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Digital Government Benchmark

API study

Final Report

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European Location Interoperability Solutions for e-Government

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Executive Summary

This study provides an analysis of Web APIs as enablers for the digital transformation of government. While digital transformation of government is much wider than the technologies which can potentially support it, an analysis of the role of Web APIs in the public sector is highly relevant to illustrate how technology can enable the transformation of government.

The aim of this work has been to identify the ability of Web APIs to assist Member States with enabling their digital transformation. Areas of specific focus include cross-border interoperability between Member States and the opportunity for the EU to become involved in developing or advocating API standards.

The API landscape in the Public Sector

This work set out to explore the API landscape in the EU public sector. API is the acronym for Application Programming Interface and it refers to a set of clearly defined methods of communication between a service and any other software or components[1], essentially, a software intermediary that allows two applications to interact with each other. The purpose of the study has been to identify the ability of Web APIs (hereafter "APIs") to assist Member States with enabling their digital transformation. Areas of specific focus include aspects such as cross-border interoperability between Member States, and the opportunity for the EU to become involved in developing or advocating API standards. To deliver the insight required, both desk-based research and structured interviews with public sector organisations that have developed successful APIs were carried out.

The report provides a useful baseline overview of APIs, considering what they are used for, the different types of API that can be leveraged, and the API standards that exist. A glossary of terms and API types in the appendices provide further resources from this work. The work considers how APIs are used in the public sector, where the findings showed that their role includes helping organisations to achieve their goals in four main ways:

1. Enabling ecosystems
2. Overcoming complex integration of large systems
3. Supporting Open Government initiatives
4. Enabling innovation

The use of APIs is not without its challenges, however. This study highlighted IT security and enhanced EU regulation around privacy as important issues for API owners to take into account. An API is another gateway into a computer network and requires the security features and ongoing maintenance that such an interface deserves.

Differences with the private sector were also considered. The report found that to date, government has (in the main) harnessed the power of APIs to make data more open and available to their citizens, and

[1] https://www.definition.net/define

between government organisations themselves. The benefits range from increasing transparency, to enhanced efficiency of the existing service models. The private sector has harnessed APIs for a more transformative and disruptive end, giving rise to completely different business models, such as those which have made Netflix and Amazon leaders in their field. For public sector organisations, APIs can similarly be leveraged to self-disrupt itself in the face of increasing citizen demand and cost pressures.

Our research also considered the future of government, which will be to some extent built on APIs as key enablers. As the demands of government move forward, it appears that APIs are well-positioned to keep apace. They provide the access points needed to enable fast and secure data-sharing to support government's needs for integrating technologies across sectors, from law and order, to healthcare and the environment.

Finally, in line with its purpose, the study suggested areas regarding the economic stimulation provided by APIs, and the way in which APIs will play a role in the future of government, including enabling wider ecosystems incorporating the private sector and the exploitation of disruptive tools, such as 'Artificial Intelligence' and Robotics.

1. Introduction

At a policy level, the Tallinn Declaration, signed on 6th October 2017[2], confirms the commitment to the vision laid out in the EU eGovernment Action Plan 2016-2020[3] and in the European Interoperability Framework (EIF)[4]. In the next five years (2018-2022), steps will be taken towards the declared principles in EU public administrations, namely: “digital-by-default, inclusiveness and accessibility”, “once-only”, “trustworthiness and security”, “openness and transparency”, and “interoperability by default”, as well as national interoperability frameworks based on the European Interoperability Framework (EIF).

In the Declaration the “user-centricity principles for design and delivery of digital public services” is key. When interacting with public administrations and using digital public services, citizens and businesses should have: digital interaction, accessibility, security, availability and usability, reduction of the administrative burden, digital delivery of public services, citizen engagement, incentives for digital service use, protection of personal data and privacy, redress and complaint mechanisms. Whilst not specifically covered within the scope of this study, AI has the potential to improve public services and contribute to the objectives set out in the Tallinn Declaration. For example, the Commission will look into AI's potential to analyse large amounts of data and help check how single market rules are applied[5].

Moreover, the digital transformation of society, business and government is raising issues for a range of policy matters across the European Union. As e-government has been in place for the last 20 years, it is timely to explore the interplay between technology and government activities from the perspective of digital government. To understand the intertwined forces that play a role in this transformation process, and their dynamics, contributions from disparate fields and discourses on this topic should be contrasted and compared.

At the same time, the Communication on “Building the data economy” (COM (2017) 9) looks at proven or potential blockages to the free movement of data and presents options to remove unjustified and or disproportionate data location restrictions in the EU. It also considers the barriers around access to, and transfer of, non-personal machine-generated data and data liability, as well as issues related to the portability of non-personal data, interoperability and standards. In particular, it calls for the fostering of technical solution development for the reliable identification and exchange of data.

A further avenue for research, complementary to this context of the digital transformation of government, is the use of Web Application Programming Interfaces (hereafter called “APIs”)). APIs can be seen as “safe entry ports for new and innovative uses of data” held by companies and, potentially, public administrations.

An opportunity exists to understand the current context and uptake of this technology early in the innovation cycle of e-government in Europe, including for, but not limited to, geospatial data.

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[2] http://ec.europa.eu/newsroom/document.cfm?doc_id=47559
[3] https://ec.europa.eu/digital-single-market/en/news/communication-eu-egovernment-action-plan-2016-2020-accelerating-digital-transformation
[4] https://ec.europa.eu/isa2/eif_en
[5] https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe

In this context, Gartner was mandated by the Joint Research Centre (JRC) to conduct a study to provide an analysis of the Web APIs as enablers for the digital transformation of governments. While digital transformation of government is much wider than the technologies which can potentially support it, an analysis of the role of APIs in the public sector is highly relevant to illustrate how technology can enable transformation of government.

This study explores APIs, and their role in the EU public sector. It is divided up into the following sections:

- **Introduction.**
- **Methodology**: A description of the way in which this study has been conducted using different research designs, including desk based research, consultation of API experts and multiple-case study investigation. Also, using diverse research methods, including API reference and specific document review, and interviews.
- **Use of APIs in the Public Sector**: Explores typical uses of APIs, such as to enable ecosystems, before looking at some specific examples of API use.
- **Relationship with location data**: Explores how adding an additional layer of location data, with other data (via APIs) can provide powerful use cases in many settings such as Smart Cities and Gazetteers.
- **Differences with the Private Sector**: Explores any differences which may exist between the public sector and private sector use of APIs.
- **Future trends for API use**: A view on how APIs may evolve, and their future uses in a world where AI and Robotics are becoming prevalent.
- **Case Study Insights** – Presentation of the findings from case study interviews and associated desk based research, plus analysis.
- **Conclusions & Recommendations**.
- **Conclusion**.

Glossary

Table 1 Glossary

Term	Definition
API	Application Programming Interface - It is a set of clearly defined methods of communication between the service and any other software or components.
API Ecosystem	The developers, and the users of the application constructs they build through an API, either within a company or on the Internet with business partners, customers, citizens etc.
API Economy	A set of business models and channels — based on secure access of functionality and exchange of data to an ecosystem of developers and the users of the app constructs they build — through an API, either within a company or on the Internet with business partners, customers, citizens etc.
API Versioning	The ability to change without rendering older versions of the same API inoperable.
API Standardisation	A uniform way for APIs to be expressed and consumed, from COM and CORBA object brokers to web services to today's RESTful patterns.
API information control	A built-in means for enriching and handling the information embodied by the API. This information includes metadata, approaches to handling batches of records, and hooks for middleware platforms, message brokers, and service buses. It also defines how APIs communicate, route, and manipulate the information being exchanged
API portal	A means for developers to discover, collaborate, consume, and publish APIs. To support the overall goal of self-service, these portals describe APIs in a way that represents their functionality, context (the business semantics of what they do, and how they do it), non-functional requirements (scalability, security, response times, volume limits, and resiliency dimensions of the service), versioning, and metrics tracking usage, feedback, and performance. For organizations without mature master data or architectural standards, the API portal can still offer visibility into existing APIs and provide contact information for individuals who can describe features, functions, and technical details of services.
API gateway	A mechanism that allows consumers to become authenticated and to "contract" with API specifications and policies that are built into the API itself. Gateways make it possible to decouple the "API proxy"—the node by which consumers logically interact with the service—from the underlying application for which the actual service is being

	implemented. The gateway layer may offer the means to load balance and throttle API usage.
API brokers	Enrichment, transformation, and validation services to manipulate information coming to/from APIs, as well as tools to embody business rule engines, workflow, and business process orchestration on top of underlying APIs.
API management and monitoring	A centralized and managed control level that provides monitoring, service level management, SDLC process integration, and role-based access management across all three layers above. It includes the ability to instrument and measure API usage, and even capabilities to price and bill charge-back based on API consumption—to internal, or potentially external, parties.
RESTful API	REST stands for “representational state transfer.” APIs built according to REST architectural standards are stateless and offer a simpler alternative to some SOAP standards. For example, REST enables plain-text exchanges of data assets instead of using complex WSDL protocols. It also makes it possible to inherit security policies from an underlying transport mechanism. At a high level, these and other simplified approaches can deliver better performance and faster paths to develop, deploy, and triage.

1.1 API Landscape in the Public Sector

APIs have become a foundational technological component of modern digital architectures, impacting every sector of the global economy. In the public sector specifically, APIs are a key enabler of the accelerated evolution of government and its agencies from analogue (manual, paper) operations, to digital.

The purpose of our study is to create a report that will support member states with the adoption of APIs when in pursuit of their digital transformation. In order to explore this purpose, our investigation has incorporated (but is not limited to) the following topics:

- The current use of APIs in the EU public sector.
- Differences between API use in the public sector and the private sector.
- The future trends for APIs.
- The relationship with location data.
- Insights from eight case study interviews, using real world examples to explore different dimensions of the API landscape, including API Strategy, API Ecosystems, and specific APIs.

Our approach is covered in detail in the Methodology section later in this report. In summary, we have used a combination of desk based research and interviews to gather information for analysis. For the interviews, we used a questionnaire to collect information from representatives of a set of successful but diverse API based case studies from a range of EU countries and sectors.

API Overview

API interaction occurs when one application would like to:

- Access or query the data held by another application
- Send data to that application
- Update data held in that application
- Request a service from another application

Types of APIs

Crucially, the use of APIs therefore simplifies, and standardises the interface reducing complexity and cost of deployment over that of custom built interfaces. APIs represent an architectural approach that revolves around providing programmable interfaces to different applications. It is technology agnostic, and creates a flexible, loosely coupled architecture that allows a solution to be made up of components that can more easily be switched in and out. The API approach is also a key enabler for application developers to build apps that rapidly adapt to end user needs[6].

[6] https://www.hcltech.com/white-papers/systems-integration/api-fication-core-building-block-digital-enterprise

In the public sector, APIs enable important functionality and information held in one agency's system or department to be readily available to another without significant and expensive development effort. As well as cross-departmental (agency) access to functionality and information (or even cross-border with a different country's administration) APIs also provide the ability to share information and functionality more widely, i.e. to developers and ultimately to citizens for consumption through web or mobile based applications.

Although there are many different types of API (see Appendix I), this study is most concerned with Web APIs. Web services expose these APIs as endpoints that any internet-enabled language or software can access, in exactly the same way browsers access websites and services[7]. Web APIs deliver requests to the service provider, and then deliver the response back to the requestor, i.e. they are an interface for web applications, or applications that need to connect to each other via the Internet to communicate[8].

Web APIs themselves can be broken down further based on the type of data format that they harness, for example, well known types are Simple Object Access Protocol (SOAP), Remote Procedure Call (RPC) based APIs, and the Representational State Transfer (REST) architectural style. GraphQL – is a data query language growing in popularity and has been adopted by leading social media outlets such as Facebook and Pinterest[9] as a type of API. While typical REST APIs require loading from multiple URLs, GraphQL APIs get all the data an app developer needs in a single request enhancing speed of response even on slow mobile network connections[10].

Whilst the more traditional APIs are used as integration points within systems hidden from view, Web APIs are often publicly available and can be 'advertised' via API Directory sites online. Tens of thousands[11] are available for developers to deliver consumable information to end users to do everything, from checking traffic and weather, to updating a social media status, or even to make payments.

In the geospatial domain, besides existing private companies famous API proposals (e.g. Google Map), the Open Geospatial Consortium (OGC) has created standards to support the exchange of geospatial information[12]. They describe their Web services API standards as an agreed specification of rules and guidelines about how to implement software interfaces and data encodings[13]. Geospatial software vendors, developers and users collaborate in the OGC's consensus process to develop and agree on standards that enable information systems to exchange geospatial information and instructions for geoprocessing. OGC standards are open standards. The OGC interface standards are also available in the REST style, and cover a number of aspects:

- Visualisation standards e.g. Web Map Service (WMS).
- Data Access Standards e.g. Web Feature Service (WFS), SensorThings API.

[7] https://federaltechnologyinsider.com/government-agencies-leading-app-economy-using-innovation-drive-economic-growth/
[8] https://www.definition.net/define/api
[9] https://graphql.org/
[10] https://graphql.org/
[11] From e.g. https://www.programmableweb.com/
[12] http://www.opengeospatial.org/standards
[13] http://cite.opengeospatial.org/pub/cite/files/edu/ogc-standards/text/services-ogc.html

- Processing Standards e.g. Web Processing Service (WPS).
- Metadata & Catalogue Service Standards e.g. Catalog Service for the Web (CWS).
- The informatics contract between the client code which manipulates normalized data structures of geographic information based on the published API and the library code, e.g. the GeoAPI Implementation Standard.

The standards above are part of the few globally agreed specifications adopted by the Technical Committee 211 of the International Organization for Standardization (ISO). ISO is also known to be working on standards in other sectors, notably in Financial Services with ISO 20022[14]: however, because of they are work in progress, details about them are still limited.

Whilst standards of this formal and specific nature are used in the EU, there is clear evidence that the need for harmonising APIs lifecycle has been recognised. For example, the UK Government Digital Service recognised that departments were developing APIs using different tools, platforms and approaches[15], and have set about working with industry to create a set of common principles for API design. The output has been a set of guidelines on how developers working in any UK public sector organisation should build APIs[16] to ensure consistency, and success. Although they are titled as a ‘standard’, they are generic, and not exact or specific in the way that an ISO or OGC standard is. Nevertheless, given the fact that government is increasingly using APIs to automate processes and provide citizens with access to new services it is hoped this approach will make integration simpler and faster.

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[14] https://www.iso20022.org/news/iso-standard-apis-whitepaper
[15] https://gdstechnology.blog.gov.uk/2018/01/29/identifying-the-challenges-of-designing-cross-government-apis/
[16] https://www.gov.uk/guidance/gds-api-technical-and-data-standards

2. Methodology

The approach to data gathering in support of the reports purpose is made up of two core components:

- Desk based research coupled with industry analyst interviews.
- Case study investigation, and interviews with representatives from successful API implementations in the EU public sector.

2.1 Desk based research

Our desk based research leveraged API documentation available openly online, and also included access to the Gartner API knowledge base for the public sector.

Additionally, in order to add a quantitative element to the research, an initial high level analysis was carried out on the government originating APIs available on the globally recognised API Directory ‘ProgrammableWeb’.[17]

2.2 Case study investigation

Eight interviews relating to the use of APIs in the EU public sector were conducted. The full list of the selected case studies is in **Table 2**. The cases are purposefully diverse, and were selected to cover a variety of different circumstances and dimensions so that this study can derive insight from a broad base of the API community. They include:

- Interviews with parties focused on the high level vision, or strategy behind API use: Team Digitale (Italian Digital Transformation Team).
- Interviews with parties focused on using APIs as components of wider architectural platforms/ecosystems: Estonia X-Road, FIWARE Next Generation Service Interface v2 (NGSI).
- Specific APIs implementation: Madrid Mobility Labs, Amsterdam City Data API, Danish Address Web API (DAWA) and the Flanders Cable and Pipe Location Portal Web API (KLIP).

Collectively they cover:

- A range of Member States in the north and south of the EU.
- A range of sectors and public services impacted (Transportation, Utilities, Smart City related public services, Gazetteers, Permits and more).

[17] www.programmableweb.com

Table 2 Summary of Case studies

Ref	Case study	Overview & Status
1	**X-Road Platform** https://e-estonia.com/solutions/interoperability-services/x-road	**Country:** Estonia **Government Level:** International **Region:** North-Eastern Europe (Estonia & Finland) **Sector:** Multi **Location data:** N/A **Dimension:** API as part of a wider platform/ecosystem **Interviewee:** Andres Kütt, previously Head of IT at Estonia Tax & Customs and a long term Estonian Government architect with in depth experience of the X-Road solution. **Description:** X-Road is a government API framework developed by the Estonian government and licensed under the MIT license. It is also used as a backbone of the Finnish National Data Exchange Layer. Originally built for SOAP/XML web services, it now extends to REST APIs.
2	**FIWARE Next Generation Service Interface v2 (NGSI)** https://www.fiware.org/foundation/	**Country:** N/A **Government Level:** N/A **Region:** N/A **Sector:** Covers Smart City, Smart AgriFood, Smart Industry and Smart Energy (added in 2018) **Location data:** Likely to be part of the overall solution **Dimension:** API as part of a wider platform/ecosystem **Interviewee:** Ulrich Ahle, CEO, FIWARE Foundation **Description:** A public-private partnership funded by the EU, corporate members and venture capitalists to develop: ▪ A scalable open source platform to access and manage heterogeneous context information through open APIs ▪ A standard for exchange of context information: FIWARE-NGSI (Next Generation Service Interface) ▪ Generic Enablers and Solutions to provide Smart Services with the FIWARE Context Broker as main component
3	**Italian Digital Transformation Team**	**Country:** Italy **Government Level:** National **Region:** Southern Europe

	https://teamdigitale.governo.it/en/	**Sector:** Multi **Location data:** No **Dimension:** API Strategy **Interviewee:** Simone Piunno, Roberto Polli **Description:** The Digital Transformation Team was born to build the "operating system" of the country, a series of fundamental components on top of which simpler and more efficient services for could be built for citizens, government and businesses
4	**Amsterdam City Data** https://amsterdamsmartcity.com/projects/dataamsterdamnl	**Country:** The Netherlands **Government Level:** City **Region:** Central Europe **Sector:** Multi **Location data:** Yes **Dimension:** API as part of a wider platform/ecosystem **Interviewee:** Arris Oliemans **Description:** City Data is a single portal providing developers with access to Amsterdam's open data, and some non-public classified data with controlled access for city employees. City Data went live in 2016 for civil servants, and mid 2017 for developers. The architecture is loosely coupled, using REST APIs to deliver data to the front end portal.
5	**Denmark's 'Adressers' Web API' (DAWA)** http://dawa.aws.dk/	**Country:** Denmark **Government Level:** National **Region:** Northern Europe **Sector:** Multi **Location data:** Yes **Dimension:** API as part of a wider platform/ecosystem **Interviewee:** Finn Jordal **Description:** 'Danmarks Adressers' Web API (DAWA) displays data and functionality regarding Denmark's addresses, access addresses, road names, and zip codes. DAWA is used to establish address functionality in IT systems. The target audience for this site is developers who want to integrate address functionality into their IT systems. DAWA is part of the AWS Suite.

6	**Cable & Pipe Information Portal (KLIP)** https://klip.vlaanderen.be/api	**Country:** Flanders, Belgium **Government Level:** Regional **Region:** Central Europe **Sector:** Utilities **Location data:** Yes **Dimension:** Specific API **Interviewee:** Liesbeth Rombouts **Description:** API driven platform where all public and private utilities must share and request detailed digital maps showing the location of underground cables and pipes prior to carrying out engineering works
7	**Madrid Mobility Labs** Developers Portal: https://mobilitylabs.emtmadrid.es/portal/ API: https://openapi.emtmadrid.es	**Country:** Spain **Government Level:** City **Region:** Southern Europe **Sector:** Transport **Location data:** Yes **Dimension:** API as part of a wider platform/ecosystem **Interviewee:** Enrique Diego Bernardo **Description:** An ecosystem of APIs and a portal bringing information to citizens through multiple channels and applications for transportation related APIs such as Buses, Parking, Public bicycle, Traffic, City Hall Sensors, Third-party sensors and data

The Questionnaire

A structured questionnaire was designed to assist in gathering the information that we were most interested in capturing for this study from real world examples, i.e. information that will be of use to the European Commission itself, when considering how best to adopt, or support the adoption of APIs in the future. In order to explore this purpose, the interviews focused on obtaining information on:

- General information on the case study.
- Non-Technical aspects such as the strategy and vision of the implementing organization, as well as the purpose, usage, enablers, cost and benefits of the API.
- Technical aspects such as the API specification or standard, authentication and authorisation, management, and support.
- The appetite for the European Commission to provide/advocate regulation, guidelines, or a standard to enhance interoperability.

The table below shows the case study framework developed to elicit the information desired.

Table 3 Questionnaire

Dimension	Comment/Description to assist interviewer
General Information	
Interviewee	Name and background
Case Study Title	Name
Member State	Name of member state ‘owning’ API/API Platform
Provider	Name of Department/Agency ‘owning’ API/API Platform
Level (National/Regional/Local)	Level of government ‘owning’ API/API Platform
Sector	In this case study, which sector is the API/API Platform designed to support/enable?
Key Stakeholders	Who are the key stakeholders specific to this API/API Platform?
Non-Technical Aspects	
Setting the scene – APIs and the organisation	
Summary of organisations’ API Strategy & Vision	What is your organisations API Strategy & Vision? How does the organisation use APIs, and how does the organisation aspire to use APIs in the future - standalone point solutions or the creation of large scale platforms and ecosystems? Is this seen as a key enabler to digital government?
Interoperability	Are your APIs designed to foster interoperability? Do you see APIS as an important tool in interoperability between departments, agencies and states?
Overview of API policies	Are legal and technical contracts mandated? Have particular standards and specifications been mandated? What data is allowed to be exposed? Do you have specific policies that relate to APIs?
Resourcing/Competencies	Does the organisation have the skilled resources required? Has the organisation invested in bringing in competencies either permanently or via partners? A few words on composition of the team, who is involved in setting up an API – technologists and?

General position on access and usage	What is your general position on access and usage? Normally open or restricted? Allow reuse without condition, or place limitations on public/commercial use?
Funding	What is the funding source for API development? Is it sustainable? Depends on the requirement?
General position on business model type	Normally free or chargeable?
Views on EU support/involvement in APIs	What are your views on support that could be provided by the EU, or anything that you believe is missing at the EU level to support API adoption, e.g. regulations, guidelines, a standard for interoperability?
Relating to a specific API or API	
Description of the 'purpose' of the API/API Platform	What is the purpose of the API/API Platform? Examples might include: 1. Enable web and mobile applications 2. Integrate internal applications 3. Interface with micro services 4. Publish data 5. Create cloud and SaaS integrations 6. Enable IoT 7. Engage customers/citizens 8. Extend the Organisation 9. Create an ecosystem with citizens, customers, partners and suppliers
Objectives of the API/API Platform	What does the API/API Platform allow access to? Why was it commissioned?
Target users/consumers of the API/API Platform	Who are the target users/consumers of the API/API Platform? How about across the entire API ecosystem?
Public Services enabled by the API/API Platform	Which public services are supported by the API (or as a result of making the API available?)
Usage Statistics for the API/API Platform	• Statistics (how many users are using / was designed for, how many services are using the API) • How many services have taken advantage of the API? How many users is the API designed for? Add to design piece? Is it used, how much is it being accessed?
Date made available	When was the API/API Platform live?
Maturity of the API/API Platform	What is the maturity level of the API – Exploratory, or in production…beta or live?
Cross-border (yes/no)	If the API/API Platform has been designed to be Cross-border among

	European Union Member States, and is it being used in that way?
Cross-sector (yes/no)	If the API/API Platform has been designed to be cross-sector, and is it being used in that way?
Economic Case of the API/API Platform	Was there an economic case/imperative for building the API/API Platform?
Political Case of the API/API Platform	Was there a political case/imperative for building the API/API Platform? Policy context, traceability, Federal policy because of state case, e.g. Italian region looking into cross-border with greater Italy.
Location Data: As data (e.g. road network)	How is location data used?
Location Data: As a service (e.g. geolocation)	How are location services used?
Main sources of cost of the API/API Platform/API Ecosystem	What are the main costs of developing and maintaining the API/API Platform? Infrastructure, staff, maintenance, licenses?
Which part of the organisation funded this specific API/API Platform	Which organisation has funded the API/API Platform?
Benefits provided/anticipated from the API/API Platform	Has the API/API Platform resulted in value creation, or the creation of a wider ecosystem?
Enablers for the API/API Platform	What has facilitated/enabled the development of the API, the API Platform or the API ecosystem? EU/National policies?
Barriers to the API/API Platform	What has been a barrier to API/API Platform development and maintenance? Lack of EU/National policies? For example, it can be difficult working cross department when there is a lack of an agreed API standards? How do you leverage data from different systems in different formats and structures?
Risks & Mitigations	What risks exist, and how have you mitigated them?
Best practices/Guidelines	What best practices or guidelines have been adopted?
Training & Events	Do you engage with the developer community through training or events?
API License/Source code	What license, if any, is used for this API?

API Lifecycle – Design, Build, Test, Support & Ongoing Product Management	
API Design	
Standard	Is your API/API Platform based on a standard?
Specification	Did you use a specification to document the API/API Platform?
API first or consultation led	How did you design the API? Did you consult, or do what was easiest for you?
Interface models	Which interface model does the API use?
Data Formats	Which data format does the API use?
Message Exchange Protocols	Which message exchange protocol does the API use?
Messaging Protocols	Which messaging protocol does the API use?
Granularity	How granular is the API/are the APIs?
Authentication, Security & Privacy	What method of authentication do you use?
API Building Tools/Integration Platforms	Did you use API build or integration tools?
Testing	Did you use any API test tools?
API Support	
Developer Portal provision	Do you have an API portal for developers?
Documentation	How do the developers document their API? Complete, consistent, tested, 'Technical contract'?
Communication	How do you communicate with developers across the ecosystem? Updates, issues management, community support (via portal)
Administration	How do you provision access? Provisioning, API Key Management, Billing & Payment
Implementations	How do you provision access? Sample code, Libraries and SDKs , Sandboxes, Test harnesses
API Management	
Governance model	Who owns API Governance? Who is involved in setting and managing API Governance? IT? Business? Separate unit?
API Product Management	How do you manage Roadmaps, versioning, testing, security, access

	management, monitoring and analytics?
Contractual & Commercial – For this API/API Platform	
Legal contract	Is there a legal 'contract' available covering the aspects below?
Business model	Free, pay per call, subscription?
Access Rules	Is this API public, or restricted in some way? Open, Closed, Limited? Intellectual Property rights? Are protecting their data or are they protecting their APIs? Combine data from different sources, does this give issues?
Usage Policies	Are there any limits on numbers of calls/access of the API? Are there any constraints on what the API can be used for?
EULA	End user license agreement required?
SLA	Is there a service level agreement which describes the service level that developers can expect from you should there be incidents/issues/problems associated with your API?
What could be better	
SWOT/Concerns	A general questions about the SWOTs that exist in relation to this API

The study now moves on to consider the information gathered and analysed through the research designs and methods noted above.

3. Use of APIs in the Public Sector

The Internet, social media, smartphones, and access to real-time information have not only made people's daily lives easier, but have changed citizens' expectations of how products and services are delivered. In the public sector, this shift has raised the expectations of citizens and business in their interactions with government.

People are demanding transparency, accountability, access to information and competent service delivery from their governments. They also expect policies and services to be tailored to their needs and address their concerns.

In this section, we will explore how APIs are used in the public sector. We will firstly look at typical uses, such as the enablement of ecosystems, before looking at some specific examples of API use. In addition, we will cover some challenges and considerations, and examine data on the APIs advertised in one of the most respected API Directories, (ProgrammableWeb) as a further indicator of the way APIs are used in the public sector.

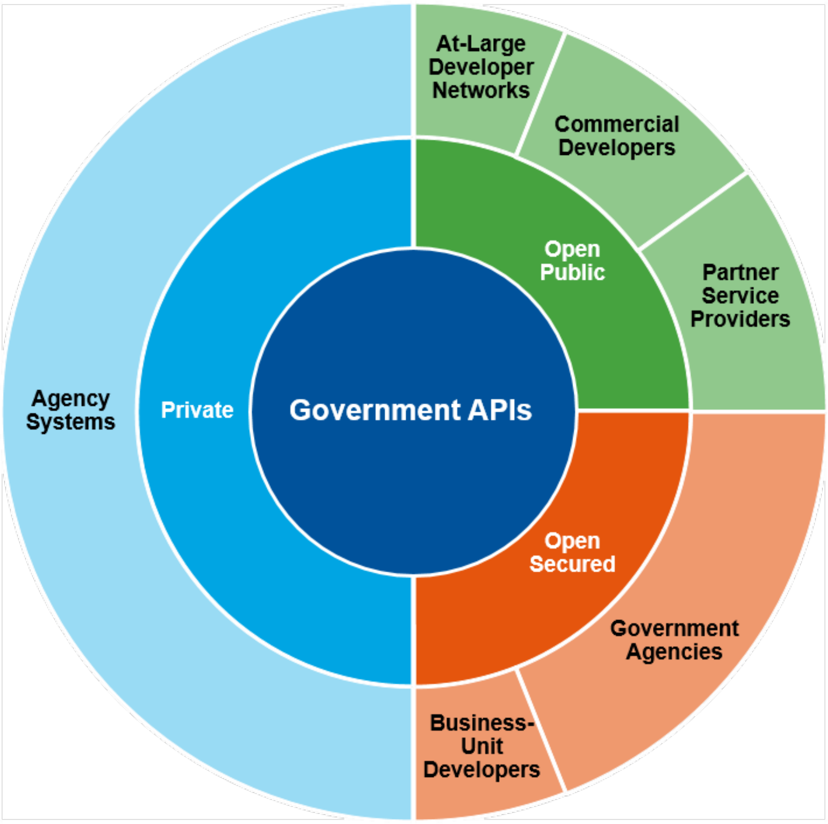
3.1 APIs enable the public sector to create 'ecosystems'

API based ecosystems can be defined as the extended interrelationships enabled by developers who create applications that link various groups of stakeholders to each other via API based solutions that use the internet to communicate[18].

An ecosystem may be created within a government agency, between agencies, or it may be wider reaching, for example between a government and another government or between a government, their citizens, and potentially third party providers.

[18] (Gartner Paper) From APIs to Ecosystems: API Economy Best Practices for Building a Digital Platform; Malinverno P, O'Neill M, Moyer K; 2017

Figure 1 Ecosystems enabled by government API



Source: Gartner (December 2017)[19]

The figure above illustrates the way in which APIs are used, and the typical ecosystem that they facilitate in the public sector.

- Private – Agency Systems: These APIs are generally used to facilitate the sharing of data between systems within an agency, avoiding the need for complex point to point integration. They are not visible to any person or body outside of the agency and are generally in the domain of the IT department. An example maybe a link between an internal HR system and a Payroll solution.
- Open Public – At Large Developer Networks: Open APIs (i.e. you do not require permission to access them) are the access point for developers to access large public data sources such as a census information or other similar statistical data, perhaps live sensor data from which to create citizen-facing applications.
- Open Public – Commercial Developers: As above, but developers who are looking to gather freely available data for use, generally, in applications that can be sold. They may add value by 'mashing'

[19] (Gartner Paper) Accelerate Data-Centric, Digital Government With a Proactive API Program; Lachea, Dean; 2017

the data, i.e. combining data on public transportation networks with location data available on an individual's smart phone to help the citizen make travel choices in real-time... Because of this openness, third-party integration of software is not only easier but less problematic. Developers have access to the API at all times, so they can ensure that the two-way communication between assorted pieces of software is correct, rather than having to guess at the appropriate methods to use.

It is also worth noting the economic stimulation that this can bring. Transport for London's policy of working with major IT players (Google, Apple, Waze etc.) but allowing their data to be available via the Open Government License has led to the creation of additional economic activity in the order of £100m of direct value and has enabled some 1,000 jobs20.

- Open Public/Secured – Partner Service Providers: The APIs are open to partners perhaps in the private sector which may include healthcare providers for example, who in some member states are interested in sharing healthcare records, or confirming eligibility for free or subsidized treatment based on data held by a government agency.
- Open Secured – Government Agencies: These APIs are available to other government agencies and allow them to share data only once they have authenticated. This supports many of the core tenets of digital government, allowing agencies to collect data on a citizen only once, and then share it securely. An example may involve the sharing of citizen data between say the agency responsible for income and taxation, and those providing benefits in order that eligibility could be confirmed. Please see later case studies relating to Estonia X-Road, and Amsterdam City Data for more on this.

  Although not specifically mentioned in the diagram above, the ability to use APIs is not constrained by sector or geographical boundaries. Open Secured – Government Agencies could include an application to application link between governments of different member states. A good example (explored further later) would be the Estonian X-Road Platform which uses APIs to share citizen's healthcare information with Finland.
- Open Secured – Business Unit Developers: Similar to the above, but instead of basic inter-agency data sharing, in this case the data is being consumed and then in some way supplemented in order to be useful by developers within a government agency. They are used to create custom applications around internal data assets for agency use.

In summary, the creation of an 'ecosystem' of providers and consumers fosters openness and efficiency, and can also spawn the development of innovative service models, some of which may lead to revenue generation for the agencies concerned (for example mapping data[21], or gazetteer data). Their ability to

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[20] Workshop report, Data access and transfer with a focus on APIs and industrial data platforms, June 8 2017 - http://ec.europa.eu/information_society/newsroom/image/document/2017-32/report_final_for_web_C285AA6E-0C77-373C-999BF6DFBCC3F995_46252.pdf

[21] https://developer.ordnancesurvey.co.uk/os-places-api

provide access into the heart of government, in turn allows government to realise its objectives of openness, and of delivering efficient, secure, transparent and interoperable citizen centric services. The APIs are, therefore, a crucial technological component, which will underpin empowering the evolution of public service delivery models, enabling agencies to accelerate their transformation from eGovernment to Digital Government.

3.2 APIs enable public sector agencies to overcome complex integration

Nearly all EU countries have developed their computing infrastructure over many years, constructing a legacy of large, complex information systems featuring interfaces to pass information from one system to another. The majority of these interfaces were point to point and custom built to meet the needs of a particular project or agency at a point in time. As the number of interfaces grew, so did the maintenance burden; the inter-relationships and the data duplication leading to an expensive, complex and inefficient architecture[22]. In summary, these “siloed”, legacy government systems and associated business processes increase risk and exacerbate challenges in data sharing and service delivery across the ecosystem.

APIs provide an opportunity, in effect a structural ‘workaround’, to enable the information within these legacy systems to be exposed with comparably low complexity and investment. They can be plugged into legacy systems of record such as ERP systems[23], or citizen facing records to make the data records directly available, thus helping to bypass the complex interfaces of existing systems, and allow data sharing to be accomplished more easily. This means that a well-designed government ecosystem could help minimise the frequency that citizens or businesses will have to provide the same information (Once Only Principle, OOP).

A good EU example of where API infrastructure is currently being used to overcome the restrictions of traditional integration solutions is Estonia’s X-Road Platform. It allows citizens to provide common ‘private and sensitive’ information to public administrations only once, for example, marital status. The ecosystem also includes private institutions such as banks who can have access in order to perform various functions. X-Road is examined in more detail in the case studies section of this report.

EU Example: ESTONIA X-ROADS PLATFORM

> *“X-Road is the backbone of e-Estonia. Invisible yet crucial, it allows the nation’s various public and private sector e-Service databases to link up and function in harmony.”*[24]
>
> *X-Road is a government API framework developed by the Estonian government and licensed under the MIT license. It is also used as a backbone of the Finnish National Data Exchange Layer. Originally built for SOAP/XML web services, it now extends to REST APIs. Rather than requiring*

[22] API imperative: From IT concern to business mandate: Tech Trends 2018 – Deloitte Insights
[23] https://www.mulesoft.com/resources/esb/erp-integration-application-architecture
[24] https://e-estonia.com/solutions/interoperability-services/x-road/

governments to develop API management directly, X-Road provides an API management layer, including an API gateway, which is open-sourced and available to governments worldwide.[25]

The X-Road solution includes a security server to provide identity and access management for government API access. It also provides central monitoring of API traffic. In addition to the management of APIs, it also provides an aggregation layer in front of multiple databases. This facilitates the creation and delivery of data access APIs.

Since each government service/agency has its own databases they all use X-Road to securely communicate and share 'private and sensitive' data to protect the 'once only' principle of sharing data with government. The service also incorporates many other sectors numbering over 900 organisations and enterprises including those in the banking, health and utility sectors[26]*. Whilst they may use the platform to perform functions such as identity verification, powerful use cases such as automated extraction of funds from bank accounts for those failing to keep up to date with taxes are possible.*

All that being said, the X-Road itself is a 'very low level engineered application'[27]*. Following certification, an organisation deploys an x-road gateway so that it can hold secure private communications via APIs with other certified organisations that are legally able to share data with it. As a collective toolset, the e-Estonia services provide the government of Estonia and its partners, including Finland, with a platform on which to innovate and use digital transformation to deliver new services across the globe.*

3.3 APIs support the public sector open government initiatives

Open Government can be defined as the opening up of government processes, proceedings, documents and data for public scrutiny and involvement, and is now considered as a fundamental element of a democratic society[28]. The Open government initiative started in 2009 by Barak Obama[29], after that, numerous governments adopted open data initiatives. It is founded on the belief that greater transparency and public participation can not only lead to better policies and services, they can also promote public sector integrity, which is essential to regaining the trust of citizens in the neutrality and reliability of public administrations.

APIs have become synonymous with facilitating the opening of large data sources to citizens and other third parties. The Open Government imperatives have meant that API technology has been exploited outside of the 'IT department', providing access into large open data stores so that developers and their applications and websites can more easily consume it. When a government agency publishes an API for their data set,

[25] (Gartner Paper) A Digital Government Technology Platform Is Essential to Government Transformation
[26] https://e-estonia.com/solutions/interoperability-services/x-road/
[27] Interview with Andres Kütt
[28] http://www.oecd.org/gov/open-government.htm
[29] https://obamawhitehouse.archives.gov/open

they open up new and innovative ways to access the data. A developer might create a mobile or web app to display the data intuitively or allow simple queries or automatically generate charts.

The most relevant public sector that expose government datasets is The European Data Portal[30] (EDP).

EU Example: European Data Portal (EDP)

The EDP provides access to 79 different catalogues, most with tens of thousands of open datasets provided my member state governments. The same site also provides access to over 300 use cases (services or applications) that have been developed using the open data sets available. Some of these applications have been created using APIs to query the EDP.

The access to the Portal is provided by a machine-readable API which enables its users to search, create, modify and delete metadata on the portal.[31] APIs are available both via the Comprehensive Knowledge Archive Network (CKAN)[32] and SPARQL[33] endpoints.

3.4 APIs enable the public sector to innovate

APIs enable new innovative service models which better engage citizens and allow for more efficient delivery of their services. These services no longer have to be provided directly by the agency, partners and citizen developers can use available data to enable new solutions. Smart Cities and the vast amount of data produced by sensors supports the development of dynamic platforms and ecosystems providing contextualized, real-time location-based data from IoT or crowdsourcing to business partners and startups giving them opportunities to create new services or improve existing ones.

Transport for London have delivered successful innovation based on API use. Although other more innovative services are coming of age in areas such as Smart Cities, this example is one of concrete success in enhancing efficiency and citizen service delivery.

EU Example: TRANSPORT FOR LONDON (TfL)

At recent European conference[34], Transport for London detailed the investment that that they had made:

- *200 data elements are made available through an API to some 12,000 developers producing some 600 apps that 40% of Londoners use.*
- *TfL has formed partnerships with major IT players such as Apple (for mobile payment, rental of bikes), Twitter (for pushing alerts out), a two-way data-sharing agreement with Waze (enriching*

[30] https://www.europeandataportal.eu/en/using-data/use-cases
[31] https://www.europeandataportal.eu/sites/default/files/2016_understanding_the_european_data_portal.pdf
[32] http://www.europeandataportal.eu/data/en/api/3
[33] http://www.europeandataportal.eu/sparql
[34] Workshop report, Data access and transfer with a focus on APIs and industrial data platforms, June 8 2017 - http://ec.europa.eu/information_society/newsroom/image/document/2017-32/report_final_for_web_C285AA6E-0C77-373C-999BF6DFBCC3F995_46252.pdf

the app with data from the road network that TfL manages while benefiting from data collected through Waze) and Google (enriching the maps application with real-time data).

- *The data can be consumed under the terms of the UK Open Government Licence with some minimal additions for free. This is done under a statutory requirement as part of UK legislation. Mechanisms are in place to ensure that consumption remains at an acceptable level. There is one single set of data at the base that are both consumed by TfL for its purposes and by third party developers. Developers must give attribution to TfL for the fact that their app includes TfL data.*
- *In terms of creation of additional economic activity, it has been calculated that this policy generates GBP 100m of direct value and has enabled some 1,000 jobs.*
- *For data acquired by a third party, e.g. Waze data, restrictions resulting from the partnership agreement apply.*
- *All data made available is data that TfL collects anyway for its own purposes. TfL is not collecting additional data merely to make available to third parties.*
- *Mashing data provided by TfL with privately-held data can bring additional insights (e.g. "Are there correlations between rainfall and collisions involving cyclists?").*

3.5 Challenges & Considerations

For the most part, externally facing public sector APIs involve the movement of data that is sensitive as it often, in some way, refers to information about a citizen. This poses a number of consistent challenges for government:

- Security – APIs expose data, services, and transactions in order to build new services. This inherently increases the permeability of an organisation's network, which can expose new vulnerabilities for exploitation. Therefore, APIs must be appropriately secured to ensure data privacy and to ensure citizen confidence in the service delivery channel. APIs intended for access to public data must be protected from inappropriate use or abuse such as denial of service. A number of security solutions exist such as OAuth and Certificate based authentication, which are used in conjunction with a wider cyber security strategy and cryptography.
- Regulation – APIs play a significant role in the facilitation of government transparency. A recent EU ruling[35] makes providing transparency into all IT services that will be used in technology projects a condition for receiving government funding, and it is more than likely that APIs are the core technology required to support the transparency principle.

[35] https://europa.eu/european-union/about-eu/funding-grants_en

- Further regulatory considerations which must be adhered to when sharing data through any type of interface are the General Data Privacy Regulation[36] (GDPR), the Payment Services Directive (PSD2)[37] and the Public Sector Information Directive (PSI)[38].
- Specifications or Standards - Standards for APIs are available in small pockets such as the OGC[39] standard, and the developing ISO standard in Financial Services[40]. However, many organisations are developing APIs based on an agreed internal specification or style guide to promote consistency, rather than what might normally be recognised as a de facto 'standard'. Each API comes with detailed documentation for consumers which provides clarity on the type of API (RESTful, GRAPHQL, GRPC etc.). There appears to be limited appetite for further standard development in the aftermath of 'Open Government' which is different to the impact 'Open Banking' has had in the EU which precipitated the agreement of an API standard (in the UK initially at least)[41].

The work conducted by the FIWARE Foundation (Future Internet Ware) tries to overcome some of the challenges listed above. FIWARE will be analysed later in the document, but in summary it is funded by a combination of EU, corporate membership and venture capital funding and has created a scalable open source platform used to access and manage heterogeneous context information through open APIs[42]. A standard for exchange of context information: FIWARE-NGSI (Next Generation Service Interface) is an open standard API to be used for Smart Cities, Smart Industry and Smart Agrifood[43]. The EU has noted its success to date, however, its success in landing a standardized API that is universally used will be known only in time.

- Business Models – In the public sector, generating income from the provision of data that is publically owned, and is being used for the public good, has not led to the charging of users who wish to consume or query this type of data. Examples of charging mechanisms being in place are limited, one being the UK's Ordnance Survey maps[44], and KLIP (one of the case studies explored later in the Section dedicated to the case studies) which charges map requestors to have a digital map of utility services generated for a specific location.

3.6 Quantitative assessment of API use in the public sector

It is hard to realistically quantify the number of public sector organisations that are using APIs internally, but the total amount across all enterprises and organisations is likely to run into the millions[45].

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[36] https://www.eugdpr.org
[37] https://ec.europa.eu/info/law/payment-services-psd-2-directive-eu-2015-2366_en
[38] https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information
[39] http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html
[40] https://www.iso20022.org/news/iso-standard-apis-whitepaper
[41] https://www.europeanpaymentscouncil.eu/news-insights/insight/how-can-application-programming-interface-standardisation-be-achieved-context
[42] https://ec.europa.eu/digital-single-market/en/news/fiware-final-report-new-model-eu-innovation-programmes
[43] Interview with Ulrich Ahle, CEO FIWARE
[44] https://developer.ordnancesurvey.co.uk/os-places-api
[45] API imperative: From IT concern to business mandate: Tech Trends 2018 – Deloitte Insights

Organisations that create outwardly facing APIs to enable interaction with large data sources are common globally. We know that they are common globally because of the number of APIs now registered with API directories – the name given to the many searchable catalogues of Web APIs available on the internet. In order to ensure that APIs attract the maximum amount of developers to leverage the data being exposed, organisations will publish their API with high-level technical specification. Therefore, conducting an analysis of a well-recognised directory is likely provide indicative information regarding the number of EU public sector APIs, and the sectors and associated public services that they support.

ProgrammableWeb[46] is the best known and globally recognized API directory. Nordic APIs[47] comments that it is ‘exhaustive’ and ‘comprehensive’, and is hand curated and searchable. Therefore, as one method of obtaining quantitative, data led insight, this study undertook a basic analysis of the almost 20,000 listed APIs (as at February 2018).

We selected the ‘Government’ category which reduced the number searched to 787. After initial high-level analysis, our findings were that only 110 of the 787 Government category APIs advertised on the directory originated from the EU. This may well be because of the US-based nature of ProgrammableWeb. The initial breakdown suggested that the majority of the registered APIs were at the National level:

Table 4 ProgrammableWeb analysis

Scale	Number of APIs	Example API
City	12	▪ Transport for London ▪ City of Helsinki Service Mapping
Regional	7	▪ The Statistical Institute of Catalonia ▪ Open Greater Manchester
National	71	▪ Denmark Central Business Register (CVR) ▪ Where Does My Money Go (UK budget spend)
International	7	▪ Openspending ▪ World Government Data
EU-wide	12	▪ Open Patent Services ▪ VAT ▪ OrganiCity Permissions ▪ OrganiCity Assets Discovery ▪ Organicity Datasource ▪ Engage ▪ LobbyFacts Data ▪ Joinup ▪ It's Your Parliament EU Data ▪ Nephics European VAT Number Validation ▪ iTranslate4.eu ▪ European Union Legislation

[46] https://www.programmableweb.com/apis/directory
[47] https://nordicapis.com/api-discovery-15-ways-to-find-apis/

Most of the APIs provide access to open data sources for developers to use in order to create applications for commercial sale. Others have more democracy/citizenship based aims.

3.7 Conclusion

APIs enable cost effective data sharing through both private and public ecosystems, which is in turn leveraged by developers to generate benefits for the citizen, for business and for the economy. The number of APIs is continuing to grow year on year (as demonstrated by the numbers recorded by ProgrammableWeb) is testament to the value that they provide for the public sector across a variety of use cases.

4. The relationship with location data

This study is done within the Interoperability Solutions for Public Administrations (ISA[2]) programme, ELISE action, which targets those working in public administrations or private companies that deal with information, data, services and processes using the power of location. Within the ELISE action, and because of its recommendations in the area of location web services, it is worth to mention the European Union Location Framework (EULF) project[48], which was part of the ISA programme and took action to tackle the challenge of sharing location information. The EULF vision is to create and promote a coherent European framework of guidance and actions to foster cross-sector and cross-border interoperability and use of location information in digital public services. The aspiration is to build on INSPIRE[49] resulting in more effective services, savings in time and money, and contributing to increased growth.

Beside the adoption of horizontal frameworks, such as the EULF, we would also like to remark, through some concrete examples in the following sections, how adding the additional layer of location data, with other data (via APIs) can provide powerful use cases. For example, knowing the location of an individual or device connected to the internet (or via another locational tracking system e.g. GPS etc.) is now commonplace. The known location can be associated and combined with both geospatial, meteorological and sensor data to provide both administrations and the citizen with an enhanced interaction with the world around them. Location intelligence, which makes a combined use of analytics, geospatial information and location based services, has many use cases in government. Examples are also Internet of Things applications that integrate government data (such as demographic data, geological maps or planning/zoning information) into their real-time solutions, including those supporting Smart City programmes. In the following sections, to give an idea of how location information can be combined and used through APIs, we will explore some concrete examples of the use of APIs.

4.1 Smart City

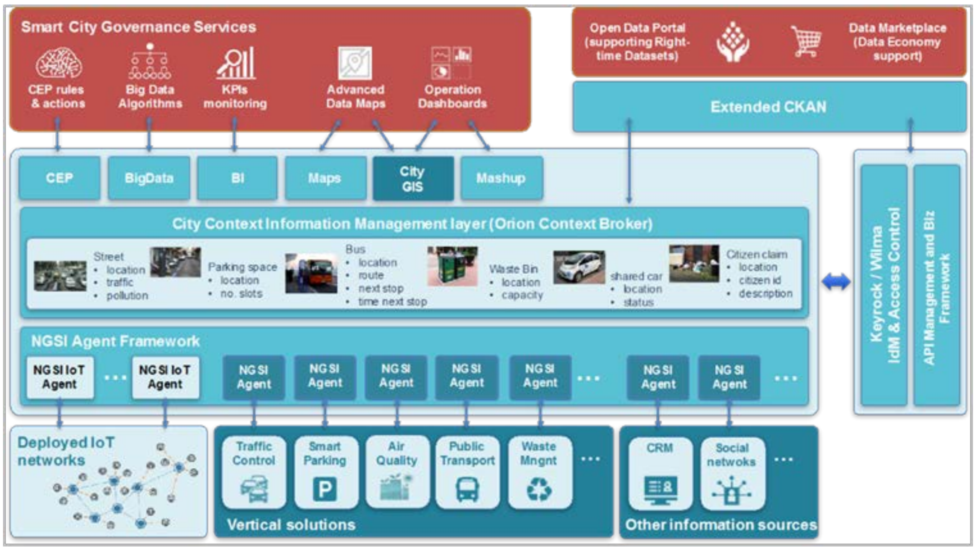
In a Smart City environment a public bus service, or perhaps more futuristically an autonomous car, could be routed to avoid congestion, or to parking locations based on live parking space availability data from a private or public car parking service provider. The ability to provide this type of information in an interoperable format is something that platforms such as FIWARE are actively developing (FIWARE was a selected case study for this investigation and is explored in more detail in the section dedicated to the case studies).

The FIWARE reference architecture diagram below provides a schematic overview of how location data, associated with sensor data is combined in a ‘contextual layer’ before being communicated via APIs (NGSI – The Next Generation Service Interface is a standardised open RESTful API) to the public service provider. The use case encapsulated in the red box illustrates that of next generation waste management

[48] https://joinup.ec.europa.eu/sites/default/files/custom-page/attachment/2017-10/EULF-Blueprint-v6.pdf
[49] https://inspire.ec.europa.eu/

where data from sensors in household or commercial waste bins, coupled with associated location data of the bin, can be passed to the servicing organisation to plan for efficient waste collection.

Figure 2 FIWARE Reference Architecture for Smart Solutions



A growing use case in city environments is in helping citizens obtain parking. In Belgium today Vrije Parking[50] provides a smartphone application similar to the Park Shark City Platform[51] in the Netherlands which is designed to provide citizens with open access to their city's parking data. The Park Shark app uses an API to build in mapping data and the smartphones locational data to display parking places in the locality. The API allows developers to programmatically specify when, where, and for how long a user wishes to park. The API responds with a JSON list of possible parking locations including geolocation and total price. The Park Shark API currently accesses parking data in Amsterdam and Antwerp, with access to more cities under development. The API may provide custom functions in some cities, such as the ability to query the nearest meter to top up your parking time using Amsterdam's centrally connected meters.

Amsterdam City Data (explored in more detail in the section dedicated to the case studies) also uses APIs to enable data sharing between agencies, and the citizen. One powerful location related example is the application for permits for construction, or for parking. The citizen will find sections of their permit pre-populated using existing government records on their address for example, and will then be able to use a mapping tool (based on a mapping API) to select the area of land, or the parking space that the application is for. Bringing together these 'sources of truth' based on validated data from the outset not only reduces the citizens time in completing the application it also reduces the potential for fraud and for error, freeing up more time for the civil servants who can reduce the number of checks they conduct.

[50] https://www.vrijeparking.be/stad/gent
[51] https://www.citysdk.eu/amsterdam-jumps-the-park-shark/

4.2 Weather

The Foreca Weather API[52] integrates severe weather warnings from many national warning systems worldwide and presents them in a harmonized global offering. When queried with coordinates, the Foreca Warning feed returns a sorted list of active warnings for the given location by importance. For each event, the warning feed provides the generic significance level, generic warning class, and a more detailed event description. The original data from the official sources is also included. The generic codes developed by Foreca are meant to ease visualizing the end-user services, while the event descriptions provide more specific textual information.

Governmental severe weather warnings are currently delivered countries around the world, including the following EU countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Spain, Sweden, and the United Kingdom.

4.3 Emergency Resilience Planning

Emergency or resiliency planning also benefits from the uniting of location data with API capability. Access to geospatial (mapping) data via API, coupled with GIS datasets and multichannel communication tools gives governments the tools needed to provide alert notifications for pending or active events. This allows the jurisdiction to target the messaging to only those in the affected area such as evacuation zone or those downwind from a toxic chemical spill. Governments can use this technique to ask residents to take particular actions in response to an event. In some countries, these technologies are integrated with national notification systems that push messages to all mobile devices without the user needing to download an app or sign up for a service[53]. In the US, the OpenFEMA API provides free, read-only access to FEMA (Federal Emergency Management Agency) for the public to get accurate information on publicly funded projects, grants, and disaster declarations.

The Hungarian National Association of Radio Distress-Signalling and Info-communications (RSOE) operates Emergency and Disaster Information Service (EDIS). The objective is to monitor and document all the events on the Earth which may cause disaster or emergency. They monitor and process several foreign organisation's data and then display them in near real time – for the sake of international compatibility – according to the CAP protocol[54] and REST-API interface on a secure website[55].

4.4 Gazetteers

Core location information (e.g. address data) is relevant to most digital public services and broader location-based information is important in many digital public services (e.g. land registration) and in public sector information provided to citizens and businesses (e.g. location of schools and hospitals). The publishing of

[52] https://corporate.foreca.com/en/weather-data/weather-warnings
[53] (Gartner Paper) Three Geospatial and Location Intelligence Use Cases to Meet Governments' Biggest Challenges; Finnerty, Bill; 2017
[54] https://en.wikipedia.org/wiki/Common_Alerting_Protocol
[55] https://hisz.rsoe.hu

national gazetteers, and centrally owned mapping information which can be accessed via API is now fairly commonplace within the EU.

In the section dedicated to the case studies, later in this study, we examine the Danish Address Web API (DAWA) and the role that it plays in providing access to the Danish Address Registry (DAR). DAWA is used to provide address data and functionality into consuming IT systems. The target audience for this API is therefore developers who want to implement address data and functionality in their IT systems. For each address, a wide range of address relevant data points are included, such as location in the form of coordinates, connection to the municipality, parish, district court, police district, etc. as well as height above sea level.

4.5 Conclusion

APIs provide access to various aspects of location data, retrieving a variety of data points which on their own may have some use, but they become much more powerful when combined with contextual information such as that from a sensor. We will see in some of the selected case studies (e.g. DAWA, KLIP, Madrid Mobility Labs and Amsterdam City Data) how the role of location data and services is fundamental in the APIs provided by a public administration.

5. Differences with the Private Sector

In this section of the study we will explore the differences between how the private sector exploit APIs, and how the public sector also exploits them.

5.1 API availability

Although it is hard to quantify the number of APIs that are in existence due to many of them being internal unadvertised APIs, externally available APIs are to some degree tracked by API directories such as ProgrammableWeb[56], or RapidAPIs[57]. A recent survey by Deloitte[58] indicates that the public sector may have slower growth than the private sector which is also deemed to be slowing, or maturing. According to Deloitte, across global markets, public-sector API adoption lags and they suggest that this may be due to ongoing Open Government guidelines that mandate longer time frames for organising and executing larger-scale API transformation initiatives[59]. However, as explored earlier in this paper, a huge amount of government data is being made available for exploitation by citizen developers and commercial developers alike.

5.2 Business Models & Disruption

APIs have great transformative powers to disrupt business, when coupled with other technologies such as the powerful forces of Mobile and Cloud. The API is integral to the digital disruption in the commercial space, especially in retail, entertainment and social media[60]– probably to a far greater extent than government has been disrupted today. Some of the world's biggest brands have been significantly disrupted, or taken out of business by a new breed of companies that leverage technology to open up different ways of providing much sought-after services.

- The impact that Netflix had on Blockbuster made possible by Netflix's internal API, which handles two billion requests a day, and enables Netflix to develop and package new services for different platforms at speed.
- Amazon has required that all data-based communication between departments be done via API, naturally positioning Amazon to lead disruption in a world where APIs are becoming more and more ubiquitous. Amazon's disruption of the book industry was closely followed by providing access to their cloud via APIs creating a new business now worth $50bn.
- Dun and Bradstreet (D&B) as another example of APIs disrupting traditional business. The long established credit approval company has innovated with their API, enabling D&B lookups to be

[56] https://www.programmableweb.com/
[57] https://rapidapi.com/
[58] API imperative: From IT concern to business mandate: Tech Trends 2018 – Deloitte Insights
[59] API imperative: From IT concern to business mandate: Tech Trends 2018 – Deloitte Insights
[60] https://19yw4b240vb03ws8qm25h366-wpengine.netdna-ssl.com/wp content/uploads/theapieconomy.pdf

performed from within third-party apps, or within SaaS services such as SalesForce.com leveraged APIs, creating a new revenue channel and disrupting the industry.

- First Utility, have demonstrated that APIs having destructive potential to alter the electric utility industry within the UK. They help users easily switch utility providers, aided by an API that enables customers to receive quotes and sign up for their service. In this way, their API is disrupting a whole industry.

The disruption of government may be driven by the ease in which private sector, or even third sector providers can integrate with government platforms via APIs to share and use data to drive new and improved service delivery models. Gartner's series of recent papers on the state of government in 2030 predicts that governments will relinquish service delivery by empowering the ecosystem, through intelligence and innovation, to improve citizen services. Architectures will become modular and flexible so that they can be agile and responsive to changing demands from the ecosystem. Thus, differences with the private sector use of APIs will converge.

5.3 Making money from APIs

APIs are an increasingly important part of revenue generating activities for business. In a recent survey of IT decision makers, Mulesoft, recently acquired by Salesforce[61], a vendor of integration software found that 50% of large enterprises (10,000+ employees) surveyed were making more than $10 million a year from API initiatives[62]. In the public sector, generating income from the provision of data that is publically owned, and is being used for the public good, has rarely attracted fees. Examples of charging mechanisms being in place are limited, one being the UK's Ordnance Survey maps , and KLIP (one of the case studies explored later in the section dedicated to the case studies) which charges map requestors to have a digital map of utility services generated for a specific location.

Governments may need to become more financially driven/savvy as cost pressures become significant, and may choose to adapt to make revenue streams from ecosystems. This may manifest itself in a cost per API call model where, for example, transport data is being used by developers to create commercial applications. However, it is more likely to be part of a service delivery ecosystem with the private sector that provides efficiency and cost saving. For example, cities and local governments are predicted to collaborate with the automotive, insurance and health sectors to create ecosystems powering applications that deliver innovative solutions.

5.4 Conclusion

To date, government has harnessed the power of the API to make data more open and available to their citizens, and to themselves. The benefits range from increasing transparency, to enhanced efficiency of the existing service models. The private sector has harnessed APIs for a more transformative and disruptive

[61] https://www.mulesoft.com/press-center/salesforce-acquisition
[62] https://blogs.mulesoft.com/biz/api/how-much-is-an-api-worth/

end, giving rise to completely different business models, such as those which have made Netflix and Amazon great. The next section will deal with what the public sector may do in the future to disrupt itself in the face of increasing citizen demand, and cost pressures.

6. The future trends for API use in the Public Sector

In this section, we will identify current thinking on how the use of APIs may evolve over the next 3 to 5 years.

- **Growth Rate -** There is some evidence that the growth of APIs has slowed to some degree[63]. However, although the number of APIs may not be growing at the rate that was predicted a few years ago, their use and the ecosystems that they support continue to thrive.
- **Digital Government Platform growth requires APIs** - Predictions on the future trends in Digital Government from research companies such Forrester and Gartner indicate that Digital Government Platforms (interoperable, horizontal microservices that are orchestrated by RPA (Robotic Process Automation) software will become more prevalent in the 3-5 year window[64]. Digital Government Platforms require APIs as the integration mechanism to move data between component systems and therefore governments will continue to invest in switching from a service-oriented architecture (SOA) to a modular architecture (MASA) utilising APIs and micro-services.
- **Government will invest in Intelligent Things requiring APIs –** It is likely that governments will continue to increase investments in intelligent things, across many domains — from defence, policing, waste management, health, agriculture and smart communities[65] to enhance service delivery quality, and efficiency. Sensor and video networks, intelligent drones, fleets of automated vehicles, and robotic devices will become core to government service delivery capability and serve as a real-time data source for government, using APIs to transfer data among IT systems and layers.

  It is anticipated that the next progression will see the environment composed of many physical things with both sensor and computation capabilities, which make the technology direction pervasive and invisible[66].

  Applications will be capable of communication, cooperation, and negotiation with each other. Unlike general applications, agents will be designed with goals to be fulfilled on behalf of its users. That is, agents will take necessary actions efficiently towards its environment over the P2P protocol. For example, an agent can be designed to read a patient's biometrics from a patients wearable sensor devices and adjust thermostats to heat or cool a patient's room appropriately. In this way, the new platform is not limited to a certain set of devices, and it opens many possibilities over the P2P protocol to produce novel (multi-Agent) applications that enrich the idea of ubiquitous computing[67].

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[63] https://19yw4b240vb03ws8qm25h366-wpengine.netdna-ssl.com/wpcontent/uploads/theapieconomy.pdf
[64] (Gartner Paper) A Digital Government Technology Platform Is Essential to Government Transformation; Finnerty, Bill 2018
[65] (Gartner Paper) Top 10 Strategic Technology Trends for 2017: Intelligent Things; Mike J. Walker, Alexander Linden, David W. Cearley; 2017
[66] https://dzone.com/articles/how-iot-is-strengthening-ubiquitous-computing-part-2 and the paragraphs below
[67] https://en.wikipedia.org/wiki/Ubiquitous_computing

- **APIs as products** – APIs are products, and as such should have a product lifecycle from conception and improvement through to retirement. Government IT departments will continue to move away from APIs just being a technology to implement and forget. Given growing ecosystems dependent on APIs, communicating to third-parties, monitoring usage, and removing at an acceptable time (i.e. versioning) will be important.
- **API Standards** – The cost savings that can be realised by not having to redesign an API due to its 'drag and drop' portability seem compelling. The ability for applications and data sources to be able to link without the need for a bespoke API takes us one step closer to the ubiquitous platform of unbounded data. However, for many, knowing the specification of an API, and then getting to know the specific nuances of the API via the developer portal of an API provider seems to be a necessary, and perhaps keeps the developer community in work.
- **Citizen developers and Open APIs -** Open APIs make it very easy for citizens to make use of open data, or improve existing applications which leverage it. Hackathons will become more widespread as a way for the public sector to engage with citizens, helping member states to meet the aims that they have of conducting significant user research prior to releasing any citizen facing services or data[68] changes could potentially come faster than if we were to wait for the vendor to implement them. This process is very similar to open-source software, which is widely used and very helpful for developers.

6.1 Conclusion

The future of digital government seems deeply linked to the use of the APIs as enablers. As the technological demands of digital government move forward, it appears that APIs are well positioned to keep pace, and provide the access points needed to enable fast and secure data sharing to support government's needs from law and order, to healthcare and the environment. As with all aspects of technology, the use and development of APIs will evolve over time.

[68] https://resources.mygov.scot/standards/digital-first/

7. Case Study Insights

This section provides analytical insight and associated interpretation of the findings drawn from the case studies.

7.1 Case Study Analysis

Introduction

As noted in the methodology sub-section earlier in this section, the case studies that have been investigated cover a variety of different circumstances and dimensions so that this study can derive insight from a broad base of the API community. We recall them below.

They include:

- Interviews with parties focused on the high level vision, or strategy behind API use: Team Digitale (Italian Digital Transformation Team).
- Interviews with parties focused on using APIs as components of wider architectural platforms/ecosystems: Estonia X-Road, FIWARE Next Generation Service Interface v2 (NGSI).
- Specific APIs implementation: Madrid Mobility Labs, Amsterdam City Data API, Danish Address Web API (DAWA) and the Flanders Cable and Pipe Location Portal Web API (KLIP).

Collectively they cover:

- A range of member states in the north and south of the EU.
- A range of sectors and public services impacted (Transportation, Utilities, Smart City related public services, Gazetteers, Permits and more).

The eight case studies investigated provide the basis for this analysis section. The cases are introduced with a high level overview in the first sub-section below as they are covered in much more detail in the previous section. The remaining part of this section provides an analytical overview of case study findings in relation to the following headings:

- Functionality
- Governance
- Usage
- Technical Architecture
- Enablers
- Barriers & Risks
- Costs & Benefits
- Thoughts on EU involvement

It is recognized that it is not possible to draw direct comparisons where the case studies cover different dimensions. However, where relevant comments have been made by an interviewee they will be considered within the appropriate sections.

Functionality

Table 5 Summary of functionality of each case study

Ref	Name	Description
1	Estonia X-Road	Each government service/agency retains its own databases for use within the delivery of their own services, however, they all leverage the X-Road API management layer, including an API gateway to provide consistency, and simplification when securely sharing 'private and sensitive' data.
2	Future Internetware (FIWARE)	The FIWARE Next Generation Service Interface (NGSI) API provides the transport layer (i.e. it provides the mechanism for data exchange) between a large amount of contextual information (static and dynamic) to a solution, for example parking space availability in a multitude of car parks to a mobile phone app.
3	Team Digitale (Italian Digital Transformation Team)	As Italy's national source of advice and support for Digital transformation programmes, Team Digitale supports many Italian public sector agencies in the production of their own API solution, and therefore functionality differs depending on the requirement of what the API (if an API is needed at all) is to be used for. The aim of leveraging APIs as enablers is a lower total cost of ownership (TCO) and higher adoption of digital government services. As a nationally focused initiative, Team Digitale is concerned with creating APIs that operate cross-sector but not cross border.
4	Amsterdam City Data	The City Data API enables the user/developer to query data and have it shown in a map, downloaded as a data set, or use the API to gather data to be added to another system. It also allows civil servants to query data across departments.
5	Denmark Addresses Web API (DAWA)	DAWA has a lot of functionality that can be used in connection with addresses, e.g. functionality for searching with many different parameters, address entry with autocomplete, data mask of addresses, reverse geocoding and more. Used by citizens, business and government itself.
6	Madrid Mobility Labs	An ecosystem of APIs and a portal bringing information to citizens through multiple channels and applications for transportation related APIs such as Buses, Parking, Public bicycle, Traffic, City Hall Sensors, Third-party sensors and data.
7	KLIP	A Web API is used directly to manage both the demand for digital maps from large contractors, and from the citizens (via a user interface). A Web API is also used to supply maps to KLIP from utilities.

There are the following common areas of functionality.

- **Access to data**: The Estonia, Amsterdam and Denmark case studies all enable information being held in one system or department to be readily and securely available to another without significant and expensive development effort. The FIWARE API also allows for a solution provider to access a large contextual layer of information from which applications can be created for agencies and citizens. The FIWARE (in the Smart City context) and Madrid case studies are both more focused on processing of large amounts of dynamic/live data in conjunction with more static data such as timetables, or fixtures in the city environment such bins for example, and making that data available via API to developers who can create powerful mobile apps/websites etc. to inform citizens.
- **Map services**: KLIP, Madrid, Denmark and Amsterdam all have fundamental relationships with location data, providing the users with maps, and in some cases full address data. FIWARE is also very likely to be given that location is often an important component of the contextual information it harnesses. The functionality is however enhanced in the case of Amsterdam to enable permit applications for example, which use APIs to pre-fill forms for citizens, drawing in validated personal data, address data and other location data using a mapping API.

Governance

Table 6 Summary of governance arrangements

Ref	Name	Description
1	Estonia X-Road	The Estonian Government ISA (Information Services Team) are the product owners, they manage feature development and ecosystem management under an SLA. There is a user community group who are a vital part of the ecosystem management function comprising of representatives from the agencies and companies that use the service. Each API owner is responsible for their API access point.
2	Future Internetware (FIWARE)	The FIWARE Foundation is open: anybody can join contributing to a transparent governance of FIWARE activities. The FIWARE Community comprises all individuals and organisations contributing to achieve the FIWARE Mission. The FIWARE Community is not only formed by contributors to the technology (the Open Source Community working on the FIWARE platform), but also those who contribute in building the FIWARE ecosystem and making it sustainable over time. The FIWARE Technical Steering Committee governs the technical direction of the FIWARE platform and activities of the FIWARE Open Source Community. Governance of the rest of the activities carried out by members of the FIWARE Community is organized through the Mission Support Committee.
3	Team Digitale (Italian Digital	Currently API access is subject to direct legal agreements between both parties, however, new policies should allow an easier framework where

	Transformation Team)	technical agreements are based on adopting an API-first approach with Open API specifications.
4	Amsterdam City Data	Government governance structure in place for strategic and tactical planning. Business owners come directly to the City Data teams for new requirements. Permissions for API access where the APIs access is controlled is determined by the data providing organization.
5	Denmark Addresses Web API (DAWA)	There is no official roadmap for the API, although there is monitoring of the solution but operation and development is managed by AWS.
6	Madrid Mobility Labs	The company is private but 100% of the shares are public (Municipality of Madrid). Subjected to the control and decision of public sector. Forums, and contact forms are open for input from the external developers.
7	KLIP	There is a Steering Committee and a Working Group with representatives from both the supply and demand side. This group is responsible for the governance around the API and the rest of KLIP, inputting to the prioritisation of the product roadmap. The agency that develops and maintain KLIP goes to excavation sites, or contractor offices and utility companies, to understand their processes, 'not just sit in an ivory tower'.

Although most of the APIs are owned and provided by a central authority, they each, apart from DAWA, have user community based forums to assist with prioritising updates. No other compelling information was drawn regarding governance.

Usage

Table 7 Summary of target users and usage statistics for each case study

Ref	Name	Target users	Statistics
1	Estonia X-Road	▪ Agencies or authorised private sector participants such as banks, telecom providers and energy companies who want to deploy an X-Road gateway or security service to be able to participate in secure and private communications. ▪ Data sharing is now cross-border since health records are now shared with Finland via X-Road	▪ Over 1bn transactions ▪ 500m queries annually ▪ 925 institutions and enterprises connected, including 706 public sector institutions ▪ 99% of government services covered ▪ Circa 52,000 organisations as indirect users of X-Road services ▪ 1,642 interfaced information systems securely ▪ 346 servers installed by members
2	Future Internetware (FIWARE)	FIWARE targets organisations within 4 sectors ▪ Smart Cities	Used by many cities around the world (actually more than 110 from 24 different countries).

		▪ Smart Industry ▪ Smart AgriFood ▪ Smart Energy FIWARE is then used by developers to create usable solutions which may be free, or for profit	
4	Amsterdam City Data	▪ Developers ▪ Internal civil servants	▪ Requests per year: 350m ▪ Visitors per month: 8000, average time spent using the data interface: 20 minutes
5	Denmark Addresses Web API (DAWA)	▪ Developers ▪ Internal civil servants	▪ The number of API requests is limited to 100 requests per second ▪ There is approximately 5k IT systems which draw data regarding Danish addresses using DAWA. ▪ In 2017 there were 1.5bn requests and approximately 350k unique users per week
6	Madrid Mobility Labs	▪ Developers ▪ Citizens (indirectly)	▪ 2500 developers registered in the System. ▪ 40m hits are received per month.
7	KLIP	▪ Citizens ▪ Contractors ▪ Utility Companies	▪ 10713 registered Map Requester Initiators (MRI), made up of 1502 companies and 1258 citizens ▪ 216 Utility Network Authorities (UNA) ▪ 70 Public Domain Authorities (PDA) ▪ 200,000 map requests a year, for each request 6-7 utility company involved. ▪ 10m service requests via API each month (bigger number because the public API is fragmented. Order map requests for the zone, then the request itself, confirm you have it, answer the map request, are all separate services).

Our case studies from Estonia (500m/yr.), Amsterdam (350m/yr.), Denmark (1.5bn/yr.) and Madrid (480m/yr.) all demonstrate a huge volume of transactions passing through their APIs every year, delivering accurate data to other IT systems via developer built applications.

The end user, or the consumer, includes the citizen, the government, sharing information between agencies, and business. But, as indicated above, the APIs themselves are not targeted at the end user, they are essentially a tool that a developer can harness to query many different data types (live, static, location based etc.) in order to create a product (application) that presents the data to the citizen in the form that they need it. In the example of Madrid this could be in the form of a smart phone app that provides live bus data, and could, for example, show the 'minutes until the arrival of bus 44 at your favourite stop'.

Technical Architecture

Table 8 Summary of the technical architecture, specific to the APIs, of each case study

Ref	Name	Description
1	Estonia X-Road	▪ Specification: Originally built for SOAP/XML web services, X-Road now extends to REST APIs. ▪ Standard: Open source, but does not follow the OpenAPI standard. ▪ Authentication: Certificate based authentication.
2	Future Internetware (FIWARE)	▪ Specification: The FIWARE NGSIv2 is a RESTful API via HTTP which may support XML or JSON as representation format for request and response parameters. ▪ Standard: NGSI is Open source, and follows the OpenAPI standard[69]. ▪ Authentication: OAuth, Basic Authorisation, Token.
3	Team Digitale (Italian Digital Transformation Team)	▪ Specification: State of the art implementation of HTTPS should be mandatory in all cases including public non-authenticated APIs. XML remains prevalent in the existing integrations but moving to REST/JSON. SOAP only for legacy/interoperability purposes in G2G context. ▪ Standard: Swagger-v2 is used for current implementations, and OpenAPIv3 will be the new (enforced) standard. ▪ Authentication: It depends. eID currently based on SAML but we are in the process of adding OpenID Connect to it.
4	Amsterdam City Data	▪ Specification: SOAP WSDL designed to synchronise data, but moving towards REST APIs. REST APIs, WMS/WFS services and map tiles with access control for restricted data. ▪ Standard: OpenAPI. ▪ Authentication: OAuth 2.0.
5	Denmark Addresses Web API (DAWA)	▪ Specification: The REST API is open (HTTP, JSON) ▪ Standard: Open source, but not OpenAPI standard ▪ Authentication: No authentication is required.
6	Madrid Mobility Labs	▪ Specification: RESTFUL API or SOAP ▪ Standard: Open source, but not OpenAPI standard ▪ Authentication: Mostly simple and personal API KEY (email/password) previous register from portal. d. There are some session keys and token sessions.
7	KLIP	▪ Specification: 2007 - SOAP and only allowed map requests. 2015 onwards was a big release of a new more modern with REST API services rebuilt. Available on mobile and therefore the API had to handle mobile, so SOAP was not appropriate. ▪ Standard: JSON and XML, GML (extended from XML it is OGC standard for Geography Markup Language) and GeoJSON. ▪ Authentication: OAuth 2.0.

- **Restful vs SOAP architectures**: Although only a small sample, our case studies support the findings of our desk based research, i.e. that the adoption of RESTful APIs is fast becoming the

[69] https://github.com/Fiware/specifications

normal way in which to build APIs, superseding the WS* SOA solutions. They are used to help developers query both dynamic and live datasets for example relating to public transport information in Madrid, as well as static data (or data with a limited propensity to change) such as address data (Denmark) or WW2 bomb sites in Amsterdam.

- **Open APIs**: The majority of the APIs are public and open, except for those that provide the capability for civil servants only to access personal data (e.g. the secure parts of Amsterdam City Data). The adoption of standards such as OpenAPI for documenting APIs is, non-uniform among our sample case studies. Our Madrid based case study provided the clearest insight explaining that adhering to standard documentation can add a significant extra burden in order to be fully compliant and in many cases it simply isn't needed when following a known specification, and providing all information open source. Our interviewee for Estonia's X-Road platform also questioned the adherence to standards, and although he acknowledged they were a necessity he explained that in his view, they can lead to compromise and 'fuzzy edges', and ecosystems prefer to provide APIs in the way that suits them best based on a number of factors relating to time, budget, audience, purpose etc. rather than being constrained by a standard.
- **Authentication**: There was also a range of authentication in use, based on 'fitness for purpose' for the APIs they are controlling access to, this ranged from the use of OAuth 2.0, to certificate based permissions.

Enablers for development and success

Table 9 Summary of the enablers for development and success

Ref	Name	Description
1	Estonia X-Road	▪ Legislation – the Estonian Government passed legislation that made the use of X-Road mandatory.
2	Future Internetware (FIWARE) - NGSI API	▪ Although theoretical enablers exist for the FIWARE solution end to end, without any data on a successful implementation of the NGSI specifically it has not been possible to draw out any specific enablers.
3	Team Digitale (Italian Digital Transformation Team)	▪ Legislation - the national "Three Year Plan for Digital Transformation" that was signed by the Prime Minister in 2017.
4	Amsterdam City Data	▪ Government policy - to connect systems more easily to achieve transparency and efficiency has provided the necessary funding and urgency. ▪ Drive for innovation – desire to foster a developer led innovation in the City. ▪ Adopting REST and open source. ▪ Agile development method. ▪ User consultation.
5	Denmark Addresses	▪ Government policy - it is part of the "basic data program" (*Grunddataprogrammet*) initiated by the Danish government which has

	Web API (DAWA)	provided funding. ▪ Agile development method. ▪ Early involvement of users.
6	Madrid Mobility Labs	▪ Internal initiative, approved by the municipality. ▪ The willingness to let external developers to develop something more powerful than the applications developed internally. ▪ Provide their data additional use outside the transportation domain. ▪ No limits on the use of the data. ▪ In July 2016, EMT, with the collaboration of Medalab Prado, the FP7 COSMOS project, ESRI España and MongoDB launched the MobilityLabs hackathon, to select useful apps, based on EMT datasets and digital services, in the field of sustainable transportation in Madrid. MOBIAUTENTIA won the hackathon with a proposal on alternative public transportation and bicycle routes.
7	KLIP	▪ Creating a detailed financial model for investment and operational management. ▪ Conducting stakeholder management. ▪ Being a well-run project, using UX design / AGILE SCRUM development / automated testing / continuous integration. ▪ Setting up legitimacy first, by convincing users with a good ICT solution based on real user need, the later, enforce by law.

There are a number of common enablers emerging from our case studies.

- **Government Policy:** One of the most consistent enablers is government policy, motivated by the desire to provide the citizen, itself, and business with accurate data, and a single source of the truth avoiding inefficiency and providing transparency. It is likely that these member state motivations were themselves driven by the current EU directives from the Tallinn Declaration. In turn, this investment in APIs, and open APIs leads to cost savings, as well the stimulation of the local economy, encouraging digital skills to be enhanced to create commercial value.
- **Agile development methodologies:** Another common enabler was the adoption of agile development methodologies. Agile has allowed both Amsterdam, Denmark and KLIP to respond dynamically to changing needs. Amsterdam specifically commented on the difficulty caused by trying to develop a long term business case, then develop requirements and construct long term plans aligned with the traditional waterfall project delivery methodology. It had caused them to almost grind to a halt mired in bureaucracy. However, developing quickly, and adding value to both the citizens and the government itself in smaller steps, service by service, proved very successful and should be a 'lesson learned' to pass on to others who may be on a similar journey.

Barriers/Risks

Table 10 Summary of the barriers and risks for each case study

Ref	Name	Description
1	Estonia X-Road	▪ Initial difficulty in getting organisations to sign up until legislation imposed it.
2	Future Internetware (FIWARE)	▪ There is a crowded marketplace of providers and standard bearers. ▪ New competitive or innovative offerings coming to market. ▪ Standalone solutions. ▪ The size and scale of a solution such as FIWARE can make the

		implementation of the full specification a significant undertaking.
3	Team Digitale (Italian Digital Transformation Team)	▪ Lack of EU/National policies. ▪ Lack of consolidated ISO standards. ▪ Operational risks are mitigated leveraging HTTP standards and headers. ▪ Security risks on peculiar data are mitigated enforcing channel security with mutual PKI authentication.
4	Amsterdam City Data	▪ Compatibility: Some software packages still talk SOAP standards, not REST API. ▪ Local government are sometimes commercially constrained, and not always free to choose. ▪ Privacy by design and Security by design are core, and essential but this requires skills and capabilities. There is a need for an investment in-house to excel in this space.
5	Denmark Addresses Web API (DAWA)	▪ There is always a risk that an API will not be used. To minimize the risk DAWA has been attractive by providing correct data. It is easy to use, quick response times and high availability. ▪ A risk going forward can be the maintenance of funding.
6	Madrid Mobility Labs	▪ The non-existence of standards at European level is a barrier. ▪ The current risks have to do with two aspects: the first is always security, derived from the exposure of processes through the Internet, the second is the quality and speed of response, which is always linked to the constant growth in the number of uses of the API.
7	KLIP	▪ Legal concerns around privacy. Some data is not supposed to be public and should not be included on maps like the location and attributes of NATO pipelines. ▪ Stakeholder management can be challenging, many of the commercial organisations that are forced by law to participate in KLIP are both providers and consumers of KLIP data map outputs. Our interviewee remarked the strong effort needed to mediate and find an agreement with the data providers. In some cases, they were reluctant to provide their data because of the importance to guarantee high quality standard, immediate updates, accountability and reliability for them. Also, competitors are not always keen in sharing their information among them. And this these are the reasons for which it was not possible to create a central database for KLIP.

One case study interviewee (DAWA) mentioned that to maintain the quality of the service (API lifecycle management) provided by the API infrastructure there is the need to guarantee an annual budget dedicated to it. This is likely due to the fact that the return on investment achieved due to the provision of an API means that it is self-funding several times over.

Both Madrid and Team Digitale[70] mentioned that the lack of European standards was a barrier, and this will be revisited below in the 'Thoughts on areas for EU involvement' sub-section. However, the adoption of a

[70] The Team Digitale also strongly agree where the text says (see section 2.8.5):"*a standard recommended by the EU would be beneficial, but that it must be kept 'light-weight' and not try to be all encompassing*"

standard/specification can also be seen as a barrier, too (e.g. FIWARE) because (maybe) of the learning curve and constraint to be imposed to the IT system. An equilibrium has to be found: making standards is good, but it must not be too difficult to adopt.

Security was a common talking point with all respondents with regard to risk. Those that deal with sensitive personal data were unsurprisingly worried about the potential for unauthorised access to things such as health records, and as a result had invested in securing their APIs.

Whilst versioning is often regarded as an ongoing issue for both providers, and consumers, it was not specifically cited as concern within these interviews. Although the cost of ongoing maintenance is not insignificant, it is small when compared with RoI. It is perhaps possible that versioning and its associated costs were not brought up because of this.

Cost and Benefits

Table 11 Summary of the costs and benefits for each case study

Ref	Name	Costs	Benefits
1	Estonia X-Road	▪ X-Road is a distributed system and therefore it is difficult to understand the true full Total Cost of Ownership. The initial investment was in the region of EUR300,000, i.e. six man years of development	▪ If 8% of requests on X-Road are submitted by human users, and assuming that every request saves 15 minutes - those requests have saved 800 year of working time every week. ▪ Improves the quality of existing services and products ▪ Enables new types of service innovations ▪ Savings in infrastructure, archiving and other costs ▪ Standardised data security and privacy protection ▪ Easy implementation, data access via interfaces – after connecting all included services are available
2	Future Internetware (FIWARE)	▪ Cost to develop FIWARE as a whole: FIWARE is a public/private partnership funded by EUR300m from the EU, EUR100m from private enterprise membership model, and EUR100m from Venture Capital ▪ FIWARE NGSI is open source, and therefore there is no cist for the source code, but the configuration will no doubt be expensive. No 'live' implementations were questioned (or found). There are dozens of live implementations available (Santander, Porto, Lisbon, Bristol, Vienna, Montevideo, ...)	▪ 'Off the shelf' architecture with fully documented and standardised APIs reduces investment costs ▪ Creates an environment of innovation, stimulating commercial application development ▪ Efficient public services ▪ Better informed citizens ▪ The open source approach allows adopters to avoid vendor lock in

4	Amsterdam City Data	▪ Budget of EUR6m over 3 years ▪ Developers is the most significant cost ▪ Infrastructure is less than 5% - hosting cost/month is around EUR8k	▪ 2000 civil servants are using it for 10-30 mins a day, saving an estimated 1-2 hours in terms of looking for data. ▪ Estimate 1.5 hour saving, equates to a saving of 88,000 working days a year, or 400 working years every year.
5	Denmark Addresses Web API (DAWA)	▪ Initial development cost: 2 million DKK (EUR270k) ▪ Operational cost: 1 million DKK per year (includes AWS)	▪ There is an economic benefit by ensuring correct address data. ▪ Business case savings are 250 million DKK (EUR33.5m) per year ▪ It stimulates new uses of address data and functionality
6	Madrid Mobility Labs	▪ Maintenance: 60k Euro yearly (1person/y ▪ Development 3 to 4 months (1st version) ▪ Portal development 6 person months	
7	KLIP	▪ Ongoing costs of: 1.9m EUROS budget is funded from map revenues	▪ Business case they calculate the benefits and cost of going fully digital. Result was an estimated cost reduction of 80% for going fully digital.

The analysis of this section will be split into smaller paragraphs, summarising the key findings:

- **Return on Investment**
    - Analysis of the benefits information obtained from our case studies indicates that APIs, and the solutions that they enable, are delivering a sizable return on investment. For a modest outlay, these organisations are able to deliver benefits that lead to significant efficiency savings in public service delivery, and inform citizens and business in a way that can further lead to time and money savings. For example, both Amsterdam (400 working years/yr. saved) and Denmark (EUR33.5m/yr.) have business cases which are directly enabled by their APIs. Benefits may also be non-financial, and this is also explored within this section.

- **Benefits in relation to Smart City API adoption**

    At local government level several API initiatives have been observed to facilitate smart city initiatives:

    - Organisations which adopt FIWARE are taking an 'off the shelf' architecture with the benefit of fully documented and standardised APIs. This significantly reduces the investment that an organisation would need to invest if starting from scratch.
    - Provisioning this technology environment from which 'smart solutions' can be based creates an environment of innovation, stimulating the activities of developers who will build commercial, and non-commercial products (applications, websites etc.). This can make a

city or region attractive to a particular skills base caused by the adoption of smart technologies, attracting individuals and organisations to work and invest there.

- It also means that public services can be delivered more efficiently based on data, for example, using sensors in conjunction with location data and APIs to schedule bin collections when they are full only. Citizens and businesses are also better informed and make better decisions when information is at their fingertips through API enabled apps. Examples include being able to park more quickly, or choosing the optimal mode of transport, or transport route, to get to work, or to deliver goods and services. A further step in the logic suggests that getting to work without delay, or being able to deliver a business or public service has other related benefits such as enhancing the productivity of a city by reducing time lost to congestion for example. An opportunity for further study may be to determine if the use of public transport is increased when citizens have real/right time data available on journey times to provide more confidence that a train or bus will deliver them to their destination when they need it to.
- It may also enhance the safety of a city, helping to inform emergency services.
- Although Madrid Mobility Labs have also developed their own APIs (not conforming to OpenAPI, or an 'off the shelf product' like FIWARE) to power the dissemination of transport related data to citizens, they have also driven very similar benefits. Furthermore, they have also identified non-financial benefits, one specific example is being able to use sensors to inform citizens about pollen and other allergens that exist on various transport routes thus enhancing comfort and health when on the move.

- **General benefits in relation to achieving the EU Principles as laid out in the Tallinn Declaration - digital-by-default, inclusive and accessible, seek citizen and business data 'once-only', be trustworthy and secure, open and transparent, and interoperable by default.**

    - Our case studies in Estonia, Amsterdam and Denmark are each concerned with a number of related factors which are collectively helping these governments to address the member state commitments to be digital-by-default, inclusive and accessible, seek citizen and business data 'once-only', be trustworthy and secure, open and transparent, and interoperable by default. Each of them provide API based access to accurate data that is collected once only by government from citizens, and business, and shared securely between authorised groups.
    - Making accurate data available for government to use reduces the time that civil servants need to spend validating the accuracy of claims for permits or subsidies for example. Both in Estonia and Amsterdam, the time saved is substantial with Estonia claiming that the X-Road solution saves 800 working years every week. Estonia, Amsterdam and Denmark all state that accurate data, requested once and validated for future use (rather than re-requested which opens up more opportunity for error, or the purposeful provision of incorrect data) enhances service quality because the base data can be relied upon, especially when pulled through as base data for other services to be layered upon (e.g. validated address data).

- It also reduces the time required by the citizen to make an application. APIs can be used to pre-fill forms (Amsterdam) using personal data on record, and location data via a mapping API in a standard and machine readable format. Submitting an application for a building permit or parking permit can be quicker, and the time taken previously to agree on locations, and to confirm the applicant's identity are reduced to a minimum. The potential to build AI (Artificial Intelligence) and Robotic Process Automation (RPA) based solutions provides further possibilities for more efficiency in the future.
- Openness of data is a key in the Danish case. This helps to provide transparency on what a government is doing and achieving. Citizens must be able freely to access government data and information and to share that information with other citizens. Open data also releasing social and commercial value. As noted above in the Smart City section, in a digital age, data is a key resource for social and commercial activities. Open data held by government can be leveraged by developers which drives innovation and a desire to create commercial solutions.
- Openness of the source code is also a benefit, and was specifically highlighted by the FIWARE case study, but is relevant across the board. The open source approach to API development allows adopters to avoid vendor lock in to a closed source/proprietary solution. Being reliant on a supplier for costs changes to adapt APIs, to continue to invest and develop in APIs, especially if it sits at the very heart of the citizen service offering is a risk.
- Interoperability is probably best demonstrated by the Estonian X-Road solution which is now underpinning the sharing of health record data between two Estonia and Finland. This is the only true cross-border case within this study.

In summary, from this investigation, it can be seen that APIs represent a middleware that makes it possible for both internal and third party developers to build secure and reliable applications, often for citizens, and often commercially. They provide significant benefits to four key aspects essential to the programmable economy[71]:

(i) The quality of available data. When providing an API, the provider must have certain data quality standards and controls in place given the data is often used to inform behaviours of citizens and business in some way. The provider must manage and assure versioning, 24h availability of the service, and more.

(ii) The independence between the data layer and the service layer. The provider is free to change, for example the backend (e.g. the DBMS) in a transparent way for the developers.

(iii) Stimulate economic growth. The growth in the application developers and development companies themselves goes some way to creating economic growth in a region that is undergoing digital transformation. Additionally, economic growth is also stimulated by the opportunities the APIs offer

[71] https://www.gartner.com/newsroom/id/3146018

in the G2B market. As this partnership between government and business grows, APIs will enable the creation of ecosystems allowing the private sector to take on service delivery seamlessly.

(iv) Stimulate innovation. Innovation is the partner of economic growth. Innovation and disruption to traditional markets is driven by smart companies (e.g. start-ups) developing innovative services by combining APIs from different and heterogeneous resources into products that can be sold. For example, at Madrid Mobility Labs, more than 2000 developers are registered in the platform community, and between them they have created around one hundred mobile applications.

Thoughts on areas for EU involvement (specifically standardisation)

Table 12 Summary of thoughts on areas for EU involvement from each case study

Ref	Name	Description
1	Estonia X-Road	▪ Make EU Directorates DGs leveraged pre-existing solutions. ▪ Consider identical member state gateways to access data. ▪ Merely agreeing on standards: leads to compromise and fuzzy edges, standards are necessary but not sufficient.
2	Future Internetware (FIWARE)	▪ The development of FIWARE has been funded under FP7 and Horizon 2020. ▪ The use of FIWARE in new EU projects is actively supported by DG CNECT and DG ENERGY ▪ The core component of FIWARE, the 'FIWARE Context Broker' has been elected by all member states as a new CEF Building Block to make the Digital Single Market of the EU a reality.
3	Team Digitale (Italian Digital Transformation Team)	▪ The EU currently provides interoperability guidelines only for G2G cross-border in specific context, for example AS-4 standard and the OASIS stack for eDelivery. A European recommendation for APIs open to the private sector would be really useful to encourage this trend. ▪ Stronger "API-first" policy would be useful. ▪ EU documents reference some RFC like JW[TSE] but there's still no platform/reference architecture based on that. ▪ EU documents on interoperability are over-engineered and difficult to be applied, for example EIRA framework. A much more down-to-earth approach is suggested. ▪ Lack of EU/National policies.
4	Amsterdam City Data	▪ Anything that the EU does come forward with must be an agile, lightweight approach. ▪ Facilitating open source communities to enhance sharing of code.
5	Denmark Addresses Web API (DAWA)	▪ There is a need to create IT standards – but not too detailed, i.e. flexible and high level.
6	Madrid Mobility Labs	▪ It would be very interesting to have standards (API for transport) at European level.
7	KLIP	▪ Keep it lightweight. Must be kept as simple as possible ▪ Avoid being too theoretical. Some data models that have come from

		EU have been complex, avoid this when designing the API documentation. ▪ Do not try to cover all use cases or it becomes too complicated.

There is an overwhelming commonality in the responses received on the question of whether the EU should promote, or get involved in shaping, API standards. The answer is a yes, but caveated by some recurring themes – anything that is put forward should be:

- ‘Lightweight’, ’flexible’ and ‘easy to understand’. Detailed documents which are theoretical can be impenetrable and are likely to put technologists off implementing them.
- Should not seek to be all encompassing, and try to cover every use case and eventuality, i.e. stay at a high level.
- Each member state should consider a support arrangement to assist local implementations.

The respondents from Team Digitale and KLIP all commented that the EU has previously created models such as the European Interoperability Reference Architecture (EIRA)[72] which have been large, and complex.

Team Digitale also commented about the need for an API standard to include the private sector. The EU currently provides interoperability guidelines only for G2G cross-border in specific context, for example AS-4 standard and the OASIS[73] stack for eDelivery. A European recommendation for APIs open to the private sector would be really useful to encourage this trend.

7.2 Conclusions

APIs are an important component in successful sharing of personal and sensitive data

- APIs are being used successfully to share secured sensitive data internally, and externally (within some processes) delivering real efficiencies and savings (RoI) to agencies, and improving the delivery of services to citizens with high digital expectations. Relevant case studies: Estonia and Amsterdam.

- Providing the direct link between validated data sources also means that APIs improve the quality of the data provided to ecosystems.

- Our case studies show strong returns on investment, stimulating the economy, and adding accuracy to public services.

  (Relevant case studies: Madrid, Denmark, Amsterdam)

[72] https://joinup.ec.europa.eu/solution/eira/about
[73] http://ebxml.xml.org/news/as4-profile-of-ebms-30-becomes-oasis-standard

Security & Privacy must be proactively managed

- Security and privacy are both important considerations when sharing personal and sensitive data via APIs. There is a need for public sector bodies to ensure that they are 'on top of this' which can be challenging with public sector resources.
- APIs also provide another gateway into internal systems for cyber denial of service attacks (DoS).

Agile methods are more appropriate for API development

- Based on our case studies, the development of APIs as part of data sharing initiatives has been shown to work best when adopting an agile methodology, delivering value quickly and iteratively rather than gathering detailed requirements and planning extensively.
- Versioning can be difficult to manage, and can give rise to developers using other sources of data where versioning is handled more sympathetically.

Standards are not currently perceived as facilitators

- API standards are not always appropriate due to the extra rigor/volume required.
- Many case study interviewees have commented that a standard recommended by the EU would be beneficial, but that it must be kept 'light-weight' and not try to be all encompassing.
- They also suggested that language barriers can be daunting for technical personnel.
- In some cases, it has been observed that building using an API standard appears not to have a direct impact on the success of the API.
- APIs that support both cross-sector and cross border data sharing may not need to be standardized. Although standards do enhance interoperability, the use of an API gateway may mitigate this as per the way it is used by X-Road. An API gateway's front-facing nature allows the gateway to provide for new languages while the hidden APIs remain untouched, rather than updating multiple APIs separately.[74]

Location data adds context

- Location data is regularly exploited by the public sector given a large part of their role is administering land (boundaries, gazetteers etc.) and granting permits etc. APIs in conjunction with maps for example can provide accuracy and speed to decision-making – (Amsterdam).
- Location data adds context, and can be particularly powerful when used in conjunction (or mashed up) with other sources of context, such as IoT sensor data.

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[74] https://whatis.techtarget.com/definition/API-gateway-application-programming-interface-gateway

Private Sector comparison/lessons

- APIs can/will support revenue generation, and service delivery sharing. APIs will enable closer co-operation with the private and third sectors to share service delivery more easily.

8. Conclusion

This study set out to explore the API landscape in the EU public sector. The purpose of the study has been to identify areas in the ability of APIs to assist member states with enabling their digital transformation. Areas of specific focus include aspects such as cross-border interoperability between member states, and the opportunity for the EU to become involved in developing or advocating API standards. To deliver the insight required both desk based research and structured interviews with public sector organisations that have developed successful APIs were carried out.

The report provides a useful baseline overview of APIs, considering what they are used for, the different types of API that can be leveraged, and the API standards that exist. A glossary of terms and API types in the appendices provide further resources for the target audience. The report then goes on to consider how APIs are used in the public sector. The findings showed that APIs are used by the public sector to help them achieve their goals in four main ways:

1. Enabling ecosystems.
2. Overcoming complex integration of large systems.
3. Supporting Open Government initiatives.
4. Enabling innovation and economic growth.

The use of APIs is not without its challenges however. This study highlighted security and enhanced EU regulation around privacy as considerations for API owners. An API is another gateway into a computer network and associated data, and requires the security features and ongoing maintenance that such an interface deserves.

The lack of standards (except in the geospatial/mapping space where the OGC has many) was also considered, both in the desk based research and the interviews conducted. In summary, the lack of standards does in some way hinder interoperability both internally and externally to government agencies. It is forcing organisations to develop their own set of guidelines to ensure alignment, and this is something that the UK Government have recently released to all API developers[75]. However, the use of API gateways, and the predominance of RESTful architectures is in some way diluting the pressure for a standard. When case study interviewees were questioned on the potential role of the EU in developing a standard they saw the benefit, but were also cautious. Respondents were keen that anything that the EU developed, or advocated was 'lightweight' and did not try to be all encompassing and theoretical.

The study also considers the relationship between APIs and location data. It concludes that APIs provide access to various aspects of location data, and assist in retrieving a variety of data points which when 'mashed' with other contextual data can provide a powerful tool for the state, or the citizen. Many use cases

[75] https://www.gov.uk/guidance/gds-api-technical-and-data-standards

are in operation in spheres such as weather, emergency resilience, Smart Cities, and Gazetteers to name only a few.

Differences with the private sector were also considered. The report found that to date, government has (in the main) harnessed the power of the API to make data more open and available to their citizens, and to themselves. The benefits range from increasing transparency, to enhanced efficiency of the existing service models. The private sector has harnessed APIs for a more transformative and disruptive end, giving rise to completely different business models, such as those which have made Netflix and Amazon leaders in their field.

Our research also considered the future of government, which will be to some extent built on the API as a key enabler. As the demands of government move forward, it appears that APIs are well positioned to keep pace, and provide the access points needed to enable fast and secure data sharing to support government's needs from law and order, healthcare and the environment.

Our case studies provided many interesting insights into successful API adoption. Many noted the importance of the use of Agile methods, and the impact of legislation/policy to stimulate uptake and development of APIs which have given rise to substantial benefits. The benefits were probably the most revealing aspect to this part of the study, providing compelling evidence that solutions with APIs at their core such as Estonia X-Road, Amsterdam City Data Web API and Danish Address Web API are providing substantial returns on investment, in the case of X-Road this amounts to 800 person/years being saved every year. Not only does this give rise to more efficient public services, it helps government keep pace with citizens expectations.

Finally, in line with its purpose, the study suggests a number of further topics be considered. The most significant is in relation to the development of an EU API standard. This is clearly an area that can deliver benefit, and has support (based on our limited study), however, there are some key design principles that would need to be explored with a wider audience as a next step – and this audience must include API consumers and providers, not be developed in isolation or academically. Other areas for consideration are regarding the economic stimulation provided by APIs, and the way in which APIs will play a role in the future of government enabling wider ecosystems incorporating the private sector, and the exploitation of disruptive tools such as AI and Robotics.

Bibliography

- Amsterdam City, Overview of all available (open) data in Amsterdam, https://amsterdamsmartcity.com/projects/dataamsterdamnl
- Amsterdam City, Present open council information such as proposals, minutes, resolutions and voting results as reusable open data., https://amsterdamsmartcity.com/projects/open-raads-informatie
- API Platform, The API Platform Framework, https://api-platform.com/
- APIgee, The Cross-Cloud API Platform, https://apigee.com/api-management/#/homepage
- Autentia, #MobiAutentia gana el hackathon de MobilityLabs, https://www.autentia.com/2016/09/20/mobiautentia-gana-el-hackathon-de-mobilitylabs/
- Borschette, A. (2017) Data access and transfer with a focus on APIs and industrial data platforms(EC workshop). Brussels, European Commision. http://ec.europa.eu/information_society/newsroom/image/document/2017-32/report_final_for_web_C285AA6E-0C77-373C-999BF6DFBCC3F995_46252.pdf
- CitySDK, Smart Parking in Amsterdam, https://www.citysdk.eu/amsterdam-jumps-the-park-shark/
- CKAN, About CKAN, https://ckan.org/about/
- CKAN, API guide, http://docs.ckan.org/en/latest/api/index.html
- Danmarks Adressers Web API, API documentation, http://dawa.aws.dk/dok/api
- Danmarks Adressers Web API, Danmarks addresser, http://dawa.aws.dk/
- Danmarks Adressers Web API, Dataformater, http://dawa.aws.dk/dok/api/generelt#dataformater
- Definitions.net, API, https://www.definition.net/define/api
- Deloitte Insights, API imperative: From IT concern to business mandate: Tech Trends 2018, https://www2.deloitte.com/insights/us/en/focus/tech-trends/2018/api-program-strategy.html
- Digital Transformation Team, Digital innovation for citizens and for the development of the country, https://teamdigitale.governo.it/en/
- DZone IoT, How IoT Is Strengthening Ubiquitous Computing (Part 2), https://dzone.com/articles/how-iot-is-strengthening-ubiquitous-computing-part-2 and the paragraphs below
- E-Estonia, X-Road, https://e-estonia.com/solutions/interoperability-services/x-road/
- Esri España, Una app de cálculo de rutas saludables y accesibles gana el ‘hackatón’ de EMT, http://www.esri.es/una-app-de-calculo-de-rutas-saludables-y-accesibles-gana-el-hackaton-de-emt/
- EU General Data Protection Regulation, GDPR Portal: Site Overview, https://www.eugdpr.org
- European Commission, European legislation on the re-use of public sector information, https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information
- European commission, FIWARE Final report - A New Model for EU Innovation Programmes, https://ec.europa.eu/digital-single-market/en/news/fiware-final-report-new-model-eu-innovation-programmes
- European Commission, Ministerial Declaration on eGovernment - the Tallinn Declaration, https://ec.europa.eu/digital-single-market/en/news/ministerial-declaration-egovernment-tallinn-declaration
- European Commission, Payment services (PSD 2) - Directive (EU) 2015/2366, https://ec.europa.eu/info/law/payment-services-psd-2-directive-eu-2015-2366_en
- European Commission, The “Once-Only” Principle (TOOP) Project launched in January 2017, https://ec.europa.eu/digital-single-market/en/news/once-only-principle-toop-project-launched-january-2017
- European Data Portal, API version 3, http://www.europeandataportal.eu/data/en/api/3
- European Data Portal, Use Cases, https://www.europeandataportal.eu/en/using-data/use-cases
- European Data Portal, Virtuoso SPARQL Query Editor, http://www.europeandataportal.eu/sparql

- European Payments Council, How can Application Programming Interface standardisation be achieved in the context of the revised Payment Services Directive? https://www.europeanpaymentscouncil.eu/news-insights/insight/how-can-application-programming-interface-standardisation-be-achieved-context
- European Public Sector Information Platform, Understanding the European Data Portal, https://www.europeandataportal.eu/sites/default/files/2016_understanding_the_european_data_portal.pdf
- European Union, EU funding, https://europa.eu/european-union/about-eu/funding-grants_en
- Federal Technology Insider, Government Agencies Leading App Economy Using Innovation Drive Economic Growth, https://federaltechnologyinsider.com/government-agencies-leading-app-economy-using-innovation-drive-economic-growth/
- Finnerty, Bill. A Digital Government Technology Platform Is Essential to Government Transformation. Gartner Research, 23 January 2018, ID G00344044
- Finnerty, Bill. Three Geospatial and Location Intelligence Use Cases to Meet Governments' Biggest Challenges, 27 November 2017, ID G0033846
- FIRMWARE Foundation, What is FIWARE Foundation?, https://www.fiware.org/foundation/
- FORECA, Weather Warnings – Data feed of the governmental severe weather warnings, https://corporate.foreca.com/en/weather-data/weather-warnings
- freeCodeCamp Medium, REST APIs are REST-in-Peace APIs. Long Live GraphQL., https://medium.freecodecamp.org/rest-apis-are-rest-in-peace-apis-long-live-graphql-d412e559d8e4
- Github, FIWARE-NGSI v2 Specification, http://fiware.github.io/specifications/ngsiv2/stable/
- Gov.uk, API technical and data standards, https://www.gov.uk/guidance/gds-api-technical-and-data-standards
- Government Digital Service, Identifying the challenges of designing cross-government APIs, https://gdstechnology.blog.gov.uk/2018/01/29/identifying-the-challenges-of-designing-cross-government-apis/
- GraphQL, Describe your data, https://graphql.org/
- HCL Technologies, API-fication Core Building Block of the Digital Enterprise – White Paper, https://www.hcltech.com/white-papers/systems-integration/api-fication-core-building-block-digital-enterprise
- Holgate, Rick., Howard, Rick. Transitioning to Digital Government Primer for 2018, Gartner Research, 9 January 2018, ID G00344026
- How Much is an API Worth?, https://blogs.mulesoft.com/biz/api/how-much-is-an-api-worth/
- https://amsterdamsmartcity.com/projects/dataamsterdamnl
- INSPIRE, INSPIRE Video, https://inspire.ec.europa.eu/
- IoT Agenda, A world with more IoT standards bodies than IoT standards, https://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/A-world-with-more-IoT-standards-bodies-than-IoT-standards
- ISO, ISO standard for APIs – Whitepaper, https://www.iso20022.org/news/iso-standard-apis-whitepaper
- JRC Technical Reports, European Union Location Framework Blueprint, https://joinup.ec.europa.eu/sites/default/files/custom-page/attachment/2017-10/EULF-Blueprint-v6.pdf
- KLIP Web API documentation, https://klip.vlaanderen.be/apiLaboratorios para la Movilidad de Madrid, Bienvenidos al Laboratorio Abierto para la Movilidad de Madrid, https://mobilitylabs.emtmadrid.es/portal/
- Laboratorios para la Movilidad de Madrid, Hackatón 2016, https://mobilitylab.emtmadrid.es/portal/index.php/hackaton-2016/ (deprecated)
- Lacheca, Dean. Accelerate Data-Centric, Digital Government With a Proactive API Program. Gartner Research, 9 December 2016, ID G00320208

- Linden, Alexander., Cearley, David W., Walker, Mike J. Top 10 Strategic Technology Trends for 2017: Intelligent Things. Gartner Research, 21 March 2017, ID G00319575
- Malinverno, Paolo. The API Economy: Turning Your Business Into a Platform (or Your Platform Into a Business). Gartner Research, 12 June 2017, ID G00280448
- mygov.scot resources, Digital First Service Standard, https://resources.mygov.scot/standards/digital-first/
- Nordic Apis, API Discovery: 15 Ways to Find APIs, https://nordicapis.com/api-discovery-15-ways-to-find-apis/
- Nordic APIs, API Platform Defined: When an API Provider is a Platform, https://nordicapis.com/api-platform-defined-api-provider-is-a-platform/
- Nordic APIs, The API economy, https://19yw4b240vb03ws8qm25h366-wpengine.netdna-ssl.com/wp content/uploads/theapieconomy.pdf
- O'Neill, Mark., Moyer, Kristin R., Malinverno, Paolo. From APIs to Ecosystems: API Economy Best Practices for Building a Digital Platform. Gartner Research, 13 July 2017, ID G00331662
- OGC e-Learning, Introduction to OGC Standards, http://cite.opengeospatial.org/pub/cite/files/edu/ogc-standards/text/services-ogc.html
- OGC, OGC® Standards and Supporting Documents, http://www.opengeospatial.org/standards
- Open and Agile Smart Cities, List of Cities, http://oascities.org/list-of-cities/
- Open Geospatial Consortium, OGC® Open Geospatial APIs - White Paper, http://docs.opengeospatial.org/wp/16-019r4/16-019r4.html
- Ordnance Survey, OS Places API, https://developer.ordnancesurvey.co.uk/os-places-api
- Organisation for Economic Co-operation and Development, Open Government, http://www.oecd.org/gov/open-government.htm
- Phil Sturgeon, GraphQL vs REST: Overview, https://philsturgeon.uk/api/2017/01/24/graphql-vs-rest-overview/
- ProgrammableWeb, APIs, Mashups and the Web as a platform, https://www.programmableweb.com/
- ProgrammableWeb, Search the Largest API Directory on the Web, https://www.programmableweb.com/apis/directory
- Rapid API, Find and Connect to the World's Top APIs, https://rapidapi.com/
- Republic of Estonia Information System Authority, Data Exchange Layer X-Road, https://www.ria.ee/en/x-road.html
- ROE EDIS – Premium Services, ADPR* Status Report, https://hisz.rsoe.hu
- SlidePlayer, AWS Suiten, http://slideplayer.dk/slide/2682837/
- TechTarget, MIT License (X11 license or MIT X license), https://whatis.techtarget.com/definition/MIT-License-X11-license-or-MIT-X-license
- The White House President Obama Archives, Open Government Initiative, https://obamawhitehouse.archives.gov/open
- Vrijeparking.be, Overzicht Parkings Stad Gent, https://www.vrijeparking.be/stad/gent
- Wikipedia, Common Alerting Protocol, https://en.wikipedia.org/wiki/Common_Alerting_Protocol
- Wikipedia, Ubiquitous computing, https://en.wikipedia.org/wiki/Ubiquitous_computing
- WSO2, A Platform for Digital Transformation, https://wso2.com/whitepapers/a-platform-for-digital-transformation

Appendix I – Types of API

API Type	Example Data Formats	Description?
Web APIs	SOAP over HTTP/S	SOAP is a protocol that defines the communication method, and the structure of the messages. The data transfer format is XML. A SOAP service publishes a definition of its interface in a machine-readable document, using WSDL – Web Services Definition Language
	XML-RPC over HTTP/S	XML-RPC is an older protocol than SOAP. It uses a specific XML format for data transfer, whereas SOAP allows a proprietary XML format. An XML-RPC call tends to be much simpler, and to use less bandwidth, than a SOAP call.
	JSON- RPC over HTTP/S	JSON-RPC is similar to XML-RPC, but uses JSON instead of XML for data transfer
	REST over HTTP/S	REST is not a protocol, but rather a set of architectural principles. Some of the characteristics required of a REST service include simplicity of interfaces, identification of resources within the request, and the ability to manipulate the resources via the interface. The most commonly-used data format is JSON or XML. Often the service will offer a choice, and the client can request one or the other by including "json" or "xml" in the URL path or in a URL parameter. In a well-defined REST service, there is no tight coupling between the REST interface and the underlying architecture of the service. This is often cited as the main advantage of REST over RPC (Remote Procedure Call) architectures.
	GraphQL	GraphQL is a data query language developed internally by Facebook in 2012 before being publicly released in 2015. It provides an alternative to REST and ad-hoc webservice architectures. While typical REST APIs require loading from multiple URLs, GraphQL APIs get all the data an app developer needs in a single request enhancing speed of response even on slow mobile network connections
Library based APIs -	JavaScript APIs, TWAIN, Twilio	To use this type of API, an application will reference or import a library of code or of binary functions, and use the functions/routines from that library to perform actions and exchange information.
Class-based APIs (object oriented) – a special type	Java API	These APIs provide data and functionality organised around classes, as defined in object-oriented languages. Each class offers a discrete set of information and associated behaviours, often

of library-based API		corresponding to a human understanding of a concept.
Object remoting APIs	CORBA	These APIs use a remoting protocol, such as CORBA – Common Object Request Broker Architecture. Such an API works by implementing local proxy objects to represent the remote objects, and interacting with the local object. The same interaction is then duplicated on the remote object, via the protocol