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Algorithmic Government: Automating Public Services and Supporting Civil Servants in using Data Science Technologies

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The data science technologies of artificial intelligence (AI), Internet of Things (IoT), big data and behavioral/predictive analytics, and blockchain are poised to revolutionize government and create a new generation of *GovTech* start-ups. The impact from the 'smartification' of public services and the national infrastructure will be much more significant in comparison to any other sector given government's function and importance to every institution and individual. Potential *GovTech* systems include *Chatbots* and intelligent assistants for public engagement, *Robo-advisors* to support civil servants, real-time management of the national infrastructure using IoT and blockchain, automated compliance/regulation, public records securely stored in blockchain distributed ledgers, online judicial and dispute resolution systems, and laws/statutes encoded as blockchain smart contracts. Government is potentially the major 'client' and also 'public champion' for these new data technologies. This review paper uses our simple taxonomy of government services to provide an overview of data science automation being deployed by governments world-wide. The goal of this review paper is to encourage the Computer Science community to engage with government to develop these new systems to transform public services and support the work of civil servants.

Keywords: data science; government; artificial intelligence; blockchain; Internet of Things; big data

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1. INTRODUCTION

The data science 'tsunami' led by multinational companies like Amazon, Google, Facebook, Uber, Alibaba, Tencent, etc. is radically changing how we work and socialize, and is disrupting employment. The disruption caused by the key technologies—namely artificial intelligence, Internet of Things (IoT), big data, behavioral/predictive analytics and blockchain technologies—offers the greatest potential in the public sector to transform the way governments engage with citizens, make policy-decisions and manage the national infrastructure. Sophisticated data and analytics infrastructures, when combined with trusted record keeping concepts such as blockchain distributed ledger and smart contract technologies, may provide a feasible framework to redefine public services in a decentralized, lower cost, more efficient and personalized manner.

Many governments have established *digital government* or *eGovernment* programs to introduce data science technologies into the public sector [1, 2]. Leading examples include Estonia, Singapore and the UK [3–5]; however, most comprise individual AI or blockchain projects. Arguably the most comprehensive program is Estonia's *e-Estonia* (e-estonia.com) infrastructure where every citizen has a digital identity, digital signature and personal record, and virtually all government services are digital and online [6]. Estonia's latest initiative is *e-Residency* [7]; a transnational digital identity that anyone in the world can apply for to obtain access to a platform built on inclusion, legitimacy and transparency. E-residents then have access to the EU business environment and can use public e-services through their digital identity.

Data science technologies pioneered in the private sector are ripe for transforming the public sector [8–13]. Applications can

include public engagement through natural language text and speech *Chatbots* [13] and intelligent assistants [14]; support of civil servants via AI-based *Robo-advisors* [15]; securing public records using blockchain distributed ledgers [16]; and encoding and *codifying* laws using blockchain smart contracts [17]. Further application areas may include using big data and behavioral/predictive analytics for public policy development; automating the courts using AI-based judicial systems and online dispute resolution; and managing the national infrastructure in real-time using the Internet-of-Things technology.

As the basis for discussion of public sector automation, we use a simple taxonomy of government (see Fig. 1) as follows:

- **Public Services**—interaction with and delivery of service to citizens; answering enquiries, automating services, election processes, etc.
- **Supporting Civil Servants**—intelligent tools to support civil servants; *Robo-advisors* for civil servants, case management, impact / performance monitoring.
- **National Public Records**—maintaining public records and correspondence; forms & submissions, correspondences, personal/citizen data.
- **National Physical Infrastructure**—maintaining and operating the public infrastructure; smart environments, Infrastructure planning, transport/communication/environment/health/education/security.
- **Statutes & Compliance**—maintaining laws and statutes, and managing courts, judiciary, police, etc.; laws & statutes (codifying, verifying, simulating), trials & prosecution, dispute resolution.
- **Public Policy Development**—developing public policy, supporting civil servants and politicians; evidence base (data, experts, public opinion), *Robo-advisors* for policy makers.

Although we mainly focus on the *technological* automation of the public sector in this paper, further cross-sector disussions should also be undertaken to consider other major *societal* dimensions in relation to the way citizens engage with government. More qualitative and technological work around the issues of the fairness, transparency, privacy and accountability would be complementary to build comprehensive systems in the public policy space [18, 19].

2. DATA SCIENCE & TECHNOLOGIES

In transforming government, important new data technologies include

- **Government Data Facilities**—online facilities of public data collected by national and local governments,

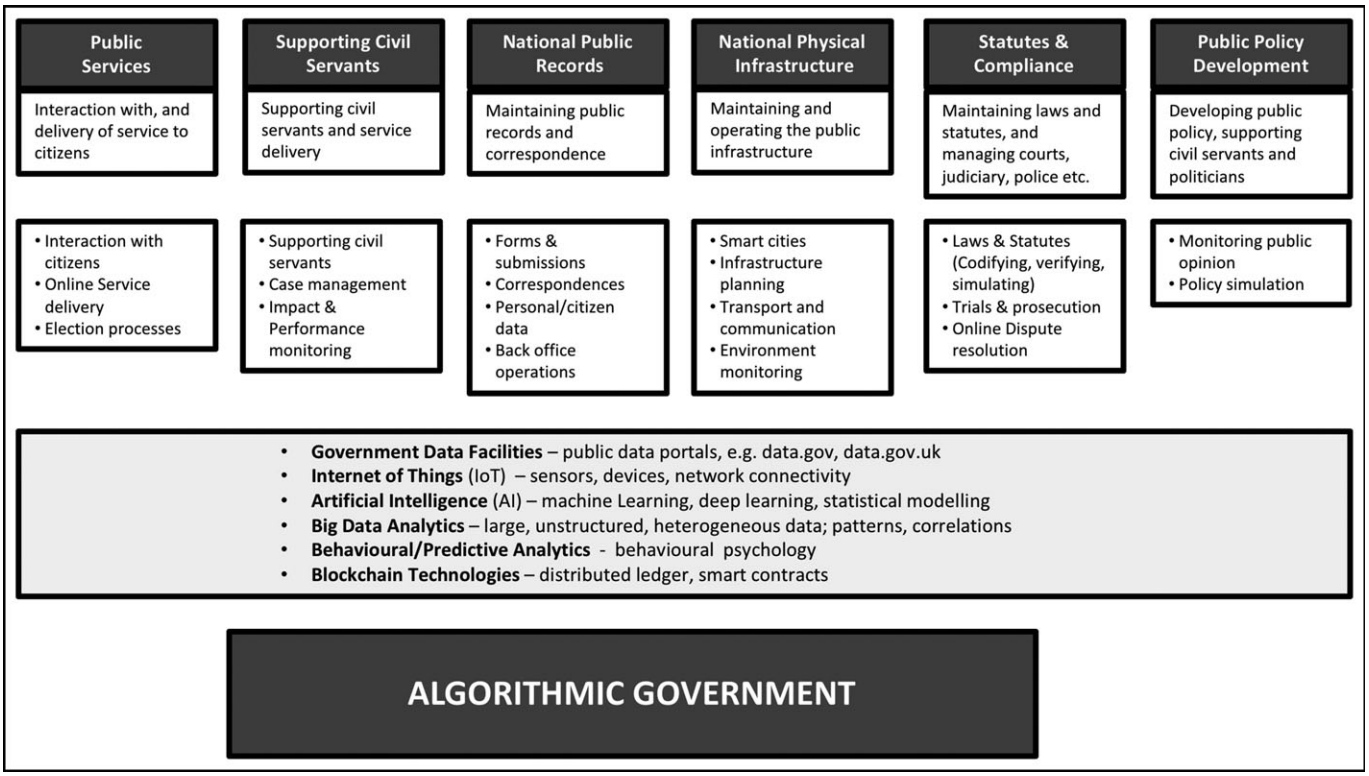

FIGURE 1. Automation of government services.

and often open for public access and analysis (e.g. www.data.gov, https://data.gov.uk).
- **Internet of Things (IoT)**—is the inter-networking of 'smart' physical devices, vehicles, buildings, etc. that enable these objects to collect and exchange data.
- **Artificial Intelligence (AI)**—systems able to perform tasks normally requiring human intelligence.
- **Big Data**—are the process of examining very large data sets to uncover hidden patterns, unknown correlations, etc.; data sets that are so complex that traditional data processing application software is inadequate to deal with them.
- **Behavioral/Predictive Analytics**—the analysis of large and varied data sets to uncover hidden patterns, unknown correlations, customer preferences, etc. to help make informed decisions.
- **Blockchain Technologies**—technology underpinning digital currency, that secures, validates and processes transactional data.

In the following sections, we explore these technologies in more detail.

2.1. Government data facilities

The open-source and open data movements [20, 21] across the globe encourage governments to make their data available through online platforms such as www.data.gov, www.data.gov.uk and www.data.europa.eu [22]. Governments providing the infrastructure to access, use and share data are a major driver of innovation in the public sector [23]. A good exemplar is the popular transport app, Citymapper (https://citymapper.com/), initially built from the open data provided by the Transport for London [24]. Open data platforms also serve as mediums to increase citizen engagement and transparency, and facilitate collaborative practices of the public sector with commercial and non-profit stakeholders.

The government data landscape is defined by a range of sources including official records and statistics; secondary data obtained through administrative operations from front-end services; user-generated data often in the form of web content such as blogs, chats, tweets and videos; sensory data gathered by connected people and devices; tracking data such as CCTV, GPS or traffic data, or satellite and aerial imagery; and transaction data from shopping or banking records etc. Other categorizations can be made based on whether it is geo-spatial, economic, demographic or other statistical data; or whether it is real-time or historical data; or by the formats of data such as text, numerical, network, image and video. If the data provided from government departments and agencies, public bodies and local authorities can further be expanded with other commercial or non-profit data sources, it provides countless opportunities for economic, political, scientific and social innovation [25].

2.2. Internet of Things (IoT)

IoT provides a unique opportunity for government to interconnect and dynamically manage the public infrastructure. Essentially, any device with an on/off switch will have an identifier, communicate and be managed by 'intelligent' software. This involves not only real-time monitoring and control but also maintaining the infrastructure without human intervention.

Two important developments related to IoT and managing the public infrastructure are the following:

- **Building Information Modeling (BIM)**—BIM [26] is a shared knowledge resource or model for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. Besides supporting Computer Aided Design (CAD) during construction or refurbishment, the digital model will also be used to manage the facility or infrastructure in real-time using the IoT resources.
- **Blockchain Smart Contracts**—is a computer program that directly controls a transaction or an IoT device. Elements of blockchain technology originally conceived for Bitcoin and other cryptocurrencies are now recognized to have far-reaching potential in other areas, including IoT [27].

2.3. Artificial intelligence technologies

AI technologies power intelligent personal assistants, such as Apple Siri, Amazon Alexa [28], 'Robo' advisors [15, 29] and autonomous vehicles. AI provides computers with the ability to make decisions and learn without explicit programming. There are two main branches:

- **Knowledge-based systems (KBS)**—are computer programs that reason, and knowledge is explicitly represented as ontologies or rules rather than implicitly via code. KBS can be subdivided into
  - o *Rule-based systems*—is one whose knowledge base contains the domain knowledge coded in the form of event-condition-action, such as using IF-THEN or IF-THEN-ELSE rules.
  - o *Case-based reasoning*—a form of the so-called expert systems that base decision-making on prior case experience, instead of on a pre-defined rule set.

- **Machine Learning**—is a type of AI program with the ability to learn without explicit programming, and can change when exposed to new data. Subdivisions include

  - o *Supervised learning*—is the task of inferring a function from labeled training data, where training data consist of a set of training examples.
  - o *Unsupervised learning*—is the task of inferring a function to describe hidden structure from unlabeled data.

Other AI technologies important for government-citizen interaction are natural language processing (NLP) and sentiment analysis:

- **Natural language understanding**—the application of computational techniques to the analysis and synthesis of natural language and speech [30].
- **Sentiment analysis**—the process of computationally identifying and categorizing opinions expressed in a piece of text [31].

These technologies are important for applications such as monitoring public opinion, policy and fraud detection. Recent implementations with social implications are covered in [32, 33].

2.4. Big data

Government, as discussed, collects huge volumes of data (increasingly published as open data) and thus has major opportunities for the so-called big data (analytics). In general, big data provide the opportunity of examining large and varied data sets to uncover hidden patterns, unknown correlations, customer preferences, etc. Big data encompass a mix of structured, semi-structured and unstructured data gathered formally through interactions with citizens, social media content, text from citizens' emails and survey responses, phone call data and records, data captured by sensors connected to the Internet-of-things and so on. The notion of 'big data' is both increasing in *volume*, *variety* of data being generated by organizations and the *velocity* at which that data are being created and updated; referred to as the 3Vs of big data [34]. More recent literature provide alternative descriptions adding other features such as *veracity*, *value*, *complexity* and *unstructuredness* and a comprehensive review is provided in [35].

Big data encompasses a number of associated technologies:

- **Big data lakes**—a 'data lake' is a storage repository that holds a vast amount of raw data in its native format until it is needed [36].
- **Cloud computing**—the practice of using a network of remote servers hosted on the Internet to store, manage and process data, rather than a local server or a personal computer [37].
- **Unstructured data & NoSQL databases**—refers to information that either does not have a pre-defined data model or is not organized in a pre-defined manner; an NoSQL database is a mechanism for storage and retrieval of data which is modeled in means other than the tabular relations used in relational databases [38].
- **Hadoop**—an open source, Java-based programming framework that supports the processing and storage of extremely large data sets in a distributed computing environment [39].
- **In-memory analytics**—the queries and data reside in the server's random access memory (RAM), so increasing the speed, performance and reliability [40].

2.5. Behavioral and predictive analytics

Closely related to big data is behavioral and predictive analytics that focuses on providing insight into the actions of people [41]. Behavioral analytics centers on understanding how consumers act and why, enabling predictions about how they are likely to act in the future. It enables providers in the private or public sector to make the right responses to the right consumer segments at the right time. Mainstream private sector uses are in eCommerce platforms, online games, web and mobile applications, and the IoT.

Predictive analytics is the practice of extracting information from historical and real-time data sets to determine patterns and predict future outcomes and trends. Predictive analytics 'forecasts' what might happen in the future with an acceptable level of reliability, and includes what-if scenarios and risk assessment. The defining function is the predictive score (probability) for an agent (individual, vehicle, machine, orgnizational unit, etc.) to aid with decision making in complex organizational processes. A representative example would be 'credit scoring' in financial services which uses customer's credit history and current data to rank their likelihood of future credit payments on time. These technologies also show significant potential to aid decisions in government operations including law enforcement.

2.6. Blockchain technologies

Elements of blockchain technology, as discussed, originally conceived for Bitcoin are now recognized to have far-reaching potential in other areas, especially for government. The core technologies are

- **Distributed Ledger Technology (DLT)**—a decentralized database where transactions are kept in a shared, replicated, synchronized, distributed bookkeeping record, which is secured by cryptographic sealing. The key distinction between 'distributed ledgers' and 'distributed databases' is that nodes of the distributed ledger cannot/do not trust other nodes—and so must independently verify transactions before applying them.
- **Smart Contracts**—are simply the rules, possibly computer programs, that attempt to codify transactions and contracts with the intent that the records managed by the distributed ledger are authoritative with respect to the existence, status and evolution of the underlying legal agreements they represent. Smart contract technology can automate transactions, such as supply chains, and have the potential to automate laws and statutes.

Governments are increasingly launching projects that apply blockchain technologies to transform regularatory compliance, contract management, identity management and government records [42, 43]. Other potential uses in facilitating elections and direct democracy models are also covered in recent literature [44, 45].

We now look at the major areas for *Algorithmic Government* outlined in Fig. 1.

3. PUBLIC SERVICES

Here we define 'public services' as interaction with and delivery of services to the general public. Broadly technologies supporting: (a) comprehensive digital government services; but also (b) using intelligent virtual assistants to answer questions; (c) automated form filling and registration; (d) automated payments from and to citizens; (e) gathering public opinion to drive policy; (f) citizen-to-citizen community engagement; (g) detecting abuse of public services and fraud; etc.

3.1. Overview

A question that might be asked: 'if Amazon or Google were automating public services, how would the services operate?' Probably the first thing would be to create a *digital identity, digital signature* and *personal citizen record* for every citizen, and a *government portal* for access. With these requirements in place, when a citizen interacts with any service the civil servant would be able to handle multiple enquiries and service functions. As discussed, a pioneering role model is Estonia's digital government *e-Estonia*.

3.2. GovTech exemplars

Most developed countries are investing in digital government services, they include Singapore's SingPass single sign-on system (https://www.singpass.gov.sg/) providing access to an holist range of government services, such as a citizen's electronic health record; the UK's 'digital by default' strategy [46]; Germany's Bundesagentur für Arbeit (https://www.arbeitsagentur.de/), virtual labor market platform to reintegrate jobseekers into the labor market; Korea's KONEPS online e-procurement system (http://www.pps.go.kr/) consolidating 120 government procurement systems; India's Aadhaar (https://uidai.gov.in/) unique identity card; Norway's Offentlig Elektroiisk Postjournal (https://www.oep.no/) electronic public record system, a portal for all citizen documents; Saudi Arabia SADAD (https://www.sadad.com/) digital payment system; and Dubai's Smart Dubai (http://www.smartdubai.ae/) initiative. The US Department of Homeland Security uses a virtual assistant, Emma (https://www.uscis.gov/emma), to respond to citizen enquiries.

In response to this global push for digital government services, a growing number of *GovTech* start-ups are emerging. Support for these start-ups includes specialist *GovTech* funders (http://govtechfund.com/), *GovTech* associations (http://govtechalliance.org/) and meet-ups, such as Angelhack's *GovTech* hackathons called Code 4 Coexistence.

3.3. Case study

As discussed, Estonia's *e-Estonia* [10] is an ideal case study of a comprehensive move to *digital government* or *eGovernment*. When Estonia regained its independence in 1991, less than half its population had a telephone line. Two decades later, it is a world leader in technology. Estonian geeks developed the code behind Skype and Kazaa (an early file-sharing network). In 2007, it became the first country to allow online voting in a general election. It has among the world's fastest broadband speeds and holds the record for start-ups per person. Its 1.3 m citizens interact with government services (universally) online; pay for parking spaces with their mobile phones and have their health records stored in the digital cloud. Filing an annual tax return online, as 95% of Estonians do, takes about 3 min. The key infrastructure components are a citizen's *e-Identity* and the *e-Services portal*.

4. SUPPORTING CIVIL SERVANTS

'Public Services' discussed above centered on engagement with citizens through a *digital identity*, *personal record* and a *government portal*. Now we look at support for civil servants, in particular professional *Robo-advisors*.

4.1. Overview

With regard to supporting civil servants, two key technologies are domain-specific *Robo-advisors* to support professional

work and *IoT* for real-time management of the national infrastructure. Currently, Robo-advisors almost exclusively focused on financial investment and asset management advice. 'Financial' Robo-advisors illustrate possible support for civil servants:

- **Account aggregation**—these provide a unified view from the Robo-advisor of client's (banking, trust and brokerage) accounts through a single sign-on via Web and mobile. In the Public Sector, a citizen might receive unified advice on benefits (e.g. tax credits, disability allowances, retirement, energy efficiency), services (e.g. health checks, housing), registrations (e.g. voting, parking permits), etc.
- **Auto investing**—again with finance, clients want the option to automatically transfer a set amount or percentage from their savings or bank account into their investing account and have it automatically invested. In the Public Sector, a citizen might have the option to automatically transfer a set amount to their pension, or to a charity, etc. or receive pension planning and saving advice.
- **Consult an advisor**—another feature for financial clients is the ability to consult (cf. triage) a human advisor about their investment approach and other financial matters. In the Public Sector, a citizen might consult a Robo-advisor which passes the query to a human advisor when specialist help is required.

The lesson from finance is that digital advice services are not a 'one-size fits all' model; there are benefits to develop hybrid models that combine the best of AI 'high-tech' and human 'high-touch'.

4.2. GovTech exemplars

Clearly the line between systems providing Public Services and Support for Civil Servants is blurred. An example is SGT STAR (https://www.goarmy.com/ask-sgt-star.html) used by the US Army to improve the efficiency of their recruitment process [47]. Other potential systems to support Civil Servants might include detection of abuse and fraud. Govtech Solutions (www.govtechsolutions.co.uk) is an exemplar company which offers two products: *webCapture* that transforms content from online self-service web forms using a fully automated process, which validates the data and updates your back office; and *eCapture* that converts content from paper form images, PDFs and structured emails into a format for a back office system, and also automatically checks claims.

4.3. Case study

An unusual example is 'Legal robots' being deployed on thousands of cases in China to help decide sentencing. The robots—which are about three feet tall and have heads shaped like toasters—review documents and identify problems with cases. They also advise on sentencing, and can generate arrest warrants and 'approve indictments', said prosecutors in the eastern province of Jiangsu, where the robots are being piloted. A 'case management' legal robot named Wu Xiaolu, who worked with prosecutors in Suzhou Credit: Jiangsu Province People's Procuratorate. Almost 15 000 legal cases have been reviewed by the robots since they were deployed last September.

5. PUBLIC RECORDS

Although blockchain is currently being driven by financial service, in the long term, the impact will be even greater in government for securing public records and managing the national infrastructure. As the blockchain-based public services are scaled and updated continuously, data emerging from such services will also be aggregated as an additional source of 'open data' that governments are increasingly offering to their citizens.

5.1. Overview

Blockchain offers a new approach to enhancing transparency and collaboration between governments, business and citizens [48]. The key blockchain attributes for securing records are (a) *Resilience*—blockchains operate as decentralized networks as opposed to a central server with a single point of failure; (b) *Integrity*—blockchains operate using distributed open-source protocols removing the need to trust a third party for execution; (c) *Transparency*—public blockchains have inherent transparency features, since all changes are visible by all parties; and (d) *Unchangeable*—records in a distributed public blockchain are largely 'immutable', allowing applications and users to operate with a good degree of confidence.

Here two important issues are

- **Permissioned blockchain**—a private or permissioned blockchain only allows known nodes to participate in the network. Typically, it is internal to an organization, such as a bank, or consortium of organizations.
- **Permissionless blockchain**—an open, unpermissioned, or public, blockchain network and allows any node to participate in the network.

5.2. GovTech exemplars

There are a growing number of exemplars that integrate public records and provide citizens with a consolidated personal record, utilizing digital blockchain technologies. Examples include [49] the UK for payment of Welfare benefits [50];

Georgia's use for land titles; Singapore where each citizen has a personal healthcare record; and Delaware storing business documents in a single location. For example, the government of Georgia uses blockchain to register land titles and validate property-related government transactions. A custom-designed blockchain system has been integrated into the digital records system of the National Agency of Public Registry (NAPR), and anchored to the Bitcoin blockchain through a distributed digital timestamping service. The digital timestamping service allows the government to verify and sign a document containing a citizen's essential information and proof of ownership of property. The system will boost land title transparency, reduce the prevalence of fraud, and bring significant time and cost savings in the registration process.

5.3. Case study

The Dubai government has launched Smart Dubai (www.smartdubai.ae/) with the goal to conduct a majority of the emirate's business using blockchain, which it expects will make government services more efficient and help promote enterprise in Dubai as it will become easier to do business there. Dubai has set up the Global Blockchain Council to explore current and future blockchain applications. The council currently consists of 47 members from both the public and the private sector and launched seven blockchain proofs-of-concept trails, covering health records, diamond trade, title transfer, business registration, digital wills, tourism engagement and shipping.

The Dubai government has partnered with IBM to trial the use of blockchain for a trade and logistics solution. The solution transmits shipment data, allowing key stakeholders to receive real-time information about the state of goods and the status of the shipment, and replaces paper-based contracts with smart contracts.

6. NATIONAL PHYSICAL INFRASTRUCTURE

Potentially the biggest impact for managing the national infrastructure is the unification of Smart Cities, Building Information Modeling (BIM), IoT and Blockchain. A Smart city is an urban development vision to integrate information and communication technology (ICT) and IoT technology in a secure fashion to manage a city's assets. These assets include local departments' information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement and other community services [51]. At the next level that of individual facilities, BIM will provide a digital model of the facilities and infrastructure available for modeling and management; and IoT will provide intelligent communication with every device; literally with an on/off switch. Finally, blockchain distributed ledger technology will secure the information; and blockchain smart contract programs will operate the system.

6.1. Overview

National and local physical infrastructure is being driven by smart cities at the urban level and BIM at the facilities level with IoT and blockchain providing the IT infrastructure.

A smart city [52] uses urban informatics and technology to improve the efficiency of services. ICT allows city officials to interact directly with the community and the city infrastructure and to monitor what is happening in the city, how the city is evolving, and how to enable a better quality of life. Through the use of sensors integrated with real-time monitoring systems, data are collected from citizens and devices—then processed and analyzed. The information and knowledge gathered are keys to tackling inefficiency. The World Smart Cities Community (www.worldsmartcity.org) is a community of city professionals exploring the most important factors that hinder the broad roll out-of Smart Cities today.

6.2. GovTech exemplars

Examples of Smart City technologies and programs have been implemented in Milton Keynes, Southampton, Amsterdam, Barcelona, Madrid, Stockholm and in China [53]. In NY, data analysis predicts which buildings are most likely to have a fire, enabling fire safety inspections to be prioritized. In Seoul, mobile phone and geospatial data are used to provide a night bus service to a city of 10 m people with just 30 vehicles. The marketplace of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) (https://eu-smartcities.eu/) is a platform to drive transition of the European public infrastructures towards a low carbon, resource efficient and competitive economy. The 11 Priority Areas which have been set up so far to develop smarter cities are Sustainable Urban Mobility, Sustainable Districts and Built Environment, Integrated Infrastructures and processes across Energy, ICT and Transport, Citizen focus, Policy and Regulation, Integrated Planning & management, Knowledge Sharing, Baselines, Performance Indicators and Metrics, Open data governance, Standards, Business Models, Procurement and Funding.

6.3. Case study

Barcelona was named European Capital of Innovation in 2014 by the EU and hosts the annual Smart City Expo World Congress [54]. It has more than 100 active smart city projects ranging from smart traffic lights, telecare services and electric cars to ubiquitous public Wi-Fi. Barcelona's smart city

platform, known as the Urban Platform, brings together data from the open-source Sentilo sensor network, the city's information systems, as well as social networks and web 2.0, allowing it to solve urban challenges across silos. These include the sustainable and computerized management of infrastructure, garbage collection and recycling, and public spaces and green areas, among others. Smart LED streetlamps activate only when movement is detected, producing 30% energy savings, and are equipped with sensors to collect data from the environment. Over 70 000 elderly and disabled are connected to the city's Telecare service that proactively checks on residents. Sensors monitor rain and humidity to determine how much water is needed to irrigate parks. Municipal smart bins monitor waste levels and are cleared only when they are full, optimizing waste collection operations. Digital bus stops provide bus arrival times, free Wi-Fi and USB charging ports, while a smart parking system guides vehicles to available parking spaces, reducing congestion and emissions.

7. GOVERNMENT LAWS, STATUTES AND COMPLIANCE

Government judiciary, legal services, regulators and law firms are entering a period of major disruption caused by new legal technologies (LawTech). In the Public Sector, an example is 'digital' courts, such as using automated online dispute resolution (ODR—https://ec.europa.eu/consumers/odr/), and Regulators automating online compliance and regulation. The goal is to use LawTech (https://law-tech-a2j.org/) to fully automate and interlink the judiciary, court and legal practices.

7.1. Overview

Online dispute resolution has traditionally been used for consumer ODR to facilitate the resolution of disputes between e-commerce parties, typically online suppliers and consumers. The best-known private consumer ODR service is eBay, which resolves 60 million disagreements every year. eBay offers two services: a free web-based forum which allows users to attempt to resolve their differences on their own or if necessary, the use of a professional (human) mediator. In the public sector, the EU consumer ODR Platform is a web-based platform developed by the European Commission to help consumers and traders resolve their contractual disputes about online purchases of goods and services out-of-court at a low cost in a simple and fast way.

In the private sector, online 'judicial' services and commercial example services include (a) **VirtualCourtHouse**—disputing parties can choose from a directory listing over 300 neutrals, ranging from family mediators to construction arbitrators, and retired judges, who mediate the dispute or render an arbitral award (www.virtualcourthouse.com); and (b) **SmartSettle**—applies techniques from game theory to resolve disputes. It uses six processes, supported by a facilitator: (a) the process is explained and parties agree to the guidelines, (b) parties identify interests in dispute, (c) the demand and value are rated by both parties, (d) software proposes settlement, (e) software optimizes settlement based on negotiation and (f) the parties sign the framework agreement (www.smartsettle.com).

7.2. GovTech exemplars

In the public sector, examples include (a) **Money Claim Online** (MCOL)—is the UK HM Courts & Tribunals Service Internet-based service for claimants and defendants; and (b) **Rechtwijzer 2.0**—Rechtwijzer (Netherlands)/MyLawBC (British Columbia) is an ODR system for divorce and separation, landlord-tenant disputes and employment disputes etc.

7.3. Case study

A prominent exemplar in the public sector is the European Union (EU) Consumer ODR Platform the interactive website offering a single point of entry to consumers and traders seeking to resolve disputes out-of-court that have arisen from online transactions, allowing consumers and traders to submit complaints by filling in an electronic complaint form and to attaching relevant documents, transmit complaints to an ADR entity competent to deal with the dispute concerned, and offer an electronic case management tool.

8. PUBLIC POLICY DEVELOPMENT

New technologies provide powerful tools for future policy development and modeling. Public policy spans areas such as (a) online monitoring of public opinion; (b) community partition in policy development; and (c) modeling proposed policies and statutes.

8.1. Overview

We are entering a new era of technology-enabled policy development:

- **Monitoring public opinion**—online and social media are increasingly being 'scraped' and sentiment analysis used in the public sector to monitor public opinion and also the impact of laws and regulation.
- **Community participation**—another major paradigm is the engagement with the general public through online voting, referenda, petitions, blogs and forums in policy development.

- **Policy modeling**—complex systems technologies, such as Agent-based systems, can be used to model policy before deployment.

8.2. GovTech exemplars

Current efforts to enable citizens' engagement have led to a plethora of tools and platforms, with a growing number of pervasive technologies [55]. Several tools and platforms have been developed to communicate with, integrate and empower citizens. The aim of these platforms is to encourage and facilitate partnerships between citizens and civic authorities, enabling individuals to play a greater role. For instance Civic Lab (www.civiclab.us) performed over 2 years as a co-working space in Chicago. This space served as a meeting place, hub and educational facility. Other platforms such as Neighborland (https://neighborland.com), Citizinvestor (www.citizinvestor.com) and CitySourced (www.citysourced.com) were designed to report and share citizens' ideas and issues and to keep citizens in the loop of what was being done about the issues reported. Some projects focused on transparency as a key to engage citizens, for instance, the Sunlight foundation (www.sunlightlabs.com) makes use of the tools of civic tech, open data, policy analysis and journalism to make their government and politics transparent to all. Some other projects focused on involving citizen in voting, such as Citizinvestor (https://angel.co/citizinvestor), Civinomics (https://civinomics.com/) or PeakDemocracy (www.peakdemocracy.co), where citizens and officials are involved in the discussions. In their work, EngagementHQ (http://engagementhq.com/) drew a spectrum to represent the means through which citizens can be informed and civic engagement can be triggered. EngagementHQ is a digital engagement solution to help share stories, gather community feedback and analyze stakeholder needs. Another interesting example is the Northern Bridge public policy engagement toolkit (http://toolkit.northernbridge.ac.uk/), which introduces arts and humanities researchers to the public policy development processes.

8.3. Case study

Indonesia provides a policy development case study. Each year, forest and peatland fires spread across Kalimantan and Sumatra, mostly due to peatland drainage and the conversion of land to palm oil cultivation. Besides the damage caused to biodiversity and the ecosystems, according to UN Global Pulse, over 10 million people in Southeast Asia are affected by haze. Indonesian forest and peat fires in 1997—1998 were estimated to have caused over US$4.5 billion in damage, mostly health-related, across the region [56]. UN Pulse Lab Jakarta has developed 'Haze Gazer' [57] a web-based crisis analysis and visualization system which harnesses multiple sources of data including open data (fire hotspot information from satellites and baseline information on population density and distribution), citizen-generated data (the national complaint system in Indonesia called LAPOR; citizen journalism video uploads to an online news channel) and real-time big data (text-, image- and video-oriented social media), to provide insights on haze disaster dynamics for disaster management authorities. The platform offers real-time insights on the response strategies of haze-affected populations, informs longer term development interventions by capturing insights on health-related concerns and issues and enhances the existing functionalities of the current system used by the Indonesian disaster management authorities by adding new functions and insights based on multiple new digital data sources.

9. CHALLENGES AND PUBLIC DEBATE

In parallel to the public sector opportunities reviewed in this paper, these digital transformations also come with a number of political challenges and public unease.

The *ownership* and *stewardship of data* is increasingly becoming a public concern [58], especially given the recent major data breaches including the alleged case of Cambridge Analytica harvesting 87 Million Facebook profiles to manipulate voter behavior in the US [59] and previously the hack that exposed data of 57 million Uber users and drivers [60]. Given the even further sensitivity involved in the public sector, the technology solutions for trusted data sharing and linkage is, therefore, a core issue.

Blockchain as a *foundational technology* [61] emerges as the natural solution to the secure data sharing. The technology offers many potential applications in managing all types of contracts, transactions and the records efficiently and in a verifiable and permanent way. However, the technology is still at its infancy, especially with regards to security and privacy. The lack of standards, scalability, storage, access, change management and security against cyber criminals can be mentioned as some of the key areas of concern [62]. Permissioned systems may, therefore, be preferred over public ledgers as in many cases a smaller number of records might suffice. Bacon et al. [63] provides an overview of the different ways blockchain technology can be implemented depending on the application and the legal considerations around different permutations of the features involved. There are also unintended consequences in particular regarding the environmental and sustainability impacts of the technology [64], such as the fact that one Bitcoin transaction alone uses as much electricity as the average American household in a week's time and the excessive carbon emissions especially when the coal-based power is used to generate the computer calculations [65].

For the public sector, the promise of the IoT is the automated high-quality data collection and distributed processing through the connected sensors and remotely controlled objects. However, this also raises a number of security and

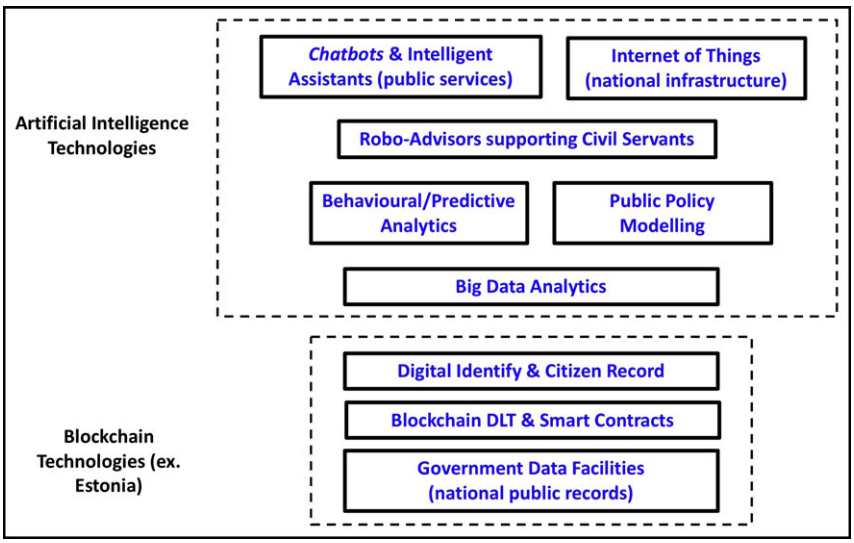

FIGURE 2. Algorithmic government technology stack.

privacy concerns both in virtual and physical terms. Within the Smart Cities framework for example, the trade-off might be between the advantages of monitoring a city's infrastructure for energy efficiency, real-time management of traffic flows or the increased neighborhood safety, and the potential attacks against critical infrastructure, such as the power-supply networks, is a crucial question.

In the case of artificial intelligence technologies, a main argument against their use in the public sector is their dependence on the data that is often biased, incomplete and/or imperfect; and their lack of transparency of the processes that produce the outcome. A useful overview of the AI and policy landscape is provided in [66]. Also, in her award-winning book 'Weapons of Math Destruction' [67], Cathy O'Neil asserts how the data-driven decisions through AI systems may be harmful throughout the important life events of individuals from job applications, to loan and insurance decisions, and to sentencing criminals.

Beyond the issues mentioned, the use of new technologies in the public sector introduces a number of philosophical discussions, such as the changing public perception of privacy, security and surveillance; or the ownership and exploitation of personal data, therefore, providing a rich domain for further interdisciplinary discussion. In promoting debate, the Open Government Partnership (www.opengovpartnership.org) is a multilateral initiative that aims to secure concrete commitments from governments to promote transparency, empower citizens, fight corruption, and harness new technologies to strengthen governance. The Open Government Partnership formally launched on 20 September 2011, with the eight founding governments (Brazil, Indonesia, Mexico, Norway, the Philippines, South Africa, the United Kingdom and the United States). OGP action plans can be evaluated on the following criteria: (a) Process: How open, participatory, and meaningful is government-civil society dialog in developing action plans?; (b) Commitments: How clear, relevant, and ambitious were action plans? Were ambitious commitments implemented? If not, why?; (c) Impacts: Can we see linkages between OGP action plans and major changes in governance?. UK is also a member of the Digital 7 or D7 (previously called Digital 5, or D5) initiative along with Estonia, Israel, New Zealand, South Korea [68], and the most recent additions of Canada and Uruguay [69].

10. CONCLUSIONS

What we refer to as *Algorithmic Government*—the Data Science revolution in the Public Sector—will have a bigger impact on society that than on finance, due to the pervasive nature of the Public Sector. We have attempted in this paper to provide a review and a full technology framework on how the emerging technologies could be utilized in the public sector based on a number of studies and projects across the globe.

Estonia's e-Estonia provides a pioneering role model. However, as discussed, this is arguably just for the blockchain technologies. As illustrated in Fig. 2, a more comprehensive technology stack should include an upper artificial intelligence layer complete with technologies like Chatbots to engage citizen enquiries, Robo-advisors to support civil servants, IoT to collect high-quality real-time data and manage the public infrastructure, behavioral/predictive analytics to gain enhanced insights into public sector challenges, policy modeling and big data to transform the decision-making processes under the ongoing digital revolution. We also realize

that automation in the public sector should be balanced with human expert intervention where and as necessary.

Although the scope of this paper has mainly been on the *technology*, we also recognize the major *societal* challenges in this domain. Within the UK context in particular, identifying a comprehensive public sector infrastructure and retrofitting the new digital technologies into that infrastructure are both major challenges, given the long established culture and the sizable population in comparison to young nations like Estonia.[1] Also the fact that interests and working practices of computing and policy domains typically tend to be very different, there is also the need to educate a new generation of civil servants and to re-train existing workforce in embracing new technologies to ensure efficiency and continuity in the public sector. Furthermore, the issues around the use of private citizen data, fairness of algorithmic decision-making practices, transparency of public operations, the accountability for any damages caused by computer-assisted processes and the natural threat of potential job-losses are all extremely valid and timely considerations.

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