applications.

One way to make more data available and to improve data quality is to push governments that use algorithms and AI systems for public service delivery to open up the data upon which these systems rely[73]. The Open Data Barometer suggests that 9 in 10 government data sets are still not open, there is therefore much potential from the public sector[74]. AI algorithms have to be trained with a large amount of high-quality dataset that sometimes is not available across all countries. **Availability of high-quality datasets** are essential to guarantee strong AI models and trustworthy outcomes, especially for cross-border care provision[75]. In EU, an individual's **right of protection of their personal data** is set out by the GDPR. Several articles of the GDPR can be applied when governing AI, and specifically AI use

[69] Bocetta, S. (2019) *What does an open source AI future look like?* Opensource website.
[70] TensorFlow (2021) Case Studies and Mention TensorFlow. TensorFlow website.
[71] Kaggle (2021) Homepage.
[72] GitHub (2021) Homepage.
[73] Web Foundation (2018) *How open data can save AI*. World Wide Web Foundation.
[74] *Open Data Barometer* (2017) Global Report. Open Data Barometer.
[75] Pharmaceutical Group of the European Union. (2019) Position Paper on Big Data & Artificial Intelligence in Healthcare. Pharmaceutical Group of the European Union.

in the healthcare sector. For ensuring that organisations comply with GDPR, a process called **Data Protection Impact Assessment** needs to be performed to assess systems when they could attempt against human rights and freedoms. Furthermore, with the adoption of the **Data Governance Act**[76], the EU is already calling to increase the amount of data available for re-use within the EU by allowing public sector data to be used for purposes different than the ones for which the data was originally collected. In this regard, data openness and the free flow of non-personal data across public and private sector[77] are being advocated as beneficial for European SMEs.

[76] COM/2020/767.
[77] Regulation 2018/1807.

5. LANDSCAPING AI IN DIGITAL PUBLIC ADMINISTRATION

The widespread adoption of digital technologies in general, and that of self-learning algorithms in particular, have given rise to much debate about their implications for the public domain, e.g., with regard to policy analysis, policy making and governance[78].

5.1. OSS and data for evidence-based decision making

At the highest level, governments have been discussing how to deal with AI systems across many functions, including how to manage and promote innovation in the business environment, how to drive best practice and regulate misuse, and, most importantly, how to fit them into the day-to-day work of government[79]. Decision-making is at the heart of administration[80]. As AI is changing decision-making practices, it could simultaneously **offer an unprecedented access to information** to guide governmental action and make sense of a daunting abundance of data about the state of society[81]. In this framework, it could be used to **model and simulate decisions** to **explore possible outcomes of certain policies**[82] or to **predict certain societal dynamics** (e.g., crime in public transportation) so that authorities can **deploy their resources more efficiently.** The expectations that are thus raised by AI systems are high, for making services to citizens proactive and personalised. Software involved in decision-making can be categorized into supportive technology assisting the person making decisions; replacement technology, meaning tasks previously carried out by humans are now done by software; and disruptive technology that changes the way decision-makers work and ultimately reshapes our understanding of the decision-making process[83]. Another distinction can be made according to the systems autonomy: there is decision support (programs helping humans to make decisions), so called "human-in-the-loop approaches" (decisions are made with some human involvement) and completely autonomous decision-making[84]. Alternatively, one can categorize such software by assuming the perspective of the people affected by the decision. Some decision-support tools concern purely technical questions such as public procurement. Humans are either, not at all or scarcely and only indirectly affected. Other decision-support tools provide information which directly influences the decision. Lastly, a decision can be rendered by software itself, thus directly deciding upon humans. In all cases a **proportionate risk-based approach** will be required under the new regulatory framework. As mentioned previously, the recently published **Proposal for the Artificial Intelligence Act**[85] provides a horizontal framework to follow a risk-based approach and impose regulatory burdens on AI systems that poses high risks to fundamental rights and safety. The obligations for ex ante testing, risk management and human oversight will also facilitate the respect of other fundamental rights by

78 Gerrits, G. (2020) "Soul of a new machine: self-learning algorithms in public administration". *Information Polity* 1, p1-14.

79 Veale, M.; & Brass, I. (2019) Administration by Algorithm? Public Management Meets Public Sector Machine Learning. In: Algorithmic Regulation (Karen Yeung and Martin Lodge eds., Oxford University Press, 2019).

80 Herbert, S.A. (1991) "Bounded rationality and organizational learning". *Organization Science, 2*(1), p125–34.

81 Janssen, M.; Wimmer, M.A.; & Delijoo, A. (2015) "Policy Practice and Digital Science: Integrating Complex Systems". *Social Simulation and Public Administration in Policy Research*. Springer.

82 Ibidem.

83 This taxonomy was developed by Sourdin, T. (2018) "Judge vs Robot? Artificial Intelligence and Judicial Decision-Making". *UNSW Law Journal*.

84 Zalnieriute, M.; Moses, L. B.; & Williams, G. (2019) "The Rule of Law and Automation of Government Decision-Making". *Modern Law Review*, 82(3).

85 COM(2021) 206 final.

minimising the risk of erroneous or biased AI-assisted decisions in critical areas such as education and training, employment, law enforcement and the judiciary[86].

5.2. Costs and benefits

Governments have been moving away from the digitalisation of documents, processes and decision-making towards a new model that involves citizens in the co-production and information sharing[87]. As a matter of fact, big data-based systems can help public administrations in financial, healthcare or education budget planning by understanding the data patterns and the relationship between them with the help of AI algorithms[88]. Furthermore, social development and OSS growth were found to be the most important facilitators for eGovernment maturity, across countries of all stages of development, with technological infrastructure and innovation as important drivers for OSS growth across all countries at all stage of development[89].

5.2.1. Costs

While digitalising government administrative tasks can save money in the long-term by improving efficiency, decision making for public spending should consider all associated direct and indirect costs including license agreements, required upgrades and extensions, technical support, training, and maintenance fees[90], which is the purely direct **economic cost.** For instance, as part of the strategy of the Digital Finland Framework, a framework which aims to maximize future opportunities through specialised IT sectors and global megatrends, the Finnish government allocated more than€400 million to support digital projects run by the country's local authorities between 2018 and 2022[91]. The **costs of hiring new workforce and training current public sector personnel** on how to use digital systems such as AI, should also be considered when choosing to digitalise. Furthermore, a cost is also determined by the potential **low level of user acceptance of digital government services**. One of the reasons of poor uptake could be the design of the digital services and the lack of proper staff within the government to understand what would make citizens use the app, chatbot, or other service[92]. In fact, experts also cite the design of technology in public administration as a high cost that has not been yet sufficiently studied, and for which implications exist in terms of public procurement. It is in this perspective that the review of the AI Coordinated Plan[93] announced the launch of a dedicated AI adopt programme, aimed at supporting public procurement of AI systems and transforming procurement processes themselves. The lack of efficiency and effectiveness in service provision, coupled with broader trends of political distrust and apathy, can translate into **low citizen satisfaction and trust.**

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86 The Proposal for an AI regulation prohibited certain AI practices considered unacceptable as contravening Union values, for instance by violating fundamental rights. The regulation follows risk-based approach, differentiating between uses of AI that create (i) an unacceptable risk, (ii) a high risk, and (iii) low or minimal risk.

87 Bani, M.; & De Paoli, S. (2020) "Ideas for a new civic reputation system for the rising of digital civics: digital badges and their role in democratic process". *ECEG2013–13th European Conference on eGovernment: ECEG.*

88 Gill, S. S.; et al. (2019) Transformative Effects of IoT, Blockchain and Artificial Intelligence on Cloud Computing: Evolution, Vision, Trends and Open Challenges. *Internet of Things,* 8(26): p100118.

89 Lakka, S.; Stamati, T.; Michalakelis, C.; & Anagnostopoulos, D. (2015) "Cross-national analysis of the relation of eGovernment maturity and OSS growth". *Technological Forecasting and Social Change*, 99: p132-147, ISSN 0040-1625.

90 Bouras, C.; Filopoulos, A.; Kokkinos, V.; Michalopoulos, S.; Papadopoulos, D.; & Tseliou, G. (2014) "Policy recommendations for public administrators on free and open-source software usage". *Telematics and Informatics*, 31(2), p237-252.

91 Ministry of Economic Affairs and Employment of Finland, Business Finland, & VITTResearch. (2018) Digital Finland Framework.

92 Reis, J.; Espírito Santo, P.; & Melao, N. (2019) "Artificial Intelligence in Government Services: A Systematic Literature Review". *Brazilian Journal of Operations & Production Management,* 18(1).

93 Annex to COM(2021) 205.

Particularly the use of AI in government may also reduce citizens' trust in government[94] and government decisions[95], which may be due to a violation of citizens' privacy or a lack of fairness in using AI for public governance[96]. These realities raise the stakes for governments since failures due to AI use in government may have strong negative implications for governments and society[97].

5.2.2. Benefits

AI systems are increasingly being used at all levels of government to automate or augment their systems and increase the efficiency of public sector operations or to support policy public making[98]. From a public sector perspective, OSS has the potential to deliver **cost savings** in public sector organizations, as well as other downstream political, economic, social and technical benefits for the country[99]. This is a crucial factor since public expenditure accounts for a quarter of Gross Domestic Product (GDP) globally and the wage bill around 8% of GDP. As such, **improvements in public-sector productivity** can have substantial implications for public finances, including development-assistance funds[100]. The Dutch government cited that releasing its own OSS could amount to € 1.1 billion in saving per year for its government alone[101]. The cost savings come from the **avoidance of in-house development costs** and **prevention of failure of information and communications technology (ICT) projects**, since with OSS there are a multitude of "best practice" code projects. The availability of source code for sharing and re-use could also avoid duplicative custom software purchases across federal agencies. The Finnish government is another example of a public authority that has and plans to achieve benefits through digitalisation of public finance activities. The digitalisation of municipalities and the state could account for cost savings of €100 million for municipalities and €100 million for the state by 2029[102]. Additionally, the automation of the Finnish payment system, including e-invoicing, and electronic receipts is citied as having the potential to generate savings of tens of millions of euros per year for the government[103]. The use of digital and AI-based applications may **increase efficiency** and lead to cost savings by automating processes, assisting resource allocation and reducing waiting time and administrative burden[104]. The Finnish government cites the reduction of tasks and obligations of municipalities, through its digitalisation reform, to have an estimated savings potential of €370 million[105]. Interestingly, as some jobs become obsoletes, AI is argued to enhance the emergence of jobs which require new skills. The challenge lies in ensuring the adequate

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94 Al-Mushayt, O. S. (2019) Automating E-government services with artificial intelligence. IEEE Access, 7, 146821–146829. https://doi.org/10.1109/ACCESS.2019.2946204.

95 Sun, T. Q.; & Medaglia, R. (2019) "Mapping the challenges of artificial intelligence in the public sector: Evidence from public healthcare". *Government Information Quarterly*, 36(2), p368–383.

96 Kuziemski, M.; & Misuraca, G. (2020) "AI governance in the public sector: Three tales from the frontiers of automated decision-making in democratic settings". *Telecommunications Policy*, 44(6), p101976.

97 Misuraca, G.; & Alvarez, T. (Forthcoming) "Governing algorithms: perils and powers of AI in the public sector". *Whitepaper for the Digital Future Society*.

98 Veale, M.; & Brass, I. (2019) "Administration by Algorithm? Public Management Meets Public Sector Machine Learning" in Yeung, K & Lodge, M. (Oxford University Press) *Algorithmic Regulation*.

99 Jokonya, O. (2015) Investigating Open-source software Benefits in Public Sector. 48th Hawaii International Conference on System Sciences, pp. 2242-2251.

100 Somani, R. (2021) "Public-Sector Productivity (Part One): Why Is It Important and How Can We Measure It?". Washington, D.C.: World Bank Group.

101 Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2017) *Onderzoek publiceren Open-source software*. Gartner.

102 Finland Prime Minister's Office (2017) *Finland, a land of solutions Mid-term review. Government Action Plan 2017-2019*. Government publications 7/2017.

103 Valtiokonttori State Treasury (2019) *The digitalisation of receipts to boost the move to real-time economy*.

104 Wirtz, B.; Weyerer, J.C.; & Geyer, C. (2019) Artificial Intelligence and the Public Sector— Applications and Challenges, *International Journal of Public Administration*, Vol. 42(7): 596-615.

105 Valtiokonttori State Treasury (2019) *The digitalisation of receipts to boost the move to real-time economy*.

support to help the affected workforce in gaining this new set of skills involving the interaction with AI solutions[106]. OSS can **stimulate economic activity** as companies and developers can create new services based on open government software. It should be noted that publishing software can also have a negative impact for some parties (software that has been made public and may be reused does not need to be rewritten by a supplier)[107]. An open source approach to AI in public administration is considered to help to unlock the "black box of AI[108]". The bias in algorithms can be caused by many different flaws at different stages of the algorithm's development[109]. Carefully designed software will display less bias than human alternatives, because the bias of algorithmic decisions does not originate from the algorithm itself but from its design, the training data, and the process of training itself. **Greater transparency** will ultimately enhance trust and accountability[110].

5.3. Cases of open source AI in public services

Current deployment of OSS AI can be found in a broad spectrum of public administration domains such as healthcare, education, defence and cybersecurity, voting, or general information accessibility. Open source AI is used to **improve transparency and access of government information for citizens**, such as the example of the Federal AI Personal Assistant Pilot, an open-source AI project implemented in the United States government in 2017. In this process, federal agencies worked with the private-sector and tech industry to make their public service information available to consumer Intelligent Personal Assistants (IPAs), such as Amazon Alexa, Google Assistant, and Facebook Messenger. Estonia and Finland have also introduced personal assistants as part of their government services, and several countries are following with dedicated automatic answering systems and Chatbots. AI is also being applied in **cybersecurity** to protect government institutions and citizens from cyber-attacks. This is the case of the open source Dutch platform Entrada, which stabilizes the *.nl* domain by increasing security and stability with features such as detecting botnets and pop-up/burner domains to sell stolen, fake, or illegal goods[111]. Public sectors are also considering using OSS AI for **voting systems**. The United States's Defense Advanced Research Projects Agency recently, in 2019, awarded a $10 million contract to design and build an "unhackable" open source online voting system[112]. Furthermore, with the current public health threat of the Covid-19 pandemic, many MS have been implementing and using open-source solutions to **track, predict, or report outbreaks of the Covid-19 virus**, examples include Spain (Covid radar[113]) and Ireland (COVID Tracker App). Another example is the use of a chatbot to **help citizens fill out their taxes,** as the one provided by the FinTech-based Intelligent Tax Administration Service[114]. In this respect, governments should regard AI solutions as an opportunity to increase citizens trust and to meet citizens expectations. So far there is an uneven adoption of OSS AI in public administration around the world[115], with Europe not being an exception. In fact, it remains challenging

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106 Susar, D.; & Aquaro, V. (2019) "Artificial Intelligence: Opportunities and Challenges for the Public Sector". *ICEGOV2019: Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, p418-426.

107 Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2017) *Onderzoek publiceren Open-source software*. Gartner.

108 Chen, P. (2020) *IBM's open source strategy champions AI trust and transparency*. IBM.

109 Kemper, C. (2020) "Kafkaesque AI? Legal Decision-Making in the Era of Machine Learning". *University of San Francisco Intellectual Property and Technology Law Journal*, 24(2).

110 Ibidem.

111 Jee, C. (2019) *DARPA is trying to build an unhackable open-source voting system.* MIT Technology Review.

112 Mehr, H. (2017) Artificial Intelligence for Citizen Services and Government. Ash Center for Democratic Governance and Innovation Harvard Kennedy School.

113 Radar Covid (2021) GitHub website.

114 Susar, D.; & Aquaro, V. (2019) "Artificial Intelligence: Opportunities and Challenges for the Public Sector". *ICEGOV2019: Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, p418-426.

115 van Loon, A.; & Toshkov, D. (2015) "Adopting open-source software in public administration: the importance of boundary spanners and political commitment". *Government Information Quarterly*, 32(2), p207–215.

to define and operationalize what is considered AI and which technologies, applications, or algorithms are to be included, in particular when it comes to public services and/or policies[116]. While governments weight the opportunities and risks associated with the adoption of OSS AI, several EU MS have already implemented successful services, with examples exhibited in Annex II.

[116] Misuraca, G.; & Van Noordt, C. (2020) AI Watch - Artificial Intelligence in public services, EUR 30255 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19540-5 (online), JRC120399.

6. REGULATIONS AND POLICIES

6.1. Examples of national OSS AI policies

The method that policymakers choose to govern the wide range of AI technologies and applications will have a dramatic effect on the ultimate array of opportunities and benefits that could result[117]. Policymakers and regulators face two competing approaches: a precautionary approach, which pre-emptively limits or even bans certain applications out of fears for worst-case scenarios, or a "permission less innovation"[118] approach, which prioritizes experimentation and collaboration by default, addressing upcoming issues while they show up. The importance of OSS in public sectors across Europe is affirmed by governments incorporating OSS as part of their country's political and legal framework. Most commonly, OSS policies and legislation are embedded in the **broader digitalisation initiatives** within the policy and legal framework of these countries[119]. However, a clear link to the AI policies and strategies are missing for most countries (see Czech Republic and Finland being the only countries with overlapping policy documents). Some MS have started to explore innovative public procurement to stimulate the development and adoption of AI[120], and a few committed themselves to the adoption of "open source by default", including OSS AI as a means to accelerate AI uptake[121,122]. **In 2020, under the Dutch Digitisation Strategy 2018-2021**[123], the Dutch government committed to the release of the source code by public administration and the application of the "open source by default" principle although administrations were encouraged to implement OSS when no clashing interests existed. In order to bring public bodies closer to both OSS and the open source community, the open source toolbox[124] was launched to help civil servants switch to open source. In 2019, Dutch government published the Strategic Action Plan for Artificial Intelligence[125], which also mentioned Public-Private-Partnerships, education and ethical concerns. The efforts on the openness of public AI solutions can also be observed at a local level with initiatives such as Amsterdam's Algorithm Register[126]. Amsterdam along with Helsinki are the only two major European cities to have opened an AI register to the public, which details how each city government uses algorithms to deliver services[127]. **Estonia's national AI strategy, known as #KrattAI**, advances the take-up of AI both in the private and public sector. Hence, #KrattAI will be an interoperable network of public and private sector AI applications (agents, bots, assistants, etc.) which would work from the user perspective as a single, united channel for accessing public direct and informational services[128]. According to the Estonian Government, AI solutions have to be open-source and reusable if there are no reasons not to[129]. In this framework, all software developed should be made available free of charge (if possible) via the e-state code repository[130], a

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117 Thierer, A.; O'Sullivan, A. C.; & Russell, R. (2017) "Artificial Intelligence and Public Policy". *Mercatus Research,* Mercatus Center at George Mason University.

118 Ibidem.

119 European Commission (2020) Status of Open-source software Policies in Europe. Waverstone's European Services Team.

120 Sharma, G. D.; Yadav, A.; & Chopra, R. (2020) "Artificial Intelligence and effective governance: A review, critique and research agenda". *Sustainable Futures*, 2.

121 Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2020) Overwegingen bij Open tenzij en Aanpak open source.

122 E-Estonia (2019) *Estonia accelerates artificial intelligence development.*

123 Nederland Digitaal (2019) Nederlandse Digitaliseringstrategie 2018-2021. Government of the Netherlands.

124 Open Source Netherlands (2021) Homepage website.

125 Government of the Netherlands (2019) Strategic Action Plan for Artificial Intelligence. Government of the Netherlands.

126 City of Amsterdam Algorithm Register (2021) Homepage Beta version.

127 Johnson, K. (2020) *Amsterdam and Helsinki launch algorithm registries to bring transparency to public deployments of AI*. VentureBeat.

128 Government of Estonia (2021) *#KrattAI: the next stage of digital public services in #eEstonia*. Government of Estonia.

129 Hillenius, G. (2020) *Open source is key to Estonia's vision for artificial intelligence* Joinup website.

130 E-riigi koodivaramu (Estonian e-repository) website (2021) Homepage (in Estonian).

platform aimed towards the collaboration and reuse of software for the entire public. However, in some cases, these solutions will not be made open source and need to be evaluated on a case-by-case basis. **Finland's ambitious national AI strategy** aims at Finland becoming a leading country in the application of AI. The National AI Strategy[131] fosters the development of AI innovation activities in an open ecosystem which encourages international cooperation. Finland also recently introduced their national e-government service platform, Suomi.fi, as part of the KaPa (Kansallinen Palveluarkkitehtuuri or National Service Architecture) program. The KaPa program involves a national data exchange layer; a shared service view required by citizens, companies and authorities; a new model of nation-wide e-identification, and national solutions for the administration of roles and authorizations for organizations and individuals[132]. In addition, the AI accelerator will be based on an open environment which includes open source code and data. The AuroraAI[133] national AI programme aims at preparing Finland for a human-centric and ethical society in the age of AI. As part of this effort it is significant to mention the development of a "Digital Twin" of the government, that is a digital platform where the user can choose which applications and services to engage with and how much data to share. This approach builds on a community of OSS developers across the country. **Beyond the European Union**, Canada was the first country in the world to adopt a national AI strategy in 2017, the Pan-Canadian AI Strategy[134] fosters the use of open data and standards[135], yet it does not include any specific mention to the use of OSS in AI. On the other hand, the United Kingdom's (UK) national AI strategy adheres to the tenth Government Design Principle: "Make things open: it makes things better[136]". According to the UK AI Roadmap[137], public AI should adopt open licenses where possible whilst AI developers should bear in mind the openness of data in the design stage.

6.2. Current achievements and ways ahead

The EU has several initiatives to support the implementation of both OSS and AI solutions in public administration across EU MS. The EC adopted its first strategy for the internal use of OSS in 2000[138], encouraging the use of open-source solutions. In the case of AI, the White Paper on Artificial Intelligence[139] (2020) acknowledged the need for increased take-up of AI technology across the EU economy to remain competitive, in particular, with the US and China, both of which exploit large amounts of data. Recently, the **Proposal for the Artificial Intelligence Act**[140] delivers on the political commitment by Commission President von der Leyen to put forward a legislation for a coordinated European approach on the human and ethical implications of AI. It further proposes a single future-proof definition of AI under Art. 3 and defines common mandatory requirements applicable to the design and development of certain AI systems, before they are placed on the market (see Art. 52). AI-

[131] Finnish Ministry of Economic Affairs and Employment (2017) *Finland's Age of Artificial Intelligence: turning Finland into a leading country in the application of artificial intelligence.* Publications of the Ministry of Economic Affairs and Employment 47/2017.

[132] Yli-Huumo, J.; Päivärinta, T.; Rinne, J.; & Smolander, K. (2018) "Suomi.fi – towards government 3.0 with a national service platform". In: Parycek, P., Glassey, O., Janssen, M., Scholl, H.J., Tambouris, E., Kalampokis, E., Virkar, S. (eds.) EGOV 2018. LNCS, 11020, p 3–14. Springer, Cham.

[133] Finnish Ministry of Finance (2021) *Implementation of the national AuroraAI programme.* Finnish Ministry of Finance.

[134] CIFAR (2021) Pan-Canadian AI Strategy. CIFAR.

[135] CIFAR (2018) *Building an AI World. Report on National and Regional AI strategies.* CIFAR.

[136] Government of the United Kingdom (2019) Guidance: Government Design Principles. Government of the United Kingdom.

[137] UK AI Council (2021) AI Roadmap. UK AI Council.

[138] European Commission (2010) *Open source strategy: History.* European Commission.

[139] COM(2018) 237 final.

[140] COM(2021) 206 final.

driven innovation is closely linked to the **Data Governance Act**[141], the **Open Data Directive**[142] and other initiatives under the **EU Strategy for Data**[143], which will establish trusted mechanisms and services for the re-use, sharing and pooling of data. The European Parliament (EP) has also undertaken a considerable amount of work in the area of AI, including Resolutions related to AI such as ethics [144], liability[145] and copyright[146]. Through the signature of the **Declaration on Cooperation on Artificial Intelligence** in April 2018[147], EU MS have committed themselves to join forces and engage in a common AI policy approach, to leverage the achievements and investments in AI of the European research and business community, while at the same time appropriately dealing with related social, economic, ethical and legal issues. The **European AI Alliance**[148] was created in 2018 as a multi-stakeholder forum for the provision of feedback to the High-Level Expert Group on AI appointed by the EC. More recently, under the new Multiannual Financial Framework, the **Digital Europe Programme** is planned to invest €2.5 billion to help spread AI across the European economy and society. Within this framework, the EC has proposed "to develop common "European libraries" of algorithms that would be accessible to all[149]". In addition, the EC along with MS is developing **European Digital Innovation Hubs** to deliver services that stimulate the uptake of AI.

The EU has made significant efforts to **open up public sector information** and publicly funded research results for re-use, such as data generated by the EU's space programmes (e.g. Copernicus). In terms of OSS, the **OSS strategy 2020-2023**[150] provides a practical instrument for achieving digital transformation in the EC. It recognises open source as a catalyst for change by building on the initiatives in the MS to help shape the conditions for open source development and government innovation. **Error! Reference source not found.** details key EU legislations and their link to OSS. An example of an OSS project launched by the EC, at the initiation of the EP, is the **Free and Open Source Software Auditing** (**EU-FOSSA)** project which aimed to improve security and integrity of critical open software[151]. Following the success of the pilot, the project was renewed for another three years (EU-FOSSA 2) and currently has ended. Furthermore, in order to facilitate knowledge sharing, the EC developed a collaborative platform based on OSS called **Joinup**[152] to promote open source adoption across Europe, including showcasing several AI initiatives (in part already mentioned earlier). In addition, the **Open Source Observatory** (OSOR)[153] is an EC project hosted on the Joinup collaborative platform that allows European public administrations to connect with other relevant stakeholders involved or interested in open source. In addition, the **White Paper on AI**[154] emphasized the need for investments to strengthen fundamental research and make scientific breakthroughs, upgrade AI research infrastructure, and develop AI applications in key sectors to facilitate the uptake of AI and the data access. It acknowledges that Europe can only reap the full benefits of AI if it is available and accessible to all. The EC will support the development of an "**AI-on-demand platform**", providing a

141 COM(2020) 767 final.
142 Council Directive 2019/0124/EC.
143 COM(2020) 66 final.
144 Resolution 2020/2012(INL).
145 Resolution 2020/2014(INL).
146 Resolution 2020/2015(INI).
147 EU Member States representatives (2018) Declaration on Cooperation on Artificial Intelligence. Brussels.
148 European Commission (2021) The European AI Alliance. European Commission.
149 European Commission (2021) *New Digital Europe Programme €9.2 billion investment between 2021-2027*. European Commission News.
150 COM(2020) 7149 final.
151 EU-FOSSA 2 - Free and Open Source Software Auditing. (2020). European Commission - European Commission.
152 Joinup website (2020) Homepage.
153 About Open Source Observatory (OSOR). (2021, April 26). Joinup.
154 COM(2018) 237 final.

single access point for all users to relevant AI resources in the EU, including knowledge, data repositories, computing power (cloud, high performance computing), tools and algorithms.

7. CONCLUSIONS AND RECOMMENDATIONS

Existing research highlights the advantages and great potential of open source. OSS AI has the potential to leverage the knowledge of an entire community, to balance out the dominance of big tech players, or build off the existing technologies and data of these tech giants. This analysis focussed on the risks and challenges of OSS AI. When considering the inherent risks to AI, it will be crucial to see how much of these risks can be mitigated with an open source approach. Furthermore, the recently published Proposal for the Artificial Intelligence Act[155] will be essential to follow, since once the act is adopted, it will provide a horizontal regulatory and trust-based approach to mitigate some of those risks. From the expert consultation, it was reaffirmed that the instruments used by the EU so far - largely non-binding in nature - have not been sufficient to boost uptake of open source despite its innovation potential. Based on the conclusion of this analysis, the following policy recommendations can be drawn:

- **Defining an OSS AI assessment policy / methodology to determine which public services are appropriate for the (experimental) use of OSS AI systems.** One of the findings of this analysis was the lack of economic research done on the costs and benefits of using OSS AI in public administration across the EU. Particularly, a case study could also be performed on OSS AI tools that the EC has released or is currently using.
- **Promoting GovTech and CivicTech ecosystems.** It is crucial to engage local entrepreneurs, social innovators and SMEs - often people who have worked in public services and can see exciting new ways of delivering improved outcomes and more efficient public services. Special attention should be made to align strategies for the deployment and scale-up of AI-powered Local Digital Twins and the creation of AI algorithm registries, for example through the AI-on-demand platform and the Living-in.EU action, as indicated in the review of the AI Coordinated Plan.
- **Facilitating good quality data access for public institutions.** It is pivotal to ensure appropriate deployment of the common European Data Spaces as part of the recently agreed Digital Europe Programme (DEP). European data spaces (covering areas like the environment, energy, agriculture and public administrations at national and local level) should consider promoting OS approaches to AI, supporting voluntary data exchange by individuals and communities of developers, setting up structures to enable key public and private sector organisations to share data and nurture a local ecosystem of OS for AI.
- **Supporting public organisations as potential OSS AI producers.** Third-party intermediaries could be used to identify and manage OSS AI projects across the EU. They could form teams of independent developers and distribute funding to various projects that align with the digital transformation goals of Europe, which should also be aligned with the 2030 Agenda for Sustainable Development as well as the goals of the European Green Deal. Having a framework contract with universities could be a way to introduce, maintain, and monitor OSS AI solutions in government in a sustainable way.
- **Using public procurement to encourage OSS AI digital solutions in the public and private sector.** As underlined in the review of the AI Coordinated Plan, the Recovery and Resilience Facility (RRF) offers an unprecedented opportunity to accelerate uptake of AI in the public sector. MS are encouraged to focus on building capacity to seize the advantages of predictive analytics and AI in policymaking and public service delivery, and for this to become a reality

[155] COM(2021) 206 final.

public procurement is considered crucial to stimulate adoption of trustworthy and secure AI. As part of the Adopt AI programme to support public procurement of AI systems and transforming procurement processes themselves, a special effort should be dedicated to developing OS approaches to AI, also within the context of the new public procurement data space proposed in the Coordinated Plan. Additionally, it is suggested to launch a new FOSSA-3 initiative, which could give an additional layer of auditing and justification for the public procurement of OSS AI.

- **Stimulating the OSS innovation ecosystems to accelerate AI development and use** through incentives to OSS collaborators, especially SMEs, and increasing the transparency of the source of software underpinning the digital infrastructure and functionalities deployed along the entire value chain.
- **Creating opportunities for strengthening the sharing of OSS data and analytical tools across communities of research and practice,** promoting the creation of repositories to support developing AI applications (such as Joinup), and the transfer of specific AI components to be used "on demand", following the approach the EC initiated with the "AI4EU platform", to develop an AI resources catalogue, which includes reusable AI datasets, models, libraries and other resources. Many AI tools require specific skillsets to make the most out of analytical software. These public platforms would thus provide data scientists with analytical options to experiment and test with dataset to train algorithms and models, so to develop innovative applications and strengthen the OSS AI ecosystems across the EU.

REFERENCES

All references were accessed between 08 March and 26 April 2021.

- Accenture (2017) *Why is Artificial Intelligence Important?* Accenture. Available at: https://www.accenture.com/_acnmedia/pdf-54/accenture-artificial-intelligence-ai-overview.pdf (Accessed 9 April 2021).
- AI Finland (2019) *Eleven key actions ushering Finland into the age of artificial intelligence*. AI Finland. Available at: https://www.tekoalyaika.fi/en/reports/finland-leading-the-way-into-the-age-of-artificial-intelligence/3-eleven-key-actions-ushering-finland-into-the-age-of-artificial-intelligence/ (Accessed 12 April 2021).
- AI Sweden (2021) *Decentralized AI*. AI Sweden. Available at: https://www.ai.se/en/projects-9/decentralized-ai (Accessed 12 April 2021).
- Almeida, F.; Oliveira, J.; & Cruz, J. (2011) "Open Standards and Open Source: Enabling Interoperability". *International Journal of Software Engineering & Applications,* 2(1).
- Al-Mushayt, O. S. (2019). Automating E-government services with artificial intelligence. IEEE Access, 7, 146821–146829. DOI: https://doi.org/10.1109/ACCESS.2019.2946204.
- Angell, R.; Johnson, B.; Brun, Y.; & Meliou, A. (2018) "Themis: automatically testing software for discrimination". In *Proceedings of the 2018 26th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering* (ESEC/FSE 2018). Association for Computing Machinery, New York, NY, USA, 871–875.
- Alpaydin, E. (2016) *Machine Learning: The New AI*. The MIT Press Essential Knowledge Series. Cambridge, MIT Press.
- Balaguer, F.; Di Como, R.; Garrido, A.; Kon, F.; Robles, G.; & Zacchiroli, S. (2017) "Open source systems: Towards Robust Practices". *13th International Conference OSS 2017*.
- Bani, M.; & De Paoli, S. (2020) "Ideas for a new civic reputation system for the rising of digital civics: digital badges and their role in democratic process". *ECEG2013–13th European Conference on eGovernment: ECEG*.
- Barcevičius, E.; Cibaitė, G.; Codagnone, C.; Gineikytė, V.; Klimavičiūtė, L.; Liva, G.; Matulevič, L.; Misuraca, G.; & Vanini, I. (2019) *Exploring Digital Government transformation in the EU - Analysis of the state of the art and review of literature*, EUR 29987 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-13299-8. DOI: 10.2760/17207, JRC118857.
- Barker, D. (2019) *12 open source tools for natural language processing*. opensource.com. Available at: https://opensource.com/article/19/3/natural-language-processing-tools (Accessed 7 April 2021).
- Bhadwal, A. (2021) *15 Best Machine Learning Libraries You Should Know in 2021*. *Hackr.io Blog*. Available at: https://hackr.io/blog/best-machine-learning-libraries (Accessed 7 April 2021).
- Berman, D. (2020) *What is a Software License? 5 Types of Software Licenses You Need to Know About*. Snyk. Available at: https://snyk.io/learn/what-is-a-software-license/ (Accessed 9 April 2021).
- Bocetta, S. (2019) *What does an open source AI future look like?* Opensource.com. Available at: https://opensource.com/article/19/9/open-source-ai-future (Accessed 7 April 2021).

- Botelho, A. J.; Stefanuto, G.; & Veloso, F. (2003) "The Brazilian Software Industry". In Arora, A. & Gambardella, A. (2005) *From Underdogs to Tigers: The Rise and Growth of the Software Industry in Brazil, China, India, Ireland and Israel*. Oxford University Press.
- Boucher, P. (2020) *Artificial intelligence: How does it work, why does it matter, and what can we do about it?* Study for the Panel for the Future of Science and Technology, European Parliamentary Research Service, Scientific Foresight Unit, European Parliament, 2020. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641547/EPRS_STU(2020)641547_EN.pdf (Accessed 23 April 2021).
- Bouras, C.; Filopoulos, A.; Kokkinos, V.; Michalopoulos, S.; Papadopoulos, D.; & Tseliou, G. (2014) "Policy recommendations for public administrators on free and open-source software usage". *Telematics and Informatics*, 31(2), p237-252.
- Canadian Centre for Cybersecurity (2020) *Security Considerations When Using Open-source software*. Canadian Centre for Cybersecurity. Available at: https://www.cyber.gc.ca/en/guidance/security-considerations-when-using-open-source-software-itsap10059 (Accessed 12 April 2021).
- Christchurch Airport (2019) *First New Zealand autonomous shuttle debuts at Christchurch Airport.* Christchurch Airport. Available at: https://www.christchurchairport.co.nz/about-us/who-we-are/media/2019/first-new-zealand-autonomous-shuttle-debuts-at-christchurch-airport/ (Accessed 9 April 2021).
- Chun, A. H. W. (2007) *Using AI for e-Government Automatic Assessment of Immigration Application Forms*. Proceedings of the Twenty-Second AAAI Conference on Artificial Intelligence. Available at: https://www.aaai.org/Papers/AAAI/2007/AAAI07-273.pdf (Accessed 9 April 2021).
- Chen, P. (2020) *IBM's open source strategy champions AI trust and transparency*. IBM. Available at: https://www.ibm.com/blogs/journey-to-ai/2020/09/ibms-open-source-strategy-champions-ai-trust-and-transparency/ (Accessed 7 April 2021).
- CIFAR (2018) *Building an AI World. Report on National and Regional AI strategies.* Available at: https://cifar.ca/wp-content/uploads/2020/05/buildinganaiworld_eng.pdf (Accessed 12 April 2021).
- City of Amsterdam Algorithm Register (2021) Homepage: Beta version. Available at: https://algoritmeregister.amsterdam.nl/en/ai-register/ (Accessed 12 April 2021).
- City of Helsinki AI Register (2021) Homepage. Available at: https://ai.hel.fi/en/ai-register/ (Accessed 12 April 2021).
- Coglianese, C.; & Lehr, D. (2019) "Transparency and Algorithmic Governance". *Administrative Law Review*, 71, p1. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3293008 (Accessed 9 April 2021).
- Collier, M.; Fu, R.; & Yin, L. (2017) Artificial Intelligence: Healthcare's New Nervous System. Accenture Report. Available at: https://www.accenture.com/_acnmedia/PDF-49/Accenture-Health-Artificial-Intelligence.pdf#zoom=50 (Accessed 9 April 2021).
- Columbus, L. (2019) *Why AI Is the Future of Cybersecurity*. Forbes. Available at: https://www.forbes.com/sites/louiscolumbus/2019/07/14/why-ai-is-the-future-of-cybersecurity/#69a04c8f117e (Accessed 7 April 2021).
- Corona-Warn App (2021) GitHub website. Available at: https://github.com/ct-report/DE (Accessed 7 April 2021).

- Cortés-Cediel, M. E.; Cantador, I.; & Gil, O. (2017) Recommender systems for e-governance in smart cities: state of the art and research opportunities. ACM RecSys 2017 Workshop on Recommender System for Citizens. Available at: https://www.researchgate.net/publication/319043437_Recommender_systems_for_e-governance_in_smart_cities_State_of_the_art_and_research_opportunities (Accessed 9 April 2021).
- "Council directive 2019/0124/EC on open data and the re-use of public sector information" (2019) Official Journal of the European Union L172/56, p. 56–83. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L1024&from=EN (Accessed 23 April 2021).
- Council of the European Union (2018) Regulation 28th November 2018 on a framework for the free flow of non-personal data in the European Union. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1807&from=EN (Accessed 23 April 2021).
- Dayaratna, A. (2019) *How Open Source Is the Key to Innovation, Productivity, Collaboration, and Transparency Within the Digital Enterprise*. GitHub. Available at: https://resources.github.com/downloads/IDC.Report.-.How.open.source.is.the.key.to.innovation.pdf (Accessed 7 April 2021).
- Desouza, K. (2018) *Delivering Artificial Intelligence in Government: Challenges and Opportunities*. IBM Center for The Business of Government Delivering.
- Desouza, K.; Dawson, G.; & Chenok, D. (2019) "Designing, developing, and deploying where is artificial intelligence systems: lessons from and for in public sector". *Business Horizons*, 63(2), p205-213.
- Devenyi, V.; Di Giacomo, D.; & O'Donohoe, C. (2020) *Status of Open-source software Policies in 28 European Countries – 2020. European Commission*. Joinup. Available at: https://joinup.ec.europa.eu/sites/default/files/inline-files/OSOR_Status%20of%20OSS%20Policies%20in%20Europe_2020_0.pdf (Accessed 7 April 2021).
- Dheap, V. (2017) "IBM QRadar Advisor with Watson: Revolutionizing the Way Security Analysts Work". *Security Intelligence,* 8th May. Available at: https://securityintelligence.com/ibm-qradar-advisor-with-watson-revolutionizing-the-way-security-analysts-work/ (Accessed 7 April 2021).
- DR2 Consultants (2021) *Data Governance Act: main elements and business implications*. Dr2 Consultants. Available at: https://dr2consultants.eu/data-governance-act-main-elements-and-business-implications/ (Accessed 9 April 2021).
- E-Estonia (2019) *Estonia accelerates artificial intelligence development*. E-estonia. Available at: https://e-estonia.com/estonia-accelerates-artificial-intelligence/ (Accessed 14 April 2021).
- E-riigi koodivaramu (Estonian e-repository) website (2021) Homepage. Available at: https://koodivaramu.eesti.ee/users/sign_in (Accessed 14 April 2021).
- Esteva, A.; Kuprel, B.; Novoa, R. A.; Ko, J.; Swetter, S. M.; Blau, H. M.; & Thrun, S. (2017) "Dermatologist-level classification of skin cancer with deep neural networks". *Nature*, 542: p115-118.
- European AI Alliance website (2021) Homepage website. Available at: https://digital-strategy.ec.europa.eu/en/policies/european-ai-alliance (Accessed 12 April 2021).

- European Commission (2010) *Open source strategy: History*. European Commission. Available at: https://ec.europa.eu/info/open-source-strategy-history_en#open-source-strategy-2011-2013 (Accessed 23 April 2021).
- European Commission (2018) *Artificial Intelligence for Europe*. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2018) 237. European Commission. Brussels. Available at: https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF (Accessed 23 April 2021).
- European Commission (2018) Coordinated Plan on Artificial Intelligence. COM(2018)795. European Commission. Brussels. Available at: https://knowledge4policy.ec.europa.eu/publication/coordinated-plan-artificial-intelligence-com2018-795-final_en (Accessed 23 April 2021).
- European Commission (2018) *New Digital Europe Programme €9.2 billion investment between 2021-2027*. European Commission News. Available at: https://ec.europa.eu/isa2/news/european-commission-has-announced-investment-%E2%82%AC92-billion-align-next-long-term-eubudget-2021_en (Accessed 14 April 2021).
- European Commission (2020) *A European Strategy for data*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the Regions. COM(2020) 66 final. European Commission. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066&from=EN (Accessed 23 April 2021).
- European Commission (2020) *Managing licence compatibility issues in free and open-source software. Methodologies and Tools.* Available at: https://op.europa.eu/en/publication-detail/-/publication/807bc813-9c04-11eb-b85c-01aa75ed71a1/language-en (Accessed 20 April 2021).
- European Commission (2020) *Open-source software Strategy 2020-2023: Think Open*. Communication to the Commission, C(2020) 7149 final. Brussels. Available at: https://ec.europa.eu/info/sites/info/files/en_ec_open_source_strategy_2020-2023.pdf (Accessed 22 April 2021).
- European Commission (2020) Proposal for a Regulation of the European Parliament and of the Council on European data governance (Data Governance Act). 2020/0340 (COD). COM(2020) 767. European Commission. Brussels. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0767&from=EN (Accessed 26 April 2021).
- European Commission (2020) *Status of Open-source software Policies in Europe*. Waverstone's European Services Team. Available at: https://joinup.ec.europa.eu/sites/default/files/inline-files/OSOR_Status%20of%20OSS%20Policies%20in%20Europe_2020_0.pdf (Accessed 14 April 2021).
- European Commission (2021) *Digital Innovation Hubs (DIHs) in Europe (2021) Shaping Europe's Digital Future*. European Commission. Available at: https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs-dihs-europe (Accessed 23 April 2021).
- European Commission (2021) *Industry 5.0 Towards a sustainable, human-centric and resilient European industry*. Available at: https://ec.europa.eu/info/publications/industry-50_es (Accessed 23 April 2021).

- European Commission (2021) *Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts*. Proposal for a Regulation of the European Parliament and of the Council. Brussels. Available at: https://ec.europa.eu/transparency/regdoc/rep/1/2021/EN/COM-2021-206-F1-EN-MAIN-PART-1.PDF (Accessed 23 April 2021).
- European Commission (2021) *Annex to Fostering a European approach to Artificial Intelligence*. European Commission. COM(2021) 205. Brussels. Available at: https://digital-strategy.ec.europa.eu/en/library/coordinated-plan-artificial-intelligence-2021-review (Accessed 23 April 2021).
- European Digital SME Alliance (2021) Digital SME position paper on the European Data Governance Act. Brussels. Available at: http://www.digitalsme.eu/digital/uploads/Data-Governance-Act-Consultation-Position.pdf (Accessed 23 April 2021).
- European Parliament (2020) Resolution of 20 October 2020 on a civil liability regime for artificial intelligence. 2020/2014(INL). Available at: https://www.europarl.europa.eu/doceo/document/TA-9-2020-0276_EN.html (Accessed 23 April 2021).
- European Parliament (2020) Resolution of 20 October 2020 on a framework of ethical aspects of artificial intelligence, robotics, and related technologies. 2020/2012(INL). Available at: https://www.europarl.europa.eu/doceo/document/TA-9-2020-0275_EN.html#title1 (Accessed 23 April 2021).
- European Parliament (2020) Resolution of 20 October 2020 on intellectual property rights for the development of artificial intelligence technologies. 2020/2015(INI). Available at: https://www.europarl.europa.eu/doceo/document/TA-9-2020-0277_EN.html (Accessed 23 April 2021)
- European Union (2020) *Proposal for a Regulation of the European Parliament and of the Council on European Data Governance (Data GovernanceAct)*. COM/2020/767. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0767 (Accessed 23 April 2021).
- European Union (2017) Tallin Declaration on eGovernment. Ministerial Meeting during the Estonian Presidency of the Council of the EU on 6 October 2017. Available at: https://digital-strategy.ec.europa.eu/en/news/ministerial-declaration-egovernment-tallinn-declaration (Accessed 23 April 2021).
- European Union (2020) Berlin Declaration on Digital Society and Value-Based Digital Government. Ministerial Meeting during the German Presidency of the Council of the European Union on 8 December 2020. Available at: https://ec.europa.eu/isa2/sites/default/files/cdr_20201207_eu2020_berlin (Accessed 23 April 2021).
- EU Member States representatives (2018) Declaration on Cooperation on Artificial Intelligence. Brussels. Available at: https://ec.europa.eu/jrc/communities/en/node/1286/document/eu-declaration-cooperation-artificial-intelligence#:~:text=Declaration%20signed%20at%20Digital%20Day%20on%2010th%20April%202018.&text=Ensuring%20an%20adequate%20legal%20and,such%20as%20transparency%20and%20accountability (Accessed 26 April 2021).
- Fatima, S.; Desouza, K.C.; & Dawson, G.S. (2020) "National strategic artificial intelligence plans: A multi-dimensional analysis". *Economic analysis and Policy*, 67(C), p178-194.

- FCAI (2021*) Improving data literacy to support ethical and responsible decision-making*. Finnish Center for Artificial Intelligence (FCAI). Available at: https://fcai.fi/news/2021/2/26/improving-data-literacy-to-support-ethical-and-responsible-decision-making (Accessed 12 April 2021).
- Feilner, M. (2013) *"LiMux – the IT evolution": an open source success story like never before*. Joinup. Available at: https://joinup.ec.europa.eu/sites/default/files/document/2013-12/LiMux-the-IT-evolution.pdf (Accessed 9 April 2021).
- Finland Prime Minister's Office (2017) *Finland, a land of solutions Mid-term review. Government Action Plan 2017-2019*. Government publications 7/2017. Available at: https://valtioneuvosto.fi/documents/10184/321857/Government+action+plan+28092017+en.pdf (Accessed 12 April 2021).
- Finnish Ministry of Economic Affairs and Employment (2017) *Finland's Age of Artificial Intelligence: turning Finland into a leading country in the application of artificial intelligence*. Publications of the Ministry of Economic Affairs and Employment 47/2017. Available at: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160391/TEMrap_47_2017_verkkojulkaisu.pdf (Accessed 12 April 2021).
- Finnish Ministry of Finance (2021) *Implementation of the national AuroraAI programme.* Ministry of Finance. Available at: https://vm.fi/en/auroraai-en (Accessed 12 April 2021).
- Galov, N. (2021) *111+ Linux Statistics and Facts – Linux Rocks! Hosting Tribunal*. Hosting Tribunal. Available at: https://hostingtribunal.com/blog/linux-statistics/#gref (Accessed 7 April 2021).
- Gasser, U. & Almeida, V. (2017) "A Layered Model for AI Governance". *IEEE Internet Computing*, 21(6), p58-62.
- Gerrits, G. (2020) "Soul of a new machine: self-learning algorithms in public administration". Information Polity 1, p1-14. Available at: https://content.iospress.com/download/information-polity/ip200224?id=information-polity%2Fip200224 (Accessed 7 April 2021).
- Gill, S. S. et al. (2019) Transformative Effects of IoT, Blockchain and Artificial Intelligence on Cloud Computing: Evolution, Vision, Trends and Open Challenges. *Internet of Things,* 8(26), p100118.
- GNU Operating System (2017) *Overview of the GNU System - GNU Project - Free Software Foundation*. GNU Foundation. Available at: https://www.gnu.org/gnu/gnu-history.html (Accessed 20 April 2021).
- GNU Operating System (2021) *What is free software?* Free Software Foundation. GNU Foundation. Available at: https://www.gnu.org/philosophy/free-sw.en.html (Accessed 20 April 2021).
- Goldstein, A. (2018) *Dual Licensing for Open Source Components: Yeah or Meh?* WhiteSource. Available at: https://resources.whitesourcesoftware.com/blog-whitesource/dual-licensing-for-open-source-components-yeah-or-meh (Accessed 9 April 2021).
- Government of Estonia (2020) *#KrattAI: roadmap for 2020*. Artificial Intelligence Programme of #eEstonia.
- Government of Estonia (2021) *#KrattAI: the next stage of digital public services in #eEstonia*. Government of Estonia. Available at: https://en.kratid.ee/ideepaber (Accessed 12 April 2021).
- Government of Ireland (2021) COVID Tracker app. Government of Ireland. Available at: https://covidtracker.gov.ie/ (Accessed 7 April 2021).

- Government of the Netherlands (2019) *Strategic Action Plan for Artificial Intelligence*. Available at: https://www.government.nl/documents/reports/2019/10/09/strategic-action-plan-for-artificial-intelligence (Accessed 12 April 2021).
- Government of the United Kingdom (2019) Guidance: Government Design Principles. Available at: https://www.gov.uk/guidance/government-design-principles#make-things-open-it-makes-things-better (Accessed 12 April 2021).
- H2O website (2021) Homepage. Available at: https://www.h2o.ai/financial-services/#overview (Accessed 7 April 2021).
- Hashem, I.A.T., Chang, V., Anuar, N. B. et al. (2016) "The role of big data in smart city". *International Journal of Information Management*, 36(5), p748–758.
- Herbert, S.A. (1991) "Bounded rationality and organizational learning". *Organization Science*, 2(1), p125–34.
- Herman, J. (2017a) *Federal Pilot to Integrate Public Services into Intelligent Personal Assistants*. Digital.gov. Available at: https://digital.gov/2017/04/24/federal-pilot-to-integrate-public-services-into-intelligent-personal-assistants/ (Accessed 7 April 2021).
- Herman, J. (2017b) *Opening Public Services to Artificial Intelligence Assistants*. U.S. General Services Administration. Available at: https://www.gsa.gov/blog/2017/06/06/opening-public-services-to-artificial-intelligence-assistants (Accessed 7 April 2021).
- Hernandez, A. (2019) *The Best 7 Free and Open-Source Artificial Intelligence Software*. Good Firms Blog. Available at: https://www.goodfirms.co/blog/best-free-open-source-Artificial-Intelligence-software (Accessed 9 April 2021).
- Hillenius, G. (2020) *Open source is key to Estonia's vision for artificial intelligence*. Joinup. Available at: https://joinup.ec.europa.eu/collection/open-source-observatory-osor/news/order-me-new-passport (Accessed 12 April 2021).
- IBM Research Trusted AI (2021) AI Fairness 360. IBM Research Trusted AI. Available at: https://aif360.mybluemix.net/ (Accessed 7 April 2021).
- Janssen, M.; Wimmer, M.A.; & Delijoo, A. (2015) "Policy Practice and Digital Science: Integrating Complex Systems". *Social Simulation and Public Administration in Policy Research*. Springer.
- Jee, C. (2019) *DARPA is trying to build an unhackable open-source voting system*. MIT Technology Review. Available at: https://www.technologyreview.com/2019/03/15/136607/darpa-is-trying-to-build-an-unhackable-open-source-voting-system/ (Accessed 9 April 2021).
- Jefferies, D. (2016) "The automated city: do we still need humans to run public services?" *The Guardian,* 20 September. Available at: https://www.theguardian.com/cities/2016/sep/20/automated-city-robots-run-public-services-councils (Accessed 9 April 2021).
- Johnson, K. (2020) *Amsterdam and Helsinki launch algorithm registries to bring transparency to public deployments of AI*. Venture Beat. Available at: https://venturebeat.com/2020/09/28/amsterdam-and-helsinki-launch-algorithm-registries-to-bring-transparency-to-public-deployments-of-ai/ (Accessed 12 April 2021).

- Johnson, P. (2021) *Open source licenses in 2021: trends and predictions*. WhiteSource. Available at: https://resources.whitesourcesoftware.com/blog-whitesource/open-source-licenses-trends-and-predictions (Accessed 7 April 2021).
- Joinup website (2021) Homepage. Available at: https://joinup.ec.europa.eu/ (Accessed 7 April 2021).
- Jokonya, O. (2015) "Investigating Open-source software Benefits in Public Sector". *48th Hawaii International Conference on System Sciences*, pp. 2242-2251. DOI: 10.1109/HICSS.2015.268.
- Kaur, R.; Chahal, K. K.; & Saini, M. (2020) "Understanding community participation and engagement in open-source software projects: A systematic mapping study". *Journal of King Saud University – Computer and Information Sciences*. Available at: https://www.sciencedirect.com/science/article/pii/S1319157820305139 (Accessed 14 April 2021).
- Kemper, C. (2020) "Kafkaesque AI? Legal Decision-Making in the Era of Machine Learning". *University of San Francisco Intellectual Property and Technology Law Journal*, 24(2).
- Keras (2021) Homepage website. Available at: https://keras.io/ (Accessed 20 April 2021).
- Klosters, D. (2016) *World Economic Forum Annual Meeting 2016 Mastering the Fourth Industrial Revolution*. World Economic Forum. Available at: http://www3.weforum.org/docs/Media/ (Accessed 22 April 2021).
- Kouziokas, G. N. (2017) The application of artificial intelligence in public administration for forecasting high crime risk transportation areas in urban environments. *Transportation Research Procedia,* 24, p467-473. Available at: https://www.sciencedirect.com/science/article/pii/S2352146517303642?via%3Dihub (Accessed 14 April 2021).
- Kuziemski, M., & Misuraca, G. (2020) "AI governance in the public sector: Three tales from the frontiers of automated decision-making in democratic settings". *Telecommunications Policy*, 44(6), p101976.
- Lakka, S.; Stamati, T.; Michalakelis, C.; & Anagnostopoulos, D. (2015) "Cross-national analysis of the relation of eGovernment maturity and OSS growth". *Technological Forecasting and Social Change*, 99, p132-147.
- Lee, J. (2006) "Government policy toward open-source software: The puzzles of neutrality and competition". *Knowledge, Technology, & Policy*, 18, p113-141. Available at: https://link.springer.com/article/10.1007/s12130-006-1007-5 (Accessed 14 April 2021).
- Lee, V.; & Radcliffe, M. (2021) *Intellectual Property basics for Startups: open-source software.* DLA Piper. Available at: https://www.dlapiperaccelerate.com/knowledge/2017/intellectual-property-basics-for-startups-open-source-software.html (Accessed 9 April 2021).
- Lessig, L. (2002) *The Future of Ideas: the Fate of the Commons in a Connected World*. Random House.
- Lerner, J. & Tirole, J. (2003) "Some Simple Economics of Open Source". *The Journal of Industrial Economics*, 50(2), p197-234.
- Li, F. & Etchemendy, J. (2021) *Letter from the Denning Co-Directors*. Stanford University Human-Centered Artificial Intelligence. Available at: https://hai.stanford.edu/about/welcome (Accessed 7 April 2021).

- Li, M.; Lin, Z.; & Xia, M. (2005) Leveraging the Open Source Software Movement for Development of China's Software Industry. *Information Technologies and International Development*, 6(2), p45-63.
- Lin, S. Y.; Shanafelt, T. D.; & Asch, S. M. (2018) *Reimagining Clinical Documentation with Artificial Intelligence*. Mayo Procurements. Mayo Foundation or Medical Education and Research. Available at: https://www.mayoclinicproceedings.org/article/S0025-6196(18)30142-3/pdf (Accessed 12 April 2021).
- Mehr, H. (2017) *Artificial Intelligence for Citizen Services and Government*. Ash Center for Democratic Governance and Innovation Harvard Kennedy School. Retrieved from: https://ash.harvard.edu/files/ash/files/artificial_intelligence_for_citizen_services.pdf (Accessed 7 April 2021).
- Microsoft (2021) *What is machine translation?* Microsoft. Available at: https://www.microsoft.com/en-us/translator/business/machine-translation/ (Accessed 7 April 2021).
- Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2017) *Onderzoek publiceren Open-source software*. Gartner. Available at: https://kennisopenbaarbestuur.nl/rapporten-publicaties/onderzoek-open-source-software/ (Accessed 12 April 2021).
- Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2020) *Overwegingen bij Open tenzij en Aanpak open source*. Available at: https://www.rijksoverheid.nl/documenten/publicaties/2020/04/17/overwegingen-bij-open-tenzij-en-aanpak-open-source (Accessed 12 April 2021).
- Ministry of Economic Affairs and Employment of Finland, Business Finland, & VITTResearch (2018) *Digital Finland Framework*. Available at: https://www.businessfinland.fi/496a6f/globalassets/julkaisut/digital-finland-framework.pdf (Accessed 12 April 2021).
- Misuraca, G. and Van Noordt, C., AI Watch - Artificial Intelligence in public services, EUR 30255 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19540-5, JRC120399. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC120399 (Accessed 12 April 2021).
- Montes, G. A. & Goertzel, B. (2019) "Distributed, decentralized, and democratized artificial intelligence". *Technological Forecasting and Social Change* 141, p354-358.
- National Vulnerability Database (2021) Homepage. Available at: https://nvd.nist.gov/vuln/detail/CVE-2017-5638 (Accessed 7 April 2021).
- Nederland Digitaal (2019) *Nederlandse Digitaliseringstrategie 2018-2021*. Government of the Netherlands. Available at: https://www.nederlanddigitaal.nl/documenten/publicaties/2019/09/30/english-version-of-the-dutch-digitalisation-strategy (Accessed 12 April 2021).
- Open Data Barometer (2017) *Global Report | Open Data Barometer*. Available at: https://opendatabarometer.org/4thedition/report/ (Accessed 9 April 2021).
- Open Data Handbook (2021) Homepage website. Available at: https://opendatahandbook.org/ (Accessed 9 April 2021).
- Opensource.org (2007) The Open Source Definition | Open Source Initiative. Available at: https://opensource.org/osd (Accessed 12 April 2021).

- Open Source Initiative (2021) Homepage website. Available at: https://opensource.org/osd (Accessed 12 April 2021).
- Opensource.org (2021) Open Source Initiative list of OS licenses. Available at: https://opensource.org/licenses/alphabetical (Accessed 12 April 2021).
- Open Source Netherlands (2021) Homepage website. Available at: https://opensource.pleio.nl (Accessed 12 April 2021).
- Park, S. (2017) "The Fourth Industrial Revolution and implications for innovative cluster policies". *AI & Society*, Vol. 33(3), p433-445.
- Pharmaceutical Group of the European Union (2019) *Position Paper on Big Data & Artificial Intelligence in Healthcare*. Available at: https://www.pgeu.eu/wp-content/uploads/2019/04/PGEU-Position-Paper-on-Big-Data-Artificial-Intelligence-in-Healthcare.pdf (Accessed 21 April 2021).
- Power, D. (2016) ""Big Brother" can watch us". *Journal of Decision Systems,* 25(1), p578-588. Available at: https://www.tandfonline.com/doi/full/10.1080/12460125.2016.1187420?scroll=top&needAccess=true (Accessed 14 April 2021).
- Predictive Analytics (2021) *Top 18 Artificial Intelligence Platforms*. Predictive Analytics. Available at: https://www.predictiveanalyticstoday.com/artificial-intelligence-platforms/ (Accessed 12 April 2021).
- Radar Covid (2021) GitHub website. Available at: https://github.com/RadarCOVID (Accessed 7 April 2021).
- Rahwan, I. (2018) "Society-in-the-loop: programming the algorithmic social contract". *Ethics and Information Technology*, 20, p5-14.
- Red Hat (2021) *What is open source software?* Red Hat website. Available at: https://www.redhat.com/en/topics/open-source/what-is-open-source-software (Accessed 12 April 2021).
- Reis, J.; Espírito Santo, P.; & Melao, N. (2019) "Artificial Intelligence in Government Services: A Systematic Literature Review". *Brazilian Journal of Operations & Production Management*, 18(1).
- Rexhepi, G., Hisrich, R. D., & Ramadani, V. (2020) *Open Innovation and Entrepreneurship: Impetus of Growth and Competitive Advantages* (1st ed. 2019 ed.). Springer.
- Riehle, D. (2007) "The Economic Motivation of Open-source software: Stakeholder Perspectives". *Computer,* 40(4), p25-32.
- Rimi, C. (2019) *Artificial intelligence: an open source future.* IT Pro Portal. Available at: https://www.itproportal.com/features/artificial-intelligence-an-open-source-future/ (Accessed 8 April 2021).
- Schaer, C. (2020) *Linux not Windows: Why Munich is shifting back from Microsoft to open source – again*. Zdnet. Available at: https://www.zdnet.com/article/linux-not-windows-why-munich-is-shifting-back-from-microsoft-to-open-source-again/ (Accessed 12 April 2021).
- Schmidhuber, J. (2015) "Deep Learning in Neural Networks: An Overview". *Neural Networks,* 61, p85-117.

- Sedghi, A.; Hamidi, S.; Mehrtash, A.; Ziegler, E.; Tempany, C.; Pieper, S.; Kapur, T.; & Mousavi, P. (2019) "Tesseract-medical imaging: open-source browser-based platform for artificial intelligence deployment in medical imaging". *SPIE Medical Imaging 10951, Medical Imaging 2019: Image-Guided Procedures, Robotic Interventions, and Modeling*. DOI: https://doi.org/10.1117/12.2513004.
- Senate of the Netherlands (Eerste Kamer der Staten-Generaal) (2020) *Considerations for "open, unless" and an open source 2020–2021 approach*. Available at: https://www.eerstekamer.nl/overig/20200417/overwegingen_bij_open_tenzij_en/meta (Accessed 12 April 2021).
- Sharma, G. D.; Yadav, A., Chopra, R. (2020) "Artificial Intelligence and effective governance: A review, critique and research agenda". *Sustainable Futures*, 2, Available at: https://www.sciencedirect.com/science/article/pii/S2666188819300048 (Accessed 26 April 2021).
- Simcoe, T. (2005) "Open Standards and Intellectual Property Rights". In (Oxford University Press) *Open Innovation: Researching a New Paradigm.*
- Somani, R. (2021) *Public-Sector Productivity (Part One). Why Is It Important and How Can We Measure It?* Washington, D.C.: World Bank Group. Available at: http://documents.worldbank.org/curated/en/913321612847439794/Public-Sector-Productivity-Part-One-Why-Is-It-Important-and-How-Can-We-Measure-It (Accessed 22 April 2021).
- Sourdin, T. (2018) Judge vs Robot? Artificial Intelligence and Judicial Decision-Making. *UNSW Law Journal*. Available at: http://www.unswlawjournal.unsw.edu.au/wp-content/uploads/2018/12/Sourdin.pdf (Accessed 22 April 2021).
- Sun, T. Q., & Medaglia, R. (2019) "Mapping the challenges of artificial intelligence in the public sector: Evidence from public healthcare". *Government Information Quarterly*, 36(2), p368–383.
- Susar, D. & Aquaro, V. (2019) "Artificial Intelligence: Opportunities and Challenges for the Public Sector". *ICEGOV2019: Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, p418-426. DOI: 10.1145/3326365.3326420.
- Tesseract-MI (2021) GitHub page Tesseract-MI. Available at: https://github.com/Tesseract-MI/Tesseract-MI (Accessed 9 April 2021).
- TensorFlow (2021) *Case Studies and Mention TensorFlow*. Available at: https://www.tensorflow.org/about/case-studies (Accessed 9 April 2021).
- Thierer, A.; O'Sullivan, A. C.; & Russell, R. (2017) "Artificial Intelligence and Public Policy". *Mercatus Research,* Mercatus Center at George Mason University. DOI:10.13140/RG.2.2.14942.33604.
- UK AI Council (2021) AI Roadmap. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/949539/AI_Council_AI_Roadmap.pdf (Accessed 12 April 2021).
- Ünver, H. A. (2018) *Digital Open Source Intelligence and International Security: A Primer*. Centre for Economics and Foreign Policy Studies.
- Valtiokonttori State Treasury (2019) *The digitalisation of receipts to boost the move to real-time economy*. Valtiokonttori State Treasuy. Available at: https://www.valtiokonttori.fi/en/uutinen/the-digitalisation-of-receipts-to-boost-the-move-to-real-time-economy/ (Accessed 14 April 2021).

- Van Loon, A. & Toshkov, D. (2015) "Adopting open-source software in public administration: the importance of boundary spanners and political commitment". *Government Information Quarterly*, 32(2), p207–215.
- Veale, M. & Brass, I. (2019) "Administration by Algorithm? Public Management Meets Public Sector Machine Learning" in Yeung, K & Lodge, M. (Oxford University Press) *Algorithmic Regulation*. Available at: https://ssrn.com/abstract=3375391 (Accessed 22 April 2021).
- Von der Leyen, U. (2019) *A union that strives for more: My agenda for Europe*. Political Guidelines for the Next European Commission 2019-2024. Available at: https://ec.europa.eu/info/sites/info/files/political-guidelines-next-commission_en_0.pdf (Accessed 23 April 2021).
- Web Foundation (2018) *How open data can save AI*. Web Foundation. Available at: https://webfoundation.org/2018/01/how-open-data-can-save-ai/#:%7E:text=Open%20data%20to%20improve%20AI&text=Opening%20key%20datasets%20will%20help,increase%20citizen%20trust%20in%20government (Accessed 9 April 2021).
- Webviz (2021) Homepage website. Available at: https://webviz.io/ (Accessed 8 April 2021).
- Wirtz, B.; Weyerer, J.C.; & Geyer, C. (2019) "Artificial Intelligence and the Public Sector— Applications and Challenges". *International Journal of Public Administration*, 42(7), p596-615. DOI: 10.1080/01900692.2018.1498103.
- Yli-Huumo, J.; Päivärinta, T.; Rinne, J.; & Smolander, K. (2018) "Suomi.fi – towards government 3.0 with a national service platform". In: Parycek P. et al. (eds) *Electronic Government. EGOV 2018. Lecture Notes in Computer Science*, 11020. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-98690-6_1 (Accessed 14 April 2021).
- Zalnieriute, M.; Moses, L. B.; & Williams, G. (2019) "The Rule of Law and Automation of Government Decision-Making". *Modern Law Review*, 82(3). DOI: 10.2139/ssrn.3348831.
- Zheng, Y.; Yu, H.; Cui, L.; Miao, C.; Leung, C. & Yang, Q. (2018) *SmartHS: An AI Platform for Improving Government Service Provision*. The Thirtieth AAAI Conference on Innovative Applications of Artificial Intelligence (IAAI-18). Available at: https://www.aaai.org/ocs/index.php/AAAI/AAAI18/paper/view/16041/16369 (Accessed 14 April 2021).

ANNEX I: LIST OF STAKEHOLDERS CONSULTED

The following stakeholders were consulted via semi-structured interviews for this analysis:

- **Jean-Luc Dorel** is programme officer at the European Commission's DG CONNECT "Next Generation Internet".
- **Gry Hasselbalch** is an independent expert on data and AI ethics and former member of the EU High Level Expert Group on AI and the Danish government's data ethics group.
- **Marijn Janssen** is full professor in ICT & Governance at the Technology, Policy and Management Faculty of Delft University of Technology.
- **Andrea Renda** is a senior research fellow and head of Global Governance, Regulation, Innovation and the Digital Economy at the Centre for European Policy Studies (CEPS).
- **Pierre Rossel** is President of Inspiring Futures SA. He is a former professor of technology assessment and foresight at the Swiss Federal Institute of Technology in Lausanne (EPFL).
- **Gianluca Sgueo** is Advisor to the Italian Ministry for Technological Innovation and Digital Transition and research associate at the Centre of Digitalisation, Democracy and Innovation of the Brussels School of Governance.
- **Colin van Noordt** is a PhD researcher at Tallinn University of Technology, and external expert for JRC on AI in public services for the European Commission's AI Watch.

ANNEX I: EXAMPLES OF CASES OF OSS AI IN PUBLIC SERVICES

	Name of public OSS AI	Country	Short description
Health & Environment	Center for Clinical Artificial Intelligence (CAI-X)	DK	CAI-X aims to improve quality in healthcare through intelligent use of data and technology.
	Green City Watch	NL	The technology maps green areas and their quality – not just quantity – on three parameters, social, ecology, and economy, through geospatial AI.
	PulseAir	EU	App developed in the context of the European project PULSE to foster user responsibility and awareness of air quality.
Administration & communication	Aurora	FI	Aurora would be the first AI assistant built by and for a country's public sector, complementing the slew of private AI assistants like Amazon's Alexa, Apple's Siri, and the Google Assistant.
	Texta OÜ	EE	Texta is aimed at identifying documents that have been published without authorisation (e.g., internal documents, personal data, etc.).
	Xtralingua 2.0	EL	Desktop GUI that provides users with an easy way to extract quantitative text profiles from multilingual texts. The tool is modular and open source, in order to be easily accessible and adaptable to specific scientific needs.
Analysis & review	Entrada	NL	Experimental Big Data platform specifically developed for building applications to detect botnets and other malicious systems. By increasing the security and stability of the .nl domain, Entrada makes the (Dutch) Internet a safer place.
	DORIS+	EU	Corporate tool for the DGs of the EC that aims to provide an accurate analysis and a more tailored visualisation of the results of Open Public Consultations. It can process the results of surveys coming from EUSurvey and the Better Regulation Portal.

Source: Authors' own elaboration based on Joinup (2021).

ANNEX II: LINK OF OSS TO KEY EU LEGISLATION, POLICIES AND STRATEGIES

Key EU legislation, policy or plan	Link to OSS
President von der Leyen's Political guidelines for the next Commission (2019-2024)	**Achieving digital sovereignty -** Open code makes algorithms transparent and allows for independent audits and reproducible builds. By extension, the strategy helps the EC stay in control of its processes, data, information and technology.
European Interoperability Framework (EIF) –— Implementation Strategy	**Removing barriers to the digital single market in Europe** - Its implementation will help bring about the mutual beneficial goals of the EIF: seamless public services that are digital, cross-border and open by default.
Digital strategy	**Digitally transformation and data-driven innovation -** open source strategy matches the political priorities and activities of the digital strategy. The principal working methods are open, inclusive and co-creative; the results are interoperable, user-friendly and end-to-end secure digital services.
Digital Europe programme	**Digital transformation of Europe's society and economy -** The EC's contributions to the OSS solutions that it uses internally are effectively for the public good. Use of OSS multiplies Europe's efforts on its digital capacities and strategic infrastructures, including the deployment of interoperable solutions in areas of public interest, and sharing technology and know-how for all.
European Data Strategy	**A society powered by data -** Open source code is available to all, which helps to creating interoperable, non-discriminatory and transparent procedures for access to data, AI and ML training methods and models.
Tallin Declaration on e-Government	**Strengthening requirement for OSS solutions –** OSS strategy creates the momentum to adapt the EC's internal rules on software distribution and make this process akin to the rules on the reuse of Commission document.
Berlin declaration on digital society and value-based digital government	**Public sector as driving force for new and innovative technical solutions for public services -** OSS Strategy supports by providing opportunities for participation through co-creation, experimentation and collaboration.
Coordinated Action Plan on Artificial Intelligence	**Scaling up AI investments by public and private actors** – OSS strategy to support the involvement of European talent in the development of AI solutions and counteract "brain-drain" from being a consumer of AI solutions developed elsewhere.
Proposal for a Regulation on a European approach for Artificial Intelligence "Artificial Intelligence Act"	**A horizontal legal framework on AI addressing the risks of AI** – OSS to support the position of Europe to play a leading role globally in the area of AI building a risk-based assessment, transparency and trustworthiness.

Source: Authors' own elaboration based on European Commission (2020)[156]

[156] European Commission (2021) New Digital Europe Programme €9.2 billion investment between 2021-2027. European Commission News.

Coupled with the numerous opportunities emerging from the use of artificial intelligence, open source comes with the potential for innovation capacity in both the public and private sector. Advantages include the ability to enhance transparency, facilitate the auditing of AI and thereby enhance citizen trust, while stimulating economic activities and domain-specific expertise. Disadvantages and limits include legal, technical, data, risk management, societal and ethical challenges. This analysis examines all main open source artificial intelligence pro and cons and proposes seven recommendations to boost its uptake.

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