European Interoperability Landscape Report 2022

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Terms and Abbreviations

AISBL - Association Internationale Sans But Lucratif (International not-for-profit Association).

AP - Access Points.

BRIS - Business Registers Interconnection System.

CEF - Connecting Europe Facility.

CIP - Competitiveness and Innovation Framework Programme.

CITIS - Center of IT Impact Studies.

DEP - Digital Europe Programme.

DSM - Digital Single Market.

EC - European Commission.

e-CODEX - e-Justice Communication via Online Data Exchange.

EESSI - Electronic Exchange of Social Security Information.

EFTA - European Free Trade Association.

eHDSI - e-Health Digital Service Infrastructure.

eID - Electronic Identification.

eIDAS - Electronic Identification, Authentication and Trust Services.

EIF - European Interoperability Framework.

EIRA - European Interoperability Reference Architecture.

EPSOS - Smart Open Services for European Patients.

e-SENS - Electronic Simple European Networked Services.

EU - European Union.

EUCARIS - European Car and Driving License Information System.

ICT PSP - ICT Policy Support Programme.

IDA - Electronic Interchange of Data between Administrations

IDABC - Interoperable Delivery of Pan-European eGovernment Services to Public Administrations, Business and Citizens.

ISA - Interoperability Solutions for Public Administrations, Businesses and Citizens.

LSP - Large Scale Piloting.

MS - Member States.

NIIS - Nordic Institute for Interoperability Solutions.

NSG - Nordic Smart Government.

OOTS - Once Only Technical System.

PEPPOL - Pan-European Public Procurement On-Line.

SDG - Single Digital Gateway.

SDGR - Single Digital Gateway Regulation.

SMP - Service Metadata Publisher.

Sitra - The Finnish Innovation Fund.

SMP - Service Metadata Publisher.

SPOCS - Simple Procedures Online for Cross-border Services.

STORK - Secure Identity Across Borders Linked.

sTESTA - Network- Trans European Services for Telematics between Administrations.

TOOP - The Once-Only Principle Project.

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1 Introduction

As the course of the digital transformation of European public administrations evolves, the demand for cross-border digital public services is steadily increasing. These deliver different benefits for different stakeholders and improve collaborations and integration of European public administrations. For citizens, cross-border digital services facilitate living, studying, and working in other European countries while having reliable and secure access to digital public services regardless of time and geographic location. Businesses also garner support through cross-border digital public services, especially to facilitate their operations in different European countries, streamlining access to information and competition laws, reducing administrative burden, and backing businesses to unlock new benefits in the Single Market. Cross-border services also add value for public administrations. They enable public organisations to optimise operational costs, provide accessible and quality digital public services, reduce duplication of effort and information and support cross-border mobility (Kalvet et al., 2018).

The delivery of cross-border digital public services is largely dependent on the ability of public administrations and businesses to transfer data across borders. Increased demand for cross-border digital public services increases requests for cross-border data exchange. Therefore, access to trusted, interoperable, and secure data-exchange solutions is essential for delivering cross-border services but is also crucial for establishing the Single Digital Gateway (SDG) and building a functioning European Digital Single Market (DSM).

The Member States (MS) face different challenges related to legal, technical, organisational, and semantic barriers. Legal barriers are mainly the heterogeneity of national legal frameworks, together with privacy and data protection concerns. On the other hand, an organisational perspective addresses obstacles and barriers concerning the complexity and costs of deployment and maintenance of cross-border solutions and the tendency to cooperate with neighbouring countries. Organisations in charge of implementing cross-border data-exchange solutions and services in general function on a non-profit basis, as the benefits of cross-border are collective and gained by the public administrations or society as a whole. Technical and semantic barriers, inter alia, are the existing heterogeneity of technical infrastructures and metadata and data types included in base registries.

The current landscape of European cross-border data exchanges also continues to be heterogeneous. Numerous projects, alliances, and partnerships have been implemented to explore and develop different solutions that would support the creation of an interoperable future for Europe. So far, there is often a lack of a clear understanding of cross-border data exchange initiatives, especially with regard to different roles, specifications, and technological differences between them. To this end, this present study starts by mapping various cross-border data exchange initiatives in Europe and develops an initial inventory of cases. For each initiative, it analyses the status of their adoption and investigates different aspects of the cross-border data exchange solutions covering related to legal, commercial, and technical specifications. Findings from this study could provide valuable insights for policymakers, solution owners, and service providers as it informs them about the interoperability, extensibility, and sustainability of European cross-border data exchange initiatives and projects.

The rest of this study is structured as follows: Chapter 2 provides an overview of key European policy initiatives and actions taken to support the implementation of the cross-border data exchange initiatives in Europe. It also provides an overview of approaches (such as Large-Scale Piloting) used by the EC and MS to develop solutions enabling cross-border digital public services. Chapter 3 outlines the methodological actions taken to conduct this study, including the mapping exercise, methods, and data collection. Chapter 4 presents findings from the mapping exercise of solutions and its use-cases, which is conducted to illustrate the European cross-border data-exchange landscape. It also provides an analysis of the cases, including relationships between solutions, the status of their development, and differences in terms of legal, business, and technical specifications. These are the initial steps towards developing a future European benchmark for the cross-border data-exchange domain. Solutions identified have been grouped in two clusters; Data-exchange solutions and other initiatives. Data-exchange solutions include X-Road, eDelivery (BRIS, EESSI, OpenPeppol), EUCARIS, and OpenNCP. The other initiatives also cover Gaia-X, IHAN, and Nordic Smart Government. Chapter 5 then introduces our analysis of this study and main findings. It provides an analysis of cross-border data exchanges' status-quo and a future outlook for Europe. Finally, Chapter 6 presents the key conclusions of this study and summarises the report.

2   Study Background

In recent decades, European public administrations have increasingly cooperated to accelerate the digital transformation and the development of cross-border digital public services. Following the European Commission's (EC) political plan to ensure a well-functioning (Digital) Single Market, numerous regulations, declarations, strategies, and funding programs were introduced at the European Union (EU) level (Schmidt & Krimmer, 2022). MSs and associated EU countries have recognised the importance and impact of European digital services for enabling a single market and promoting seamless online interactions with citizens and businesses (*Malmö Declaration on eGovernment*, 2009). Supranational solutions are encouraged to address the heterogeneous digital landscape and increase efficiency by using fewer resources at the cross-border, national, and local levels. The overall vision remains to break down silos and decreasing unnecessary differences between online and offline activities of European public administrations and businesses across borders (A Digital Single Market Strategy for Europe, 2015). This chapter provides an overview of relevant European policies that contribute toward an interoperable Europe and facilitate cross-border data exchange initiatives - starting with the most relevant declarations in this context, where MS have expressed their commitment towards the digital transformation of governments, through to key initiatives and policies that define a common European vision and shape the digital landscape - followed by EU funding programmes that financially enable interoperability projects, such as large-scale pilot projects. Figure 1 below

provides an overview of the most relevant policies, initiatives, and projects from 2005 to 2030. A more comprehensive overview is provided in Appendix A, B, and C.
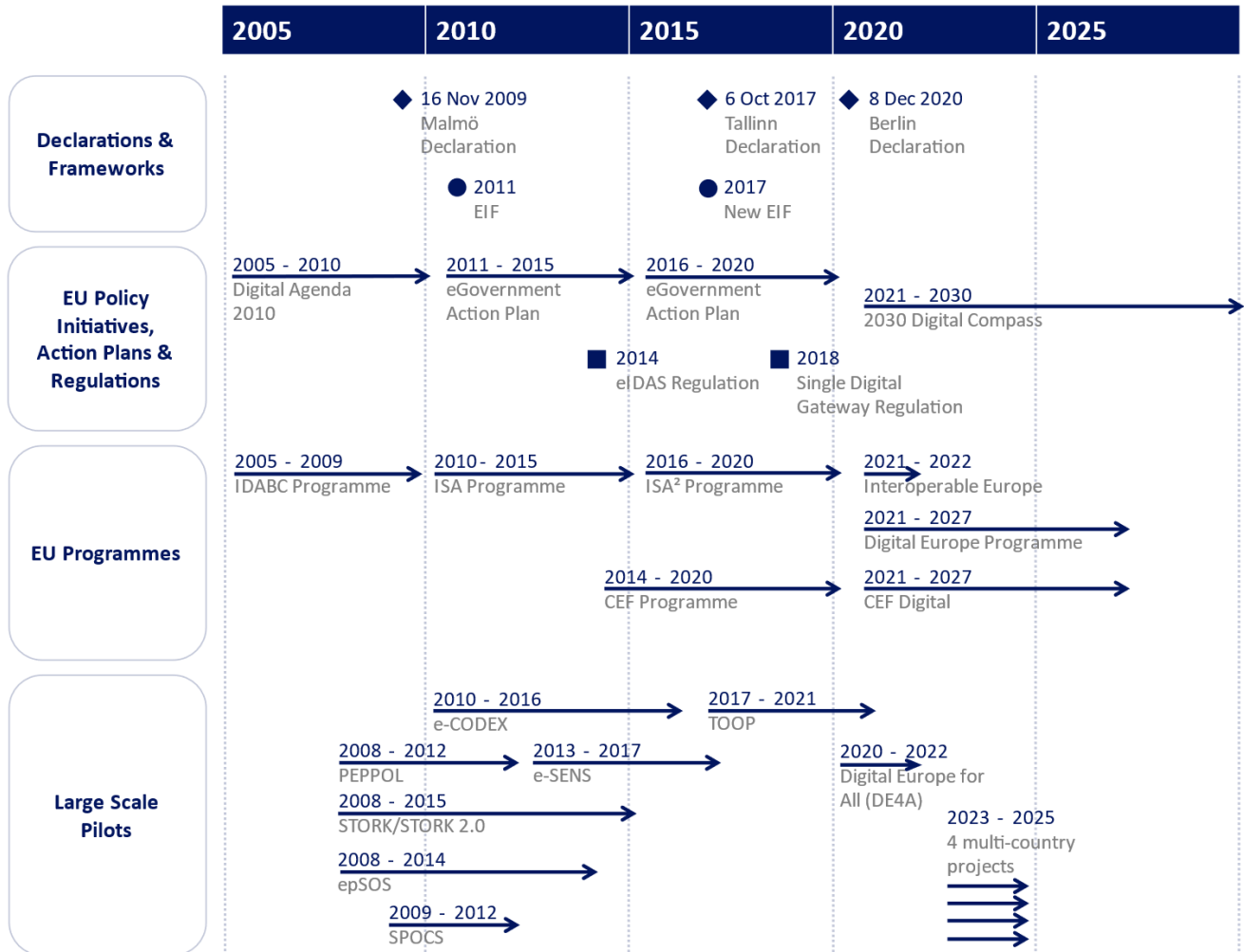
Figure 1. European Cross-Border Interoperability Policy Overview (Source: The Authors)

2.1   Policy Initiatives

The EU MS and European Free Trade Association (EFTA) countries have expressed their commitment towards the digital transformation of their governments in the form of several Ministerial Declarations. Dating back to the early 2000s, ministers declared making the digital transformation of governments their priority while strengthening coordination between MS to reinforce cross-border interoperability. Among the most relevant declarations for cross-border

aspects are the Malmö Declaration and the Tallinn Declaration (*Malmö Declaration on eGovernment*, 2009; *Tallinn Declaration on eGovernment*, 2017). The Malmö Declaration on digital government recognises the need to enhance cross-border digital government policies at the European level in order to provide better public services to European citizens. With this declaration, all EU MS and EFTA countries agreed to increase further collaboration between European governments based on a joint vision and defined policy priorities. It aims to promote interoperability and seamless cross-border services between public administrations. In October 2017, as part of the eGovernment Ministerial Conference, all EU and EFTA countries signed the Tallinn Declaration on eGovernment. This declaration marked a milestone for digital government in Europe. The signatories of 32 (EU and EFTA) countries confirmed their strong political commitment to enhancing digital public services and seamless cross-border services for citizens and businesses at the EU level. The basis for further action and policies are defined in commonly agreed-upon principles such as digital-by-default, once-only, and interoperability by default. This declaration also promotes open, transparent, inclusive, personalised, and user-friendly digital public services. Following the success of the Tallinn Declaration, ministers responsible for digital government signed the Berlin Declaration in 2020 and the Lisbon Declaration in 2021 to reaffirm political commitment toward European digital public services (*Berlin Declaration*, 2020; *Lisbon Declaration*, 2021). The signatories agreed to strengthen the Digital Single Market while recognising it as the core element of the digital ecosystem. Moreover, the declarations highlighted the importance of promoting a value-based digital transformation, digital sovereignty, and democratic principles in the virtual world.

The EC launched the eGovernment Action Plan 2011-2015 to realise policy goals and principles set out in the Malmö Declaration of 2009 (EGovernment Action Plan 2011-2015, 2010). It provides a political instrument to join European efforts by discussing and exchanging good digital government practices between the MS. As a result, several large-scale pilot projects were developed to tackle cross-border barriers recognised in earlier provisions and policy papers (Schmidt & Krimmer, 2022). These pilots are key elements for developing cross-border digital government services, as they present concrete solutions to digital government challenges. Chapter 2.3 provides an overview of the most relevant large-scale pilot projects and their contribution to developing the European digital cross-border landscape.

In 2015, the Digital Single Market Strategy launch started a new era of digital transformation in Europe (A Digital Single Market Strategy for Europe, 2015). The strategy defines the European vision to move from 28 national digital markets to only one single market in the digital sphere.

The overall objective of the Digital Single Market is to ensure Europe's leadership in the digital economy. It calls on the public and private sectors to ensure the digital ecosystem's four freedoms of movement (*of* goods, services, people, and capital). The strategy recognises the importance of interoperability across borders and aims to reduce trade barriers. Since the MS repeatedly expressed similar problems in their digital cross-border activities, the strategy defines coordinated EU action to ensure a harmonised internal market. Additionally, the strategy announced the launch of the second eGovernment Action Plan 2016-2020 to enhance the Digital Single Market by further reducing digital barriers and virtual borders (eGovernment Action Plan 2016-2020, 2016). MS recognised the digital transformation of governments to be a key element to achieving this objective. Therefore, it promotes coordination of digital government efforts and resources on the EU level to combat digital fragmentation in public administrations across Europe.

Both eGovernment Action Plans strongly follow the European Interoperability Framework (EIF) principles, which provide a generic framework of interoperability for European public administrations (European Commission. Directorate-General for Informatics, 2011). The initial version of the EIF was published in 2004, updated in 2011, and further developed into its current version in 2017 (European Commission. Directorate-General for Informatics, 2017). The new EIF provides a common framework with 47 principles based on the four main interoperability layers, legal, organisational, semantic, and technical. The aim is to support MS in developing their national interoperability frameworks and ensure interoperability between national systems. In addition, the overall objective remains to enhance seamless services and data flow between public administrations in Europe. Moreover, to prevent further digital fragmentation and promote a harmonised digital single market through a coherent European interoperability environment. The European Interoperability Reference Architecture (EIRA) provides the architecture and building blocks required to build interoperable digital government systems (European Commission, n/d). Its objective is to improve the cross-border compatibility of services and data registers between MS (European Commission, 2016c). EIRA, as well as the new EIF, were developed and maintained under the ISA² programme, which is described in more detail in Chapter 2.2.

As signatories of the Tallinn Declaration confirmed their commitment to the goals defined in the EIF and the eGovernment Action Plan 2016-2020, these initiatives lay an important foundation for further cross-border collaboration pan-European level. As part of the Declaration, MS agreed to the implementation of electronic identification to enhance national eID schemes. Moreover, to enable the eIDAS Regulation on electronic identification, authentication, and trust services (Regulation (EU) No 910/2014, 2014). It was signed in 2014 and replaced the previous Electronic

Signature Directive, which provided a common framework for the use of electronic signatures across borders to strengthen the internal market (Directive 1999/93/EC, 1999). The eIDAS Regulation marks an important milestone toward electronic identification and e-transactions across EU borders. MS agreed to enable e-signatures in all EU authorities and companies that provide public services. Furthermore, it recognises that citizens and businesses shall have access to online procedures in other EU countries without facing any discriminatory cross-border barriers. eIDAS is considered a key enabler for securing cross-border transactions in Europe. The European Parliament announced an update to the eIDAS framework, with a new proposal in June 2021. The aim is to facilitate eID access to key public services in the EU cross-border environment for at least 80% of citizens (European Parliament, 2021).

The Single Digital Gateway Regulation complements eIDAS by providing a European digital single-entry point to access information, administrative procedures, and services for citizens and businesses (European Commission, n.d.-e; Regulation (EU) 2018/1724, 2018). It was adopted in 2018 and defined common rules and guidelines for digital public services to harmonise them across the MS. With this, it is a key regulatory element of the Digital Single Market Strategy and marks an important step toward realising the once-only principle. The MS countries committed to offering online access to 21 procedures (e.g. registering a car) through the digital gateway and in all EU countries by the end of 2023. Access is provided through the 'Your Europe' portal, which has operated since 2006 to provide information to EU citizens. Together with the eGovernment Action Plans, the Single Digital Gateway lays another foundation for future cross-border initiatives and formulates a comprehensive European vision. To further promote the Digital Single Market, SDGR, eIDAS, and One-Only Principle, the Digital Europe for All (DE4A) project was launched in 2020 with a duration of three years (*Digital Europe For All (DE4A)*, n.d.). It is a MS-driven pilot to realise European Digital Public Services across national borders.

After more than two decades of EU programmes to support cross-border interoperability between MS, associated countries and their public administrations, the 2030 Digital Compass (2021) was launched, providing a common vision and actions for Europe's digital transformation (2030 Digital Compass, 2021). It recognises the changing role and perception of digitalisation in society as a result of the COVID-19 pandemic, which has highlighted prevailing barriers in the digital space and dependencies on a number of big tech companies and non-European technologies (Schmidt & Krimmer, 2022). The vision of Digital Compass communication is rooted in four domains: (1) digital skills, (2) digital infrastructures, (3) digitalisation of public administrations, and (4) digitalisation of businesses. For public administrations, Digital Compass sets three main targets

to be achieved by 2030: 100% digitalisation of key public services, 100% access to eHealth records for European citizens, and 80% eID usage.

2.2   Funding Programmes

The history of European funding programmes in the context of exchanging data between European administrations dates back to 1995, with the launch of the IDA programme (Decision 95/468/EC, 1995). The programme's objective was to facilitate a high degree of interoperability and interchange of data between MS administrations based on establishing telematic networks. The second phase of the IDA programme (1999-2004) started to increase the efficiency of trans-European networks for the electronic data exchange (Decision 1719/1999/EC, 1999). They were followed by the IDABC programme in 2005 (Decision 2004/387/EC, 2004). It builds on the previous objectives while extending its scope to deliver pan-European digital government services to public administrations, businesses, and citizens. The programme set a focus on horizontal measures for interoperability. These three programmes paved the way for the ISA programme (Interoperability Solutions for European Public Administrations), which further supported digital solutions for interoperable cross-border services (Decision No 922/2009/EC, 2009). It commenced operations in 2010 and ended in 2015. ISA sets the focus on back-office solutions to enhance interaction between public administrations. Both the EIF and the European Interoperability Strategy (EIS) were developed and maintained under this programme. In parallel, the EC - with the consent of the MS - set up several financial frameworks, beginning in 2007. The first one was the ICT Policy Support Programme (ICT PSP) as part of the Competitiveness and Innovation Framework Programme (CIP), which lasted until 2013 (Decision No 1639/2006/EC, 2006). It was followed by the Horizon 2020 research and innovation funding programme from 2014 to 2020 (Regulation (EU) No 1291/2013, 2013).

The ISA² funding programme came into force in 2016 (Decision (EU) 2015/2240, 2015). It follows the previous ISA programme and contributes significantly to the Digital Single Market Strategy of 2015. It further maintained and promoted the EIF and its principles. The four levels of interoperability set out in the framework are targeted in the actions and solutions that compose the ISA². Moreover, the programme promotes the principles of the Tallinn Declaration, such as the once-only principle, interoperability-by-default, and user-centricity. ISA² additionally complements the Connecting Europe Facility Programme (CEF), a programme supporting digital service infrastructures of MS to promote cross-border interaction (Regulation (EU) No 1316/2013,

2013). It was launched in 2014 to close the missing links in the energy, transportation, and telecom sector while functioning as a key funding instrument for infrastructure investments such as trans-European networks. Building on the vision of earlier EU initiatives, it aims to enable and promote cross-border interaction between public administration, businesses, and citizens across Europe. The programme defines ten building blocks based on the existing interoperability agreements of EU MS. They work towards achieving interoperability between IT systems and enabling the use of digital public services from all over Europe. In the context of cross-border e-services, the most relevant building blocks are considered as being eDelivery, eID, eInvoicing, eSignature, eTranslation, and the once-only principle (Nordic Council of Ministers, 2021).

The ISA² came to an end in 2020 and developed into the Interoperable Europe programme, introducing a new European interoperability policy. By so doing, it envisions a significant step towards digital transformation and interconnection of public administrations. Once again, following the principles and standards of the EIF, the programme aims to press ahead with the Joinup platform, which was established as the official channel for knowledge exchange at the EU level. Interoperable Europe builds the transition between ISA² and the Digital Europe Programme (DEP), launched in 2021 for a period of six years (Regulation (EU) 2021/694, 2021). DEP provides strategic funding (€7.5 Billion) for digital infrastructures to enhance seamless cross-border cooperation at the European level. The programme aims to shape the digital transformation of the European economy and society to improve Europe's competitiveness in the digital global economy. One of the five objectives is to deploy and make the best use of digital capacity and interoperability by providing holistic, cross-sector and cross-border support.

2.3   Development of Cross-border Data-exchange

The Single Market is a cornerstone of the EU. The digitisation and transformation into the Digital Single Market are ongoing and have an increasing impact on citizens, businesses, and administrations inside the Union. Cross-border aspects became a reality in the everyday lives and business of more or less all Europeans. This also shifted the focus of various activities from purely national to transnational. Thinking "cross-border" is now an immanent topic of the various EU initiatives. One of their main aims is to reduce the additional administrative burden that EU citizens and businesses face when they expand their activities in other MS as far as possible. The solution must provide access to national rules, requirements, and procedures that citizens and businesses from other MS must know about and comply with to achieve this.

The EC and MS have developed a special approach to test policy-driven ideas related to the Digital Single Market. The method of Large-Scale Piloting (LSP) is based on the perceptions of the action plans "eEurope 2002" and "eEurope 2005". A result of these action plans was that direct implementation of digitisation on a large scale, even if it is well planned, is risky and contains several options for failing. Therefore, the approach of the LSPs was developed. An LSP can be regarded as a kind of specific "testbed" for preparing for the implementation of new procedures or for accompanying the implementation of new legislative instruments on Europe-wide and nationwide levels. A European LSP must fulfil specific requirements defined by the EC as follows:

LSPs are targeted, goal-driven initiatives that propose approaches to specific real-life challenges (e.g., administrative, societal, or industrial). Pilots are autonomous entities that involve stakeholders from several sides. The entities involved represent governmental, administrative, research, industrial, and citizen communities. The focus is set on Europe-wide and national levels. Supply and demand sides are covered and contain all elements relating to technology and innovation, tasks relating to the use, application, and deployment, as well as development, testing, and integration activities.

Large-scale validation is characterised by the fact that it will be possible to operate the functional entities implemented in the pilot under load and constraint conditions close to those for operational load, either with real traffic/request/processing loads or with simulated loads where full implementation is not possible. Demonstrations are anticipated, operating the system across multiple sites, with scalability to a large number of heterogeneous devices and systems, as well as with a large number of real end-users. The LSP work plans must include feedback mechanisms to allow adaptation and optimisation of the technological and business approaches to the particular use case, as well as a sustainability strategy for results of the projects (European Commission, 2016b).

The LSPs allow on the one side, the involvement of private sector organisations and technical experts from the MS and associated countries and, on the other side, the participation of stakeholders. Both aspects ensure the flexibility required to develop or amend technical solutions (building blocks) of the LSPs. To deliver the required outcomes and cover all aspects of the pilots, it is essential to involve not only a limited number of countries and organisations. Besides this, as part of piloting activities within the project, the national infrastructures must be interconnected.

The EC and the countries involved strongly focused on the European aspects. Accordingly, the first step towards LSPs on a Europe-wide level was created through work by the eGovernment group. The eGovernment group was set up by the EC to encourage co-ordination between MS and prepare the ground for the eEurope Action Plan. The associated parties identified a few key domains where common solutions had to be developed on a European level. In 2005, three topics were named: eID, eProcurement and eHealth. In 2008 the Commission respectively launched the projects STORK, PEPPOL, and EPSOS (European Commission, 2014) with the financial support of the CIP ICT-PSP programme. These first projects had a sector-specific focus and related goals. e.g., to support the implementation of online public procurement procedures and showcase that such implementation is technically possible. After successfully launching these projects, as a next step, further sector-specific LSPs were initiated. The SPOCS project was commenced to support the transition of the Service Directive in 2009, and e-CODEX kicked off in 2010 to uncover and address the needs of the e-justice domain.

Soon afterwards, the idea of initiating cross-sector projects gained momentum with the eventual launch of the e-SENS project. Research organisations and SMEs became involved as partners in these projects' public legal entities (Krimmer, Prentza, et al., 2021). The basis for important CEF building blocks such as eDelivery was provided by the e-SENS project. One of the key aspects of the development of this solution was the discussion of whether data, from a technical point of view, should be exchanged in a synchronous or asynchronous manner. The decision was made after a very detailed dialogue in the e-SENS project, with relevant stakeholders' involvement and technical and legal aspects taken into account for the decision. After analysing the pros and cons, it was decided that eDelivery will exchange data in an asynchronous way.

The project results were picked up and further extended by the TOOP project that focused on the once-only principle. The difference between these projects was that e-SENS had a more technical focus, and TOOP was a policy-driven project. The projects TOOP, e-SENS and e-CODEX especially displayed the relationship between LPSs and European legal acts. The TOOP project has an influence on the implementing act for Art. 14 SDGR, the e-SENS project for the legal basis of the Connecting Europe Facility and the e-CODEX has a direct impact on the e-Justice regulation (Schmidt & Krimmer, 2022).

3   Methodology

3.1   Mapping Exercise, Data Collection, and Methods

This study aims to map key European cross-border data exchange projects, analyse the status of their progress, investigate aspects related to legal, business, and technical specifications, and establish a foundation for building a future benchmark in this domain. Therefore, this study started with a Mapping Exercise where the goal was to identify the leading European cross-border data exchange solutions, projects, and initiatives and analyse how they fit within the larger European landscape. This exercise started with CITIS researchers drafting an initial list of projects and initiatives. This list was created based on previous experiences and involvement with large-scale cross-border data exchange projects, including e-CODEX, e-SENS, and TOOP. The team's expertise was also complemented with information from preliminary desk research to compile the complete list of projects. This list was further reviewed and complemented during the kick-off meeting between CITIS, NIIS, and Sitra. To follow up, an internal workshop between the CITIS team was organised to discuss the integration of additional objectives into the study. The final list of cross-border data exchange initiatives was also drafted. This enabled CITIS's team to start planning the interviews and identify relevant speakers.

At the same time, desk research was conducted in the form of a literature study. It included an investigation of both academic and non-academic literature relating to cross-border data exchange projects that were mapped for the purpose of this study. This step played an essential role in understanding the information available for the cases and drafting the initial case descriptions. It also showed that academic knowledge in this field remains lacking, and there are no comprehensive typologies or frameworks where identified projects would fit in. In most cases, cross-border data exchange initiatives differ substantially in scope, organisation, and technological specification. That is why we identified the challenge of comparing such solutions to each other. For this reason, we introduced the framework presented in the next chapter (see Section 3.2.). Preliminary research also helped identify some of the knowledge gaps around solutions, which were later addressed as part of interviews. Lastly, desk research contributed significantly towards drafting interview questions. Especially when creating a general list of questions fit for all projects, but also tailored questions according to the solution, context, and speaker's background.

The data collection process also included conducting semi-structured interviews. This method was selected for its positive record in discovering new insights and explanations by capturing perspectives emanating from different respondents (Kallio et al., 2016). Semi-structured interviews are also flexible as they pose open-ended questions to speakers while giving interviewers more control over the flow of the discussion and the type of questions posed. For this study, CITIS researchers started designing the process of interviews by drafting an initial list of possible respondents. The first list was based on previous experiences with cross-border data exchange projects, and it included speakers associated with two data-exchange solutions, eDelivery and X-Road. Similar to the cross-border data exchange projects, the list of interviews was also reviewed and complemented during the kick-off meeting between CITIS, NIIS, and Sitra. Before sending out the invitations, a draft list was compiled. Interviewees were prioritised based on their role in managing or developing cross-border data-exchange solutions. Interviewees were invited to participate either individually or in groups of two. By the end, eleven (11) semi-structured interviews were conducted between the dates of 09/02/2022 and 26/04/2022. Nine (9) interviews had one respondent, and two (2) interviews had two respondents. See Table 1 for more information on the background and organisations that these respondents represented. The final list of interviews was left open until the end of the data gathering process. New names emerged as suggestions from several interviewees and enabled CITIS researchers to improve the list of respondents iteratively.

Table 1. List of interviews conducted for this study.

Interview Number	Solution and Policy Domain	Organisation	Country	Date	Length of Interview
Interview 1	X-Road	Nordic Institute for Interoperability Solutions (NIIS)	Estonia/ Finland	09.02.2022	92:00 minutes
Interview 2	X-Road	Finnish Ministry of Finance	Finland	28.02.2022	62:00 minutes
Interview 3	eDelivery	e-SENS	Europe	04.02.2022	48:00 minutes
Interview 4	eDelivery	DG DIGIT/European Commission	Europe	08.03.2022	58:00 minutes

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Interview 5	BRIS	DG DIGIT/European Commission	Europe	03.03.2022	78:40 minutes
Interview 6	OpenPeppol	OpenPeppol	Europe	03.03.2022	59:00 minutes
Interview 7	EUCARIS	Association of European Vehicle and Driver Registration Authorities (EReg)	Europe	08.03.2022	61:00 minutes
Interview 8	Gaia-X	VTT	Finland	22.02.2022	55:00 minutes
Interview 9	iHAN	Sitra	Finland	17.02.2022	54:00 minutes
Interview 10	Nordic Smart Government	Finnish Tax Administration	Finland	28.02.2022	59:00 minutes
Interview 11	EESSI	Task Force for the European Pillar of Social Rights/ European Commission	Europe	26.04.2022	36:00 minutes

3.2   Study Framework

After data collection, the authors have separated the identified solutions into the "Data exchange solutions" and "Other Initiatives" to set up the landscape and analyse existing cross-border data exchange solutions. For the purpose of this report, the agreed definition of cross-border data exchange solution is "*the solution or infrastructure of technologies, standards, and policies that enable interoperable data (or document) exchange within the EU.*"

The data exchange solutions are the cross-border data exchange solutions that have been used for cross-border data exchange in the EU. The selection of the data exchange solutions is based on the actual use, our team's expertise, desk research, and suggestions from relevant experts in

this field. After desk research and analysis, solutions identified as cross-border data-exchange solutions are X-Road[1], eDelivery (including domain-specific applications), EUCARIS, and OpenNCP. Furthermore, as part of this project, the use-cases for each cross-border data exchange solution have been described. Other initiatives in this project refer to initiatives that are ongoing in the EU but do not specifically provide specific cross-border data exchange solutions but provide an overall framework for establishing a cross-border framework for data sovereignty and data exchange across Europe.

The CITIS team developed a framework that provides a descriptive and analytical lens to analyse existing data exchange solutions, focusing on existing data-exchange solutions. This framework is based on the interoperability layers provided by the EIF and focuses on legal, organisational (business), and technical layers. Hence, the structure of the analysis of cross-border data exchange solutions is based on the framework developed and provides a comprehensive overview of the necessary details for a description of the existing solutions in the EU. The framework is structured in three categories, legal specifications, business specifications and technical specifications of cross-border data-exchange solutions.

Legal specifications present the legislations forming the basis for the cross-border data exchange and are enablers for the data exchange solution. Business specifications provide a general overview and details of cross-border data exchange solutions, such as solution vision, description, objectives, and solutions governance. While technical specifications provide the overview and details of criteria relevant for data exchange purposes across borders, such as data exchange (messaging) models, data transmission communication methods, network usage, code openness, and solution's specialisation. Please see Table 2. An overview of the framework developed to study European cross-border data exchange initiatives.for further details about the framework.

Table 2. An overview of the framework developed to study European cross-border data exchange initiatives.

Specifications	Criterion	Description

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[1] It is highly important to note that the analysis of the X-Road solution in this report is based only for the purpose of the cross-border context and not for national purposes as X-Road is already proven successful in that case.

Legal Specifications	Legal background	Legal acts that regulate the exchange of data across borders.
Business Specifications	Solution vision, description, and objectives, principles.	Solution vision, description, principles and objectives criterion/indicator provide information about the goals and aims of the data exchange solution. Furthermore, this criterion provides information on key characteristics, features, and objectives of the selected solution. The main purpose is to provide the reader an overview of the solution vision/goals and objectives.
	Solution governance	Governance of the solution is the criterion that provides readers an overview of who governs the solution, who is responsible for managing, updating, and monitoring the data exchange solution. Furthermore, it provides information on implications of the existing governance structure.
Technical Specifications	Data exchange (messaging) model	The data exchange model criterion describes the approach of the data exchange solution towards communication between several information systems. The most common data exchange models are: the two corner model, which is a traditional approach enabling direct communication between two information systems with the main challenge of scalability; the three corner model, on the other hand, overcomes the issue with scalability by introducing the mediator, for the purpose of exchanging data/documents; and lastly, the four-corner model where information systems communicate over the interconnected Access Points that enable communication in the network between several information systems.
	Data transmission communication method (Synchronous vs.	The data transmission type criterion involves distinguishing between synchronous and asynchronous communication types. There are a few noticeable differences between these two types of data exchange. In the synchronous messaging type, a service consumer sends a request and must stay and wait for a response suitable for real-time

	Asynchrono us)	data and document exchange. While in asynchronous communication, a service consumer sends a request and can continue processing with other tasks.
	Network usage (Public Internet vs. Closed network)	The data exchange solution network usage criterion addresses the network the solution connects to and uses to exchange data or documents. Solutions using the public internet are connected to the wider network. Solutions using private internet are connected to closed networks such as the sTESTA network developed by the EC. These choices address the benefits and challenges associated with the network usage selected.
	The openness of standards and specification s	Data exchange solution code, standards and specifications openness criterion address whether the data-exchange solution uses the specific standards or specifications that are either open code, standards, and specification or proprietary, developed specifically for the purpose of the data-exchange solution.
	Solutions specializatio n (Vertical vs. Horizontal)	Data-exchange solution specialization criterion addresses the integration of the data exchange among the organizations. This criterion follows the Layne and Lee (2001) model on the development of digital government and focuses on the last two levels, Vertical integration and Horizontal Integration. Vertical integration includes data exchange among similar functional domain databases, while horizontal integration includes data exchange among different functional domain databases.

4 Findings

A main goal of this study is to present the findings from the mapping exercise of solutions and the related use-cases, which is conducted to illustrate the European cross-border data-exchange landscape. The solutions identified, described and analysed are grouped in two clusters, data-exchange solutions and other initiatives.

4.1 Data-Exchange Solutions

4.1.1 X-ROAD

X-Road® is an open-source data exchange layer software that provides secure and unified data exchange between organisations. The key vision of X-Road is to enable distributed, seamless and standardised data exchange among organisations, primarily for national data exchange purposes. One of the main ideas of X-Road is that it enables data exchange between organisations from different sectors (private, public, non-profit) and different policy domains (i.e. justice, health, transport). Key principles that X-Road supports are that it is digital public good, open-source software, a versatile security solution, it supports the once-only principle, it is a scalable solution, and it provides a flexible implementation.

Initially, X-Road was developed in Estonia in the early 2000s and became a backbone of the Estonian digitalization of public services. As an Estonian national data-exchange solution, this solution is mainly used in Estonia for the purpose of providing digital services to Estonian residents. However, after political consultations and agreeing on cooperation with Finland in 2013, these two countries agreed to collaborate further in the field of digitalization. This agreement resulted in the creation of the Nordic Institute for Interoperability Solutions (NIIS) which has been responsible for the technical development and general management of the X-Road source code since 2017 (*X-Road® History*, n.d.). The aim of this institute is to ensure the quality, sustainability, and cross-border capability of core digital government infrastructure components, according to the Memorandum of Association of NIIS signed by Ministers of Finland and Estonia (*X-Road® History*, n.d.). In addition to Estonia and Finland, the Republic of Iceland also joined NIIS as a partner in 2019 and as a member in 2021. It must be highlighted that for comparability with the

analysis of the other solutions, the evaluation of X-Road focuses only for the cross-border context (NIIS, n.d.-b).

From an organisational point of view, an X-Road ecosystem involves an X-Road operator, member organisations and trust service providers (NIIS, n.d.-c). The owner of the X-Road ecosystem is the Operator, which in the cases of Estonia, Finland, and Iceland, at the administrational level is the Ministry responsible for digitalisation and at the more practical level, the national digital agency or similar organisation. X-Road members are all organisations (private and public) that have joined the ecosystem and produce and/or consume services with other members through their technical access points to the X-Road ecosystem. Trust service providers are mainly the time-stamping authority and certification authority, and they are selected by the X-Road operator as well (NIIS, n.d.-c) .

Currently, members of NIIS and hence main contributors to X-Road development are Estonia, Finland, and Iceland (See Figure 2 below). Additionally, X-Road in Europe is implemented in the private sector in Germany and by the public administration in the Faroe Islands. There are ongoing consultation phase discussions in several European countries with both the private sector and public administrations (NIIS, n.d.-d).

The X-Road architectural data exchange model is based on a four-corner model similar to the CEF
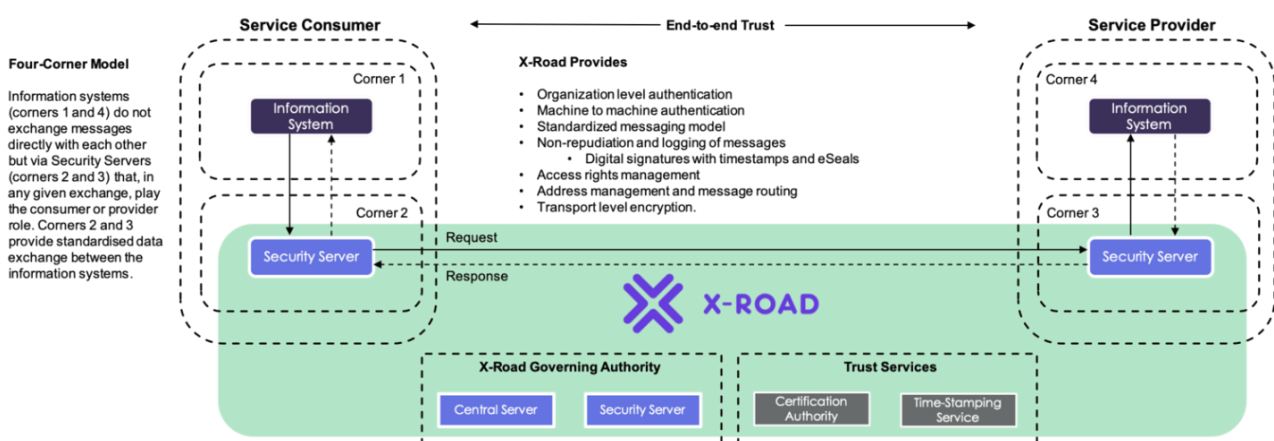

Figure 2. Cross-border data exchange X-Road. Source: (Nordic Institute for Interoperability Solutions - X-Road and eDelivery - Identical Twins or Distant Relatives?, n.d.)

eDelivery building block. The idea behind the four-corner model (OASIS, 2021) is that information systems do not exchange data directly but through additional Access Points (AP). These AP in X-

Road are Security Servers (Corner 2 and Corner 3), which are based on the same technical specifications and standards and thus enable seamless data exchange. Features that are provided with these Security Servers are, inter alia, message routing, logging, security, and authentication. Please see Figure 2 above for further details on the data exchange model.

X-Road is based on the synchronous type of data transmission. This synchronous communication enables real-time data and document exchange. In synchronous communication, a data requester sends a request and waits for a response. Thus, requesters' control flow is disrupted until the data provider has processed the request. This mode of communication supports automatic decisions and fully electronic service delivery; however, implementation of such a synchronous solution is expensive to implement and requires a high level of information system development ('Difference between Synchronous and Asynchronous Transmission', 2019).

Furthermore, the data and documents within the X-Road ecosystem are being transmitted through the public Internet. Hence, there is no need for additional network infrastructure to join the X-Road network. In case if needed, the X-Road solution can also be implemented in a private network as well, technically there is nothing that prevents it. In addition, the X-Road is open-source software published under an MIT open-source licence, and support is available through the X-Road Community (the open source community) and X-Road Technology Partners (private enterprises providing services) (X-Road Community, 2018/2022)

The X-Road solution provides horizontal data exchange in a national context, thus enabling horizontal integration and exchange of data among different datasets and domains. According to Layne and Lee (2001), this model is the last step of successful integration of information systems.

CROSS-BORDER DATA EXCHANGE USE-CASES: ESTONIA AND FINLAND USING X-ROAD

Cross-border data exchange between two countries requires several layers of agreements and infrastructure, which enables the seamless exchange of data and service delivery. According to the NIIS CEO and the instructions of the Finnish Digital and Population Data Services Agency, after enabling technical interoperability using X-Road, organisations and countries require separate agreements to enable data exchange (Interview 1). The first and foremost is agreements between country representatives, and after setting up a technical federation, separate agreements are

required between organisations willing to exchange data. Hence, there are multiple levels of agreement to set up data exchange across borders, according to Interview 1. The exact embodiment depends on the parties involved in the implementation process.

Technically, X-Road enables cross-border data exchange through a federation of X-Road ecosystems (NIIS, n.d.-b). Two X-Road ecosystems can create a federation which enables their Members to request/send data and consume services for national but also for cross-border data-exchange purposes. Federation means joining two ecosystems in which Members can exchange data as they are Members of the same ecosystem. Enabling cross-border data exchange requires not only technical interoperability but also legal and organisational agreements between data owners and data requesters (please see Figure 3 below). Additionally, X-Road could enable cross-border data exchange through an access point (Security Server) set up by an organisation in another country joining the other country's ecosystem. Such projects have been initiated, but NIIS doesn't have reports on the results and current status.
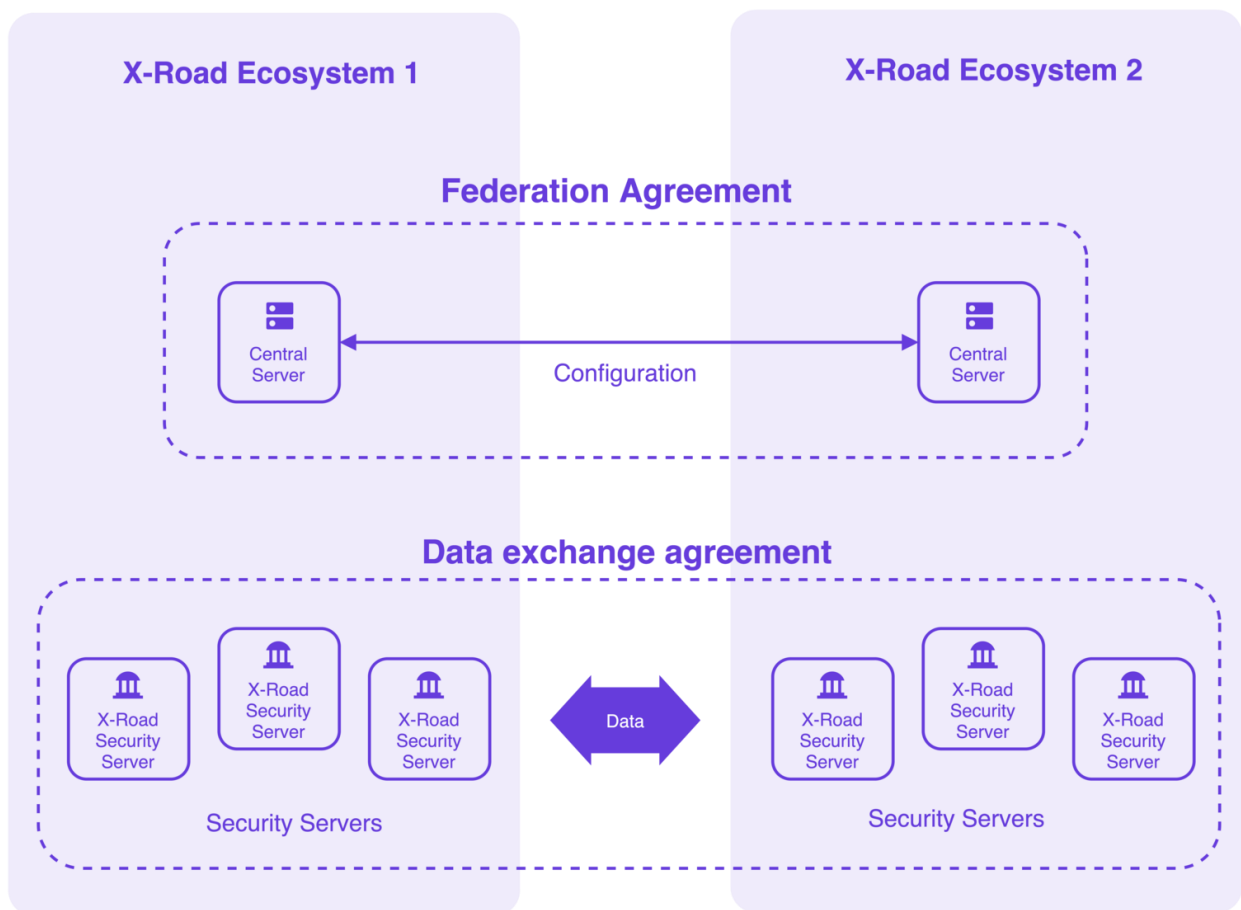
Figure 3. Cross-border data exchange through X-Road trust federation (Source: (NIIS, n.d.-b))

However, this trust federation and data exchange are not transitive (NIIS, n.d.-b). This means that the operator (or probably better "owner") of one X-Road ecosystem must sign agreements with the operator (or probably better "owner") of the other X-Road ecosystem to establish mutual trust; thus it is a one-to-one trust federation. The agreements must cover technical and organisational aspects (incl. data protection and security of data) needed to establish trust between the parties involved. The total number of these agreements as a whole builds a circle of trust that ensures the trustworthiness of the data exchanged.

Currently, at least two countries have enabled cross-border data exchange using the X-Road solution, Estonia and Finland (NIIS, 2019). They exchange data across borders using an X-Road ecosystem in the domains of business registers, population registers and tax administrations.

Report: European Interoperability Landscape Report

Cooperation in exchanging data across borders between business registers was initiated in 2016 when Finnish and Estonian Prime Ministers signed a joint declaration on the development of cross-border cooperation and data exchange (Roivas & Sipila, 2016). After this joint declaration on cross-border collaboration and after Finland decided to implement X-Road, the draft institutional agreement was signed between business registers in Finland and Estonia in 2018. Data exchange between business registers came into force in 2019 (Ministry of Justice of Estonia, 2019). The X-Road data exchange infrastructure enabled technical interoperability to exchange data between business registries. The benefit of using X-Road is increased efficiency and accuracy of data with synchronous and real-time communication between business registers. The data exchange is only intended for representatives of the business registers, and it is not meant for third party use (Ministry of Justice of Estonia, 2019).

Another active use-case of X-Road in cross-border data exchange, was between the national population registries of Finland and Estonia. Collaboration on the exchange of population data between Finland and Estonia dates from 2005. In 2005, the countries' population registries signed a collaboration agreement to exchange data on relevant subjects on deaths, name changes, changes of address and information on their dependent children. This document provided a legal foundation for exchanging relevant data about citizens between these two countries. However, the agreement that was set out only enabled batch-based data exchange with data being requested and provided on average once a year(NIIS, n.d.-a). Since 2014, the Finnish population registry (DVV) has used the X-Road infrastructure which enables the technical connection, and the agreement of 2018 established the creation of a federation between the Finnish and Estonian X-Road infrastructures. With the establishment of the federation, data exchange has been automated and enables greater data accuracy and a decrease in manual workload(NIIS, n.d.-a). One of the benefits of X-Road use is the standardised interoperability solution that improves information accuracy, security and efficiency.

NIIS is currently developing further X-Road version 7, which will support features such as asynchronous data transmission communication type. In addition, future planned development is to make X-Road more user-friendly, cost-efficient, environmentally sustainable and cloud native. All the changes are not included in the first production version, but they will be introduced one by one over time in various X-Road 7 minor versions (Interview 1).

Table 3. X-Road cross-border data exchange solution specifications.

Specifications	Criterion	X-Road
Legal Specifications	Legal background	Joint Declaration Finland Estonia 2016 Population registry data agreement Business registry data agreement
Business Specifications	Solution vision, description, and objectives, key principles	X-Road is an open-source software and ecosystem solution that provides unified and secure data exchange between organisations.
	Solution's governance	X-Road operators
Technical Specifications	Data-exchange model	Four-corner model
	Data transmission communication type/method	Synchronous
	Data-exchange solution network usage	Public/Private
	Openness of standards and specifications	Source code is open-source and published under MIT licence, all specifications and standards are open.
	Data-exchange solution specialization	Nationally: Horizontal Cross-border: Vertical

4.1.2   E-DELIVERY BUILDING BLOCK

The MS' eGovernment Expert Group agreed to endorse a number of focus areas and key enablers for digital cross-border public services. Because of divergent views, MS could not reach a formal consensus on the exact services (*Implementation and Evaluation report eGovernment Action Plan 2016 - 2020*, 2016). However, the work continued through the CIP ICT-PSP Program and the LSPs named above financed by this program (European Commission, 2016a) One of the main goals

was, especially in the e-SENS project, the development of the building blocks that can be used by the MS to produce their own cross-border services (European Commission, 2017a). One of the outcomes of e-SENS was the first version of the eDelivery building block. This building block was adopted by CEF, and was further developed and maintained. It became the reference implementation for data exchange in the EU for eGovernment services.

eDelivery is a CEF building block that enables interactions and data exchange between public administrations, businesses, and citizens in an interoperable, secure, and trusted manner (European Commission, 2019b). It functions as a distributed network of nodes, where participants constituting the nodes adopt eDelivery technical specifications to exchange data with each other and interact without setting up any additional channels. Data exchanged through the eDelivery building block can be transferred at local, national, and cross-border levels (Fillis, 2022), depending on the given project and policy domain.

The goal of the eDelivery building block is to enable data exchange and support the creation of a European digital single market (European Commission, 2019b; O'Donoghue & Kivimäki, 2021). This solution enables organisations with heterogeneous ICT systems to connect to the eDelivery network and exchange data in a trusted and secure format (European Commission, 2019b). To do this, the eDelivery solution uses a 'four-corner model' (See Figure 4 below). Data is exchanged between backends (see corner one and corner four in the Figure 4 below). However, backends do not exchange their data directly. Instead, they must connect to AP (see corner two and corner three in the Figure 4 below), which uses the exact technical specifications and rules to
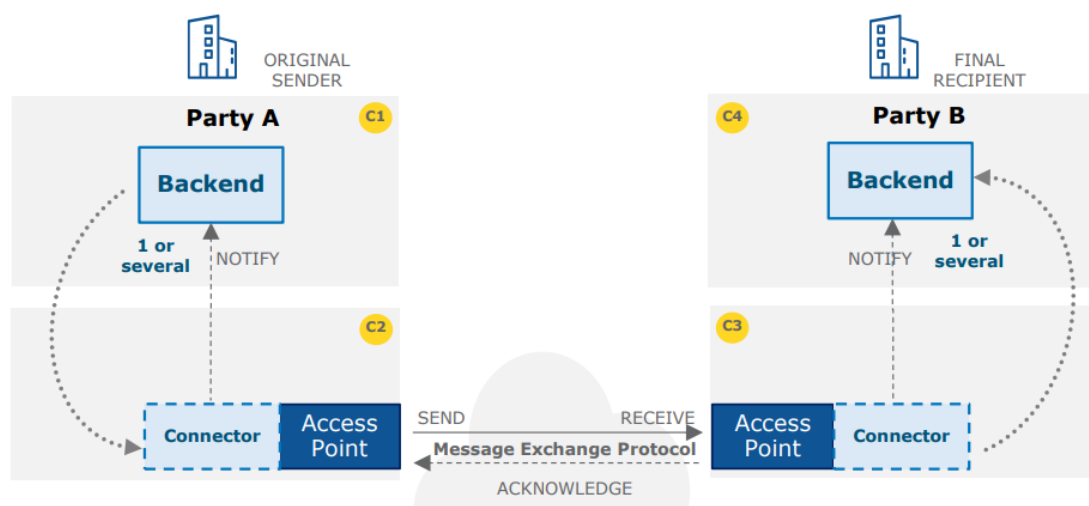

Figure 4. eDelivery Building Block data-exchange model. (Source: Sampaio, 2017).

communicate with each other and perform sender/receiver roles (European Commission, 2019b). eDelivery solution uses the AS4 messaging protocol to enable communication, which is open and free of charge for users. Also, all backends involved in data exchange must be connected to the AS4 AP (European Commission, 2015), which is not operated by a central authority, but instead deployed in the MS by a public or private sector service provider (European Commission, 2015). It can also be deployed by a public authority on a MS level, or by data exchanging party itself. For example, in SDG, one deployment alternative is MS-specific APs. For backends to exchange data, sender should also be aware of the type of documents and data transportation method that the recipient (AP) is capable to understand (European Commission, 2019b). This information is made available through Service Metadata Publisher (SMP) service, which stores interoperability metadata and enables the correct exchanges between counterparts (Rodrigues-Frade, 2018). The eDelivery SMP profile is an open specification for publishing metadata within a four-corner network and it is based on the OASIS SMP version 1.0 specifications (European Commission, n.d.-d).

CEF eDelivery is a generic solution with non-proprietary specifications that multiple vendors can offer (European Commission, 2022.). The specifications that are used are based on the open OASIS standards, more specifically eDelivery building block uses AS4 and SMP specification. When it comes to eDelivery components, the software implementing specification can be different. Currently, the EC implementation software is open-source software DOMIBUS implementing the eDelivery solution. However, there are also different vendors providing a conformant software solution for implementing the eDelivery APs, whose solutions are not necessarily open-source (*EDelivery AS4 Conformant Solutions*, n.d.).

eDelivery solution is content-agnostic, meaning that it can facilitate the exchange of any kind of data while being unaware of the content that is transferred, i.e., message exchanges (European Commission, 2022.). It enables a wide selection of services that may require particular types of data (European Commission, 2022), and it uses the public internet to allow the exchange. The eDelivery building block supports both domain-neutral and domain-specific use-cases. In domain-neutral use-cases, this solution can be used to enable the exchange of any type of data that public administrations or businesses require (European Commission, 2022). This is often referred to as 'message exchanging'. On the other hand, the eDelivery building block also supports exchanges of more specialised data required by domain-specific use-cases. For example, exchanging invoices in the field of procurement (European Commission, 2022).

An important part of the development of the eDelivery building block was the discussion of whether the result should be synchronous or asynchronous. The discussion was made very thoroughly, and, in the end, technical and legal aspects were the reason for the decision. From a legal point of view, e.g. national legislation obstructs the operator of the eDelivery building block. Regularly the data are not centralised and sits spread here and there in different systems; typically, they are distributed, possibly available in towns or environments, in regions. In some cases, e.g. the requested data are not yet digitised or it is necessary to get an additional confirmation, that the data can be shared with the requesting party. The operator of the building block is not responsible for this kind of decision. That was the main reason why asynchronous was regarded as the only option.

At present, the number of use-cases adopting eDelivery specifications to enable cross-border services is increasing, and it also includes countries from outside Europe. There are 39 projects reusing the eDelivery building block (European Commission, 2022) in projects that span in different domains, including government and the public sector, energy, science and technology, economy and finance, justice, social security, transport etc. (European Commission, 2022). Any European policy domain that needs secure and reliable cross-border data exchange can use this building block. eDelivery has links to the eIDAS Regulation (Regulation (EU) No 910/2014, 2014), also promoting the principle that electronic documents should not be denied legal effects because of their electronic format (European Commission, 2022). Article (3), (43), and (46) of the Regulation (EU) 910/2014 are relevant for eDelivery, as they define not only the electronic registered delivery service but also detail the legal effects of electronic registered delivery service and legal effects of electronic documents (European Commission, 2022). eDelivery is also mentioned in other regulations and documents, including Regulation (EU) 2015/1986 ('eForms'), Council Decision (EU) 2018/1926, and Commission Delegated Regulation (EU) 2020/473 (Regulation (EU) 2020/473, 2020; Regulation (EU) 2015/1986, 2015; Decision (EU) 2018/1926, 2018). Likewise, as it is described for X-Road, a legal basis is necessary to ensure the data exchange between the parties maintaining the eDelivery systems. The legal basis may be, e.g., an agreement (bilateral or many to many), a treaty, or a law. This is important to establish and ensure the required trust in the data exchanged.

eDelivery is also expected to evolve further within the constraints of AS4, according to the needs of MS and projects, but also to strengthen the user-centricity and user-driven nature of the solution (Interview 4). If need be, this may also include further diversification of the building block and expansion of this solution with new eDelivery features and elements (Interview 4). The

following section presents findings from the investigation of policy domains where eDelivery specifications are developed, including EESSI, BRIS, OpenPeppol, and SDGR/OOTS.

Table 4. eDelivery Building Block cross-border data exchange specifications.

Specifications	Criterion	eDelivery Building Block
Legal Specifications	Legal background	Regulation (EU) 910/2014 Regulation (EU) 2015/1986 ('eForms') Council Decision (EU) 2018/1926 Commission Delegated Regulation (EU) 2020/473
Business Specifications	Solution vision, description, and objectives, key principles	eDelivery building block enables (cross-border) data exchange by providing technical specifications, standards, installable software, and supporting services.
	Solution's governance	CEF/EC
Technical Specifications	Data exchange model	Four-corner model
	Data transmission communication type/method	Asynchronous
	Data exchange solution network usage	Public
	Openness of standards and specifications	OASIS AS4 and SMP Specification[2]
	Data exchange solution specialization	Vertical

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[2] The answer is based on the CEF eDelivery building block and the reference implementation

4.1.3 BUSINESS REGISTERS INTERCONNECTION SYSTEM (BRIS)

Another relevant EU initiative that enables cross-border data exchange between the MS is the Business Registers Interconnection System (BRIS). At the end of the first decade of this century, the financial crisis highlighted the importance of transparency across financial markets. In the context of measures for economic recovery, improving access to up-to-date and official information on companies can be regarded as a means to ensure confidence in the markets all over Europe. Also, more and more European companies operate in cross-border environments and have subsidiary branches or offices in another MS (Interview 5). That is why business registries cannot be limited to one MS, as the impact of different companies goes beyond that (Interview 5). To address this problem, the BRIS initiative was started in 2008 and focussed on the following three problems which needed solving:

- Lack of up-to-date information in business registers of foreign branches of a company.
- Difficulties with cooperation between business registers on procedures for cross-border mergers and transfers of registered office.
- Difficulties with cross-border access to business information.

The BRIS infrastructure provides a cooperation platform for all Business Registers of the MS and the EEA countries. BRIS is a solution based on technical building blocks provided and maintained by the EC. It is part of the Digital Service Infrastructure (DSI). This DSI provides citizens, businesses and public administrations with a single point of access on the European e-Justice Portal, www.ejustice.eu, on which they can search for and find the relevant information on companies and their branch offices (Krimmer et al., 2017). The BRIS infrastructure aims to improve cross-border access to business information, which enables the communication between business registries.

After establishing the BRIS solution was agreed by the MS and EEA countries, the discussion about the technical basis had started. Existing technical solutions were analysed, led by the EC. A prerequisite for analysis was that an existing solution should be re-used and extended to the specific purpose of BRIS. The evaluation focussed on the Internal Market Information System (IMI), the solution of the BRITE Project and European Business Register (EBR) and last but not least the LSP Project for eJustice (e-CODEX). In the end, it was agreed to use the results (building blocks) of the LSPs. BRIS uses the building blocks via a public network in order to enable access for citizens, businesses and public administrations to find a piece of information (Krimmer, Dedovic,

Figure 5. European countries using BRIS cross-border data exchange solutions.
(Source: The Authors)

et al., 2021). It also reuses the AP components of eDelivery- i.e., OASIS AS4 specifications (European Commission, n.d.-a). The system is distributed with a central component for storing and indexing published information (European Commission, 2019a; Krimmer, Dedovic, et al., 2021). BRIS uses the CEF eDelivery solution to enable secure and reliable data exchange. Furthermore, a solid legal basis for BRIS was established. The system is based on an European directive, Directive (EU) 2017/1132 relating to certain aspects of company law, and the secondary level law, a Commission Implementing Regulation (EU) 2020/2244 laying down rules for the application of Directive (EU) 2017/1132, as regards technical specifications and procedures for the

system of interconnection of registers (Directive (EU) 2017/1132, 2020; Directive (EU) 2017/1132, 2017). Finally, the benefits of BRIS are that it reduces administrative burdens, increases consumer confidence, increases legal certainty and efficiency of procedures (Kalvet et al., 2018; Krimmer, Dedovic, et al., 2021). BRIS is implemented in all 27 MS of the EU and the EEA countries, Iceland, Lichtenstein, and Norway (See Figure 5 above). Setting up BRIS was co-financed by the EC, 8 million EUR CEF Core Service Platform funding and 2.44 million EUR CEF funding through Generic Service Projects.

Table 5. BRIS cross-border data exchange solution specifications.

Specifications	Criterion	BRIS
Legal Specifications	Legal background	Directive 2017/1132/EU Commission Implementing Regulation (EU) 2020/2244
Business Specifications	Solution vision, description, and objectives, key principles	BRIS enables cross-border access to business information on EU companies for the public and ensures that all EU business registers communicate with each other electronically in a safe and secure manner across the borders.
	Solution's governance	DSI/EC
Technical Specifications	Data-exchange model	Four-corner model
	Data transmission communication type/method	Asynchronous
	Data exchange solution network usage	Public
	Openness of standards and specifications	OASIS AS4 specification
	Data exchange solution specialization	Vertical

4.1.4 ELECTRONIC EXCHANGE OF SOCIAL SECURITY INFORMATION (EESSI)

EESSI is the ICT system that supports local social security institutions in connecting and exchanging data across the borders (Interview 5). It replaces traditional approaches relying on paper-based forms and mail services by exchanging structured electronic forms between backends (Structured Electronic Document) (European Commission, 2022f). This system aims to speed up the exchange of social security information across borders and improve information accuracy, security, verification, combat fraud, and collect better statistics (European Commission, 2022). Information exchanged through EESSI is organised according to predefined processes, also

Figure 6. European countries using EESSI cross-border data exchange solutions.
(Source: The Authors)

known as Business Use-Cases (European Commission, 2022d). EESSI exchanged data cover for eight different social security branches, including sickness benefits, accidents at work, occupational disease, family benefits, pensions, pre-retirement and invalidity benefits, and unemployment benefits (European Commission, 2022).

The EC provided EESSI software components in 2017, and MS had two years to conclude their implementation on a national level. At the same time, EC hosts the institution repository to inform participants about the correct institutions while engaging in data exchange. (Central Registry of Affiliates, 2011). The first data exchange relating to the social security of EU citizens took place in 2019. While the transition period to EESSI was initially expanded, relevant institutions are gradually adapting to this requirement. The goal of EESSI is to have 5,000 institutions connected to the system, where now it counts up to 3,000 (Interview 11). Connected institutions are from 32 participating countries, including the EU, UK, and EFTA (European Commission, 2022b). See Figure 6 above for the list of countries currently using EESSI. The legal basis for this project is laid down in Regulation (EC) No 883/2004 and Implementing Regulation (EC) No 987/2009, also known as "modernized EU social security system coordination" (Regulation (EC) No 883/2004, 2004; Regulation (EC) No 987/2009, 2009). They both facilitate the transition towards electronic data exchanges and detail the required changes in information processing. Title V of Regulation (EC) No 883/2004 informs us of the responsibilities of MS for data processing and validity of exchanged documents. Regulation (EC) No 987/2009 simplifies and establishes the procedure for implementing Regulation (EC) No 883/2004 (Regulation (EC) No 987/2009, 2009). It facilitates citizen movement across the EU by guaranteeing equal access to social security services.

The EESSI system contains two key domains, national and international. As part of the national domain, the network includes national applications and national gateways, which is a component that integrates national applications with the international domain (Mastorodimou, 2017). On the other hand, the international domain contains the AP and central service nodes (Interview 5). AP ensures secure and reliable communication and enables data to reach the correct destination. EESSI uses multi-hop communication where the chain is managed end-to-end (e.g. acknowledgements/errors are only sent once the message reaches the destination and not in the intermediate steps) (Interview 11). In multi-hop communication, the sending national application sends the message to the sending AP, which takes the message forwards to the receiving AP (Interview 11). The receiving AP takes the message to the receiving NA. In this process, only one message is created (by the sending national application), and only one acknowledge/receipt is

created (by the receiving national application) (Interview 11). Multi-hop communication is in line with the four-corner data-exchange model that is described in the framework of this report.

Before communicating with other participants, national institutions must be connected to the EESSI AP. Data between backends are transmitted in an asynchronous communication type, meaning that national applications receive requests and apply the logic to respond (Purcarea et al., 2016). EESSI uses a closed network to exchange information, and it has a routing component that enables secure and reliable exchange of information (Interview 5; Krimmer, Dedovic, et al., 2021). EESSI also uses OASIS AS4 specifications (European Commission, n.d.-a).

According to the regulation, participating countries are responsible for developing and maintaining their national applications for their own part of the data-processing services (Council of the European Union, 2021). However, the EC had agreed to provide a Reference Implementation for a National Application; (RINA) software based on open-source software and reusable components that helped participating countries establish their national applications (Council of the European Union, 2021). The Commission agreed to distribute the last release of RINA to the countries in December 2020 and progressively phased out its support for this application. Countries are now free to either build their own application or continue operating and evaluating the 2020 version of RINA. RINA is a case management portal reference offering infrastructure and communication services, repository and publishing services, user interface services, etc. (Mastorodimou, 2017). According to the Layne and Lee (2001) model, we may conclude that EESSI supports vertical integration in the social security policy domain. It also uses CEF building blocks, including eDelivery, eInvoices, eTranslation, and eSignature (European Commission, 2022).

Table 6. EESSI cross-border data exchange solution specifications.

Specifications	Criterion	EESSI
Legal Specifications	Legal background	Regulation (EC) No 883/2004 Implementing Regulation (EC) No 987/2009
Business Specifications	Solution vision, description, and objectives, key principles	EESSI is the ICT system that supports social security institutions to connect and exchange data nationally and across the borders.

	Solution's governance	DG EMPL/EC and Participating Countries
Technical Specifications	Data-exchange model	Four-corner model
	Data transmission communication type/method	Asynchronous
	Data-exchange solution network usage	Closed network
	Openness of standards and specifications	OASIS AS4 specification
	Data-exchange solution specialization	Vertical

4.1.5   OPENPEPPOL

OpenPEPPOL provides a set of PEPPOL-based ICT products and services that enable cross-border interconnection of eProcurement systems through loosely coupled building blocks. The goal of this project was to align business processes through common standards, address legal issues, and develop open-source technologies to support cross-border communication in the procurement domain (PEPPOL, 2012b). The Pan-European Public Procurement On-Line (PEPPOL) project was one of the LSPs mentioned above, funded jointly by the EC and the PEPPOL Consortium members. The project was initiated in 2008 to simplify electronic procurement across borders by developing technology standards that could be implemented across all governments within Europe. The overall objective was to enable businesses to communicate electronically with any European government institution in the procurement process and also to manage multiple trade-related relationships to increase efficiency and reduce costs (Interview 6). Communication includes exchanging different documents, such as e-Order, eInvoices, Advance Shipping Notes etc.

The PEPPOL eDelivery network uses a set of common business processes and technical standards, AP and gateways to enable interconnection between multiple parties in the EU. APs can be provided by both public and private sector organisations (PEPPOL, 2012b). This is regulated by the PEPPOL Transport Infrastructure Agreements (TIA), which also provides a many-to-many legal framework to replace bilateral agreements between pairs of exchange partners (PEPPOL, 2012b).

The PEPPOL solution also provides technical specification and open-source software for data exchange relating to public eProcurement processes, enabling communication between heterogeneous data exchange infrastructures. Therefore, it does not require the development of new systems but rather connects existing ones. All participating organisations (such as contracting authorities or suppliers) publish their receiving capabilities (delivery addresses, business processes and document types supported, etc.) using a separate service called Service Metadata Publisher (SMP). The SMP is similar to an address book and it complements an AP by containing the details of participants within a specific eProcurment community (Works, n.d.). For backends to correctly exchange data, all PEPPOL AP need to know each other and participants they support (Works, n.d.). For this, Peppol maintains one centralized service, called the Service Metadata Locator (SML). The SML of PEPPOL defines which Service Metadata Publisher (SMP) to use, to find out delivery details for any participant in the network.

Initially, PEPPOL used AS2 technical specification to exchange messages. However, there was an agreement between OpenPEPPOL and the EC where parties agreed for a transition and AS4 became mandatory since mid-2019 (Hoddevik, n.d.). Therefore, PEPPOL re-uses different technical building blocks provided and maintained by the EC, e.g., eDelivery. Exchange of information, similarly to the eDelivery building block, is enabled through the four-corner model and AP acting

Figure 7. European countries using OpenPeppol cross-border data exchange solutions. (Source: The Authors)

as interoperable nodes. This enables a many-to-many interoperability environment and reduces costs and burdens for creating bilateral agreements and creating new systems (PEPPOL, 2012a).

OpenPEPPOL has taken up the outcomes of the eDelivery solution provided by the EC. However, PEPPOL has its own AS4 profile that is based on the OASIS AS4 specification. The base specification in PEPPOL AS4 differs from eDelivery AS4 specification in terms of exchange patters, exchange pattern bindings, and message correlation (See technical details at OpenPEPPOL AISBL, n.d.). In addition, PEPPOL has its own SMP specification too that is not the same as the OASIS SMP specification. The specifications are shared and discussed in specific Technical Committees (TC) e.g. of OASIS to ensure the alignment with the requirements of different standardisation bodies (OASIS, CEN etc.).

The results from the PEPPOL project also help comply with Directive 2014/55/EU, which sets out that all contracting authorities involved in public procurement should be able to exchange electronic invoices with public administrations by 2019 (Directive 2014/55/EU, 2014). In addition, PEPPOL solutions in other European initiatives are also relevant (Single Market Act II, A Strategy for eProcurement, eGovernment Action Plan 2016-2020, etc.), as they serve as a reference point for cross-border e-procurement and adoption of solutions/infrastructure (PEPPOL, 2012b).

The PEPPOL services, solutions and specifications are maintained by OpenPEPPOL AISBL. The organisation was established at the end of the project phase to ensure the sustainability of the project's outcomes. OpenPEPPOL AISBL is a private, not for profit international association under Belgian law (Association Internationale Sans But Lucratif – AISBL) and consists of both public sector and private sector members. OpenPEPPOL consists of ca. 250 members from 28 countries, 20 European countries and additional countries outside of Europe, e.g., Canada and the USA (See Figure 7 above). Countries can participate on three levels: as OpenPeppol members, countries with certified APs, and countries with PEPPOL authorities (a public organisation that has taken on responsibility for developing that particular market) (Interview 6). The initial PEPPOL project had a budget of 15 million EUR, co-financed 50 % by the EC.

Table 7. OpenPeppol cross-border data exchange solution specifications.

Specifications	Criterion	OpenPeppol
Legal Specifications	Legal background	Directive 2014/55/EU

Business Specifications	Solution vision, description, and objectives, key principles	OpenPEPPOL provides a set PEPPOL-based ICT products and services that enables the cross-border interconnection of eProcurement systems through loosely coupled building blocks.
	Solution's governance	OpenPeppol (AISBL)
Technical Specifications	Data-exchange model	Four-corner model
	Data transmission communication type/method	Asynchronous
	Data-exchange solution network usage	Public
	Openness of standards and specifications	Peppol OASIS AS4 specification
	Data-exchange solution specialization	Vertical

4.1.6   SDGR/OOTS

The Single Digital Gateway Regulation (SDGR) is one of the cornerstones for further development of the Digital Single Market ((Regulation (EU) 2018/1724, 2018, p. 20182018). The gateway regulation was adopted in 2018. Following adoption, the EC and MS administrations are developing a network of national portals to provide information for citizens and businesses on how EU rules are applied in each MS and the EFTA countries, for cross-border users and the services available for assistance. These services are bundled via the European portal "Your Europe". The underlying technical platform is the Once Only Technical System (OOTS). The Single Digital Gateway Regulation (SDGR) is one of the cornerstones to develop further the Digital Single Market (Regulation (EU) 2018/1724). The gateway regulation was adopted in 2018.

The origin of the proposal for the SDG is based on the urgent need for a more coherent, streamlined approach in Europe. This was flagged up by several business organisations, the European Parliament, 17 MS and via the platform of the regulatory fitness and performance

programme (REFIT) of the EC. Besides that, by public consultation on EU citizenship, with 80 % of citizens stating that repetition of provision of personal data on the one hand and unavailability of them on the other hand, is the biggest hurdle in cross-border cases (eGovernment Action Plan 2016-2020). To prepare the SDGR and for a presentation to the European Parliament, the EC investigated gaps in the digitisation of 13 essential procedures (see Figure 8 below). These key procedures related to different areas, e.g., working or studying abroad and setting up a business in another MS or associated country.
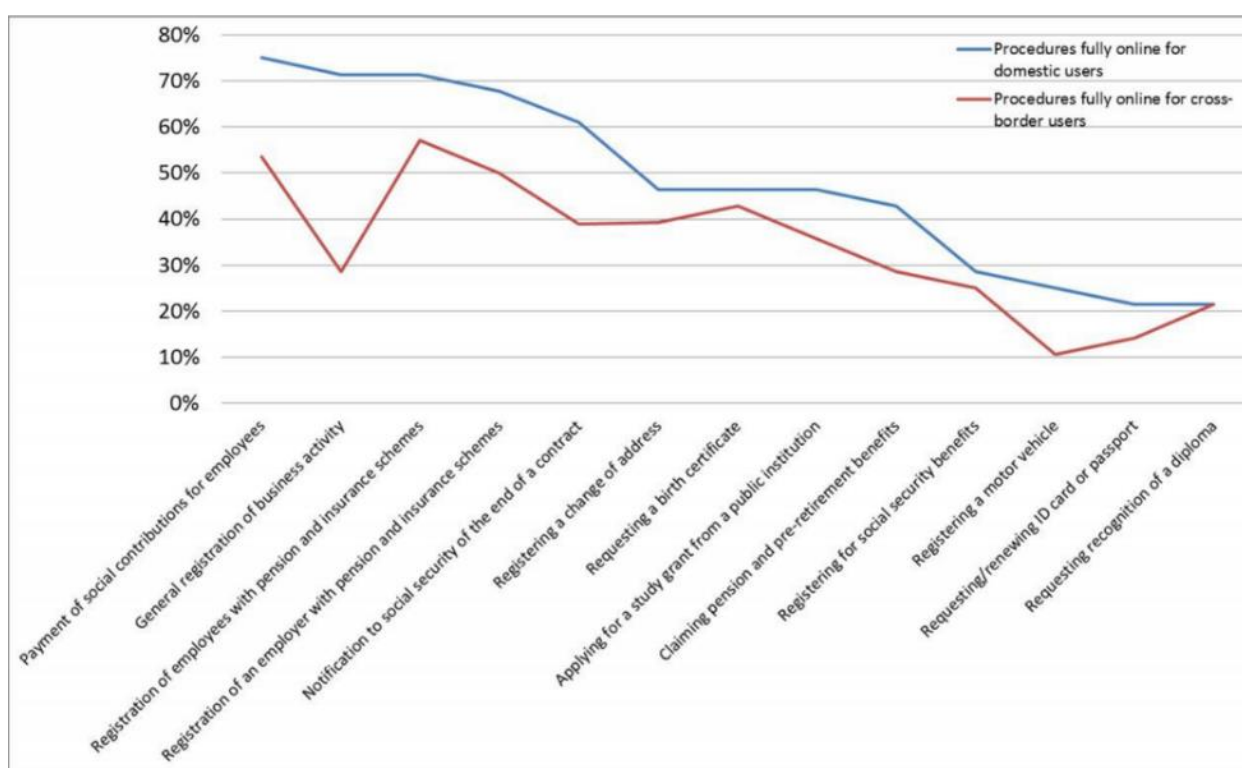
Figure 8. Gaps in the digitalisation procedures identified by the EC (Source: European Commission, 2018).

Afterwards, the EU Parliament, EC and MS acknowledged that the needs of citizens and businesses in their own country and across borders could be better met by extending and integrating existing European-level portals, websites, networks, services and systems and by linking them with different national solutions, thereby creating a single digital gateway serving as a European single-entry point. The Single Digital Gateway Regulation was established to provide a sound legal basis for the SDG. During the development of the SDGR, the EC, MS, and associated countries addressed the aforementioned needs and additional services. The EC established a special approach via a

common group, with the "gateway coordination group" to cover all of these and integrate them into the European portal. Figure 9 below highlights how different aspects of the SDGR will fit together. The purpose and aim of the Single Digital Gateway are to provide EU citizens and businesses easy and non-discriminatory online access to:

- information about EU and national rules,
- national procedures for complying with these rules and
- EU and national assistance services, in order to help them exercise their rights in the Digital Single Market.

The OOTS will be built by the EC, MS and EFTA countries. The OOTS implementing regulation draft states that eDelivery will be used as a data exchange solution. In addition, mutual recognition
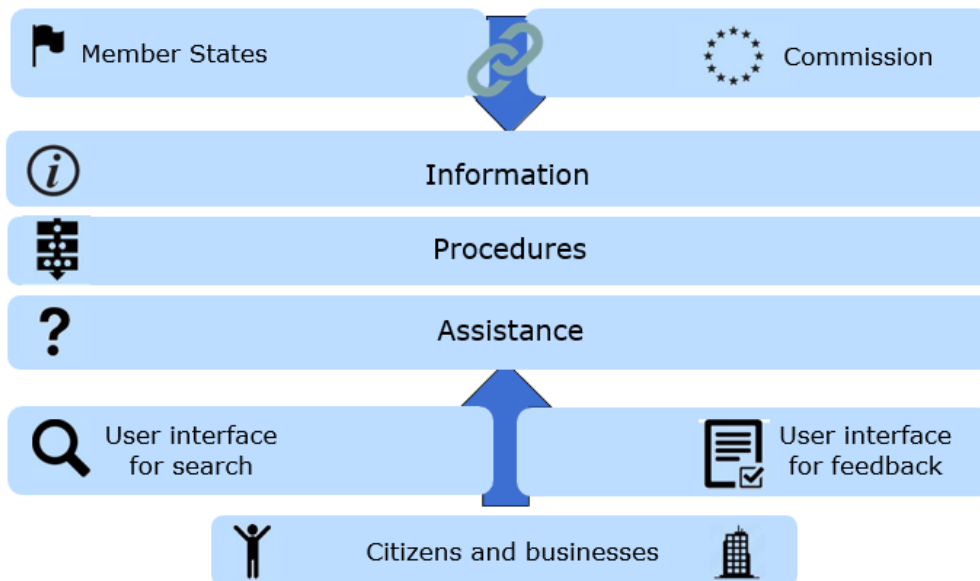
Figure 9. Outline of the single digital gateway by the EC (Source: European Commission, 2018)

of eID schemes based on eIDAS, the building blocks provided by ISA and CEF programmes together provide the basis for building OOTS.

As described above, building blocks are not created from scratch. They are based on the outcomes of LSPs. The once-only principle project (TOOP) was launched with the support of the EC) in January 2017 and with funding from the Horizon 2020 framework programme for research and innovation. The approach of the parties involved was to introduce TOOP as the LSP project for research, testing, and implementation of the OOP in Europe. The main objective of TOOP was to

explore and demonstrate the OOP across borders, focusing on data from businesses. The TOOP project consisted of more than 50 organisations from more than 20 EU MS and associated countries (See

 above). It provided inputs for the forthcoming "implementing acts (based on Art. 14 SDGR) to set out the technical and operational systems" for OOP. The project had a budget of 8 million EUR. TOOP delivered the blueprint for the European technical OOP infrastructure. The results were taken on board by the EC (CEF) and used as the technical basis for OOTS in all MS and EFTA countries. It is anticipated that OOTS will become a trusted tool and a pillar of the Digital Single Market.

Figure 10. European countries that participated in the TOOP project (Source: The Authors)

Table 8. SDG OOTS cross-border data exchange solution specifications.

Specifications	Criterion	SDG/OOTS
Legal Specifications	Legal background	Single Digital Gateway Regulation (SDGR) Regulation on electronic identification and trust services (eIDAS)

		Forthcoming "implementing acts to set out the technical and operational systems" for OOP
Business Specifications	Solution vision, description, and objectives, key principles	OOTS will allow European citizens and businesses to provide their data only once while carrying out administrative procedures across the EU, as referenced in the SDGR.
	Solution's governance	DG CNECT/GROW/DIGIT- European Commission
Technical Specifications	Data-exchange model	Four-corner model
	Data transmission communication type/method	Asynchronous
	Data-exchange solution network usage	Public
	Data-exchange solution standards and specification	OASIS AS4 specification
	Data-exchange solution specialization	Horizontal

4.1.7   EUCARIS

The European Car and Driving License Information System (EUCARIS) is a data exchange mechanism that serves as a platform, running several different services (Paul, 2009). It connects base registries of participating countries in a mesh network to exchange vehicle and driving license data, vehicle ownership and insurance data, information on traffic offenders, and other transport-related data (Council Decision 2008/616/JHA, 2008). The services are based on different legal frameworks as the type of exchanged data varies between the applications (EUCARIS, n/d). The multilateral EUCARIS Treaty laid the initial legal basis for exchanging information on vehicles

and driving licenses (EUCARIS Treaty, 2000). It defines three reasons and purposes for EUCARIS: 1) to ensure accuracy and reliability of the vehicle and driving license register; 2) to combat vehicle-related crimes; 3) to enable fast data exchange in order to increase efficiency between administrations. The legal framework of the EU serves as another legal basis for EUCARIS. In the context of cross-border data exchange, this includes the EU Prüm Council Decisions, regulating the exchange of vehicle and owner information (EUCARIS, n.d.-a). Moreover, Directive (EU) 2015/413 on facilitating cross-border exchange of information on traffic offences, as well as the 3rd Driving License Directive 2006/126 on the exchange of driving license information (Directive 2006/126/EC of the European Parliament and of the Council of 20 December 2006 on Driving Licences (Recast) (Text with EEA Relevance), 2006; Directive (EU) 2015/413, 2015). Several bilateral agreements regulate further data exchange individually (EUCARIS, n.d.-a). Figure 11 below displays EUCARIS as a technical platform that enables the exchange of different types of data by running services based on several legal bases - leaving it up to national authorities whether to use all of them or only selected ones.
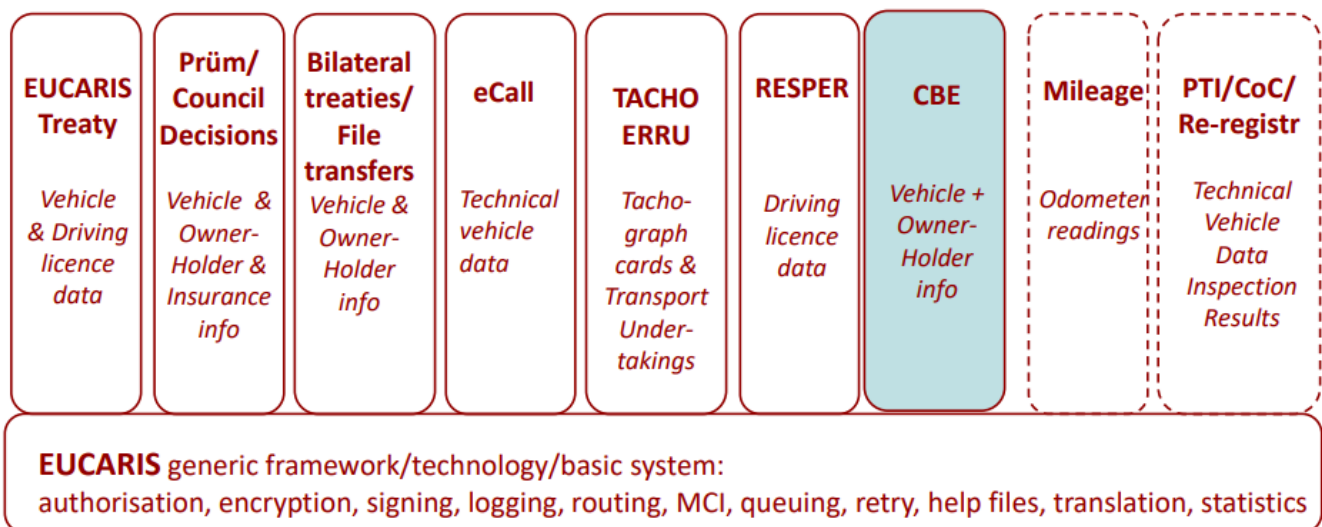
Figure 11. EUCARIS: One technical framework for different services (Source: Marek, 2016).

Dating back to the nineties, EUCARIS started as a collaboration between Germany, Belgium, Luxembourg, the Netherlands, and the UK (Paul, 2009). The initial objective was to combat criminal offences such as legally registering a stolen car in another country and using forged documents (EUCARIS, n.d.-b). It aimed to support law enforcement and police offices in order to increase road safety. The technical system was developed by and for governments as a decentralised solution

where national authorities remain holders of the data and remain responsible for their own registries (Interview 7). In that sense, EUCARIS does not require public authorities to implement new systems, networks, or hardware (Interview 7). This prevents national governments across Europe from investing in parallel networks, saving money and resources. The costs arising are shared between the participating countries (Interview 7). Therefore, EUCARIS is considered a low-cost technical solution, that is cheaper and faster to implement than having a separate system for each case (Interview 7). The EUCARIS General Assembly manages the system, takes overall decisions, and holds the highest authority (Interview 7). It is composed of representatives of national registration authorities. The EUCARIS General Assembly announced that opportunities are being explored to increase cooperation with the Association of European Vehicle and Driver Registration Authorities (EReg) by establishing a joint EReg/EUCARIS Project Group (EReg, 2021).

From the technical perspective, it is important to mention that EUCARIS is a proprietary solution developed by the EUCARIS countries (Paul, 2009). EUCARIS provides a software that must be installed by participating members (Interview 7). The data exchange is based on a distributive model and does not involve a central registry but includes data exchange between information system registries of participating countries. The EUCARIS solution is based on the four-corner model, as depicted in the Figure 12 (see below). This solution provides participating members which place specific requests with real-time data in a synchronous manner, but also with batch
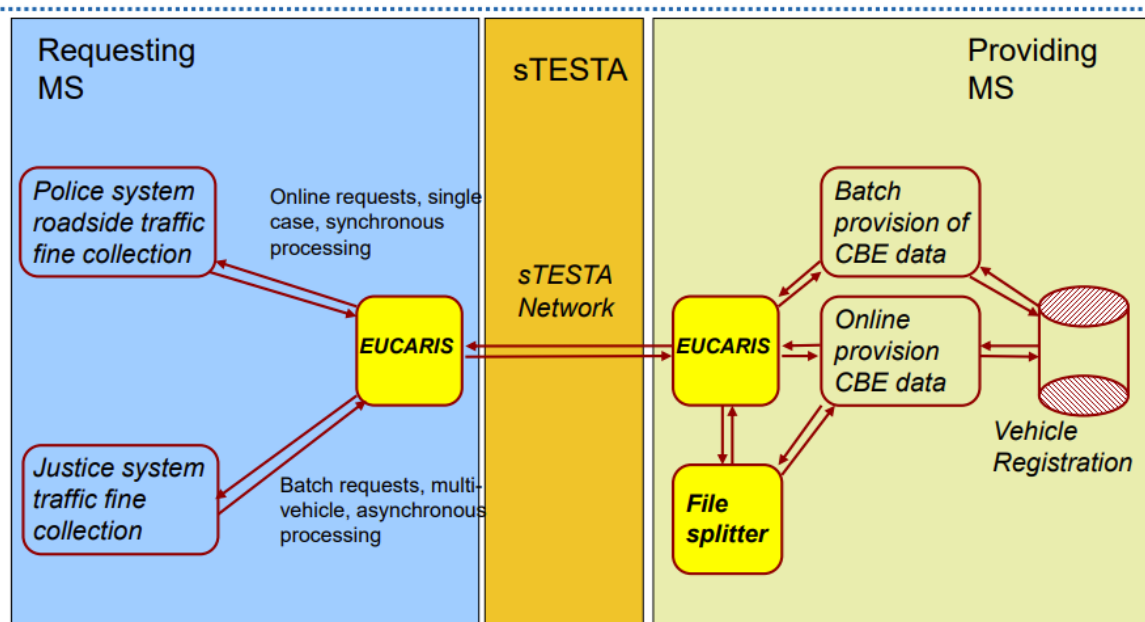

Figure 12. EUCARIS data exchange model (Source: Marek, 2016).

data in an asynchronous manner (Paul, 2009). Furthermore, the requests database relationship this solution supports is both one-to-one and one-to-many. The network used for data exchange within the EUCARIS solution is a closed network, the sTESTA network (Interview 7).

EUCARIS serves as a unique example of an established cross-border data exchange solution between all EU and EFTA countries. Several drivers have contributed to the successful usage and expansion of the system. A key factor is its political feasibility and low entry hurdles by keeping the data exchange mechanism on a decentralised level. This preserves a sense of ownership at the national level since every participating country runs their own register (Interview 7). The idea behind it is to keep the harmonisation required to exchange information across borders to a bare minimum. Another factor for the success of EUCARIS is considered to be its initial objective and relevance to combat cross-border-related crimes in the transportation sector. Since police expressed a growing need for a network to identify stolen cars and issue fines across national borders, governments indicated a high willingness to join EUCARIS. The revenue of fines collected provides an additional financial incentive for governments to participate. Most importantly, the Council Decisions 2008/615/ marked a key turning point for EUCARIS, as it set the legal basis to make EUCARIS an official data-sharing platform within the EU. Thus, making it mandatory for all EU MS to connect to EUCARIS (Council Decision 2008/615/JHA, 2008; Interview 7). This has led to a significant increase in participating countries. Over the years, EUCARIS has expanded to about 30 European countries and broadened its scope to a general exchange system for transport-related data (Interview 7). Participating countries connected to EUCARIS are displayed in Figure

13 (see below). Due to Brexit, the UK has currently been disconnected but is working on reconnection, as it was one of the founding countries (Interview 7).

Right now, EUCARIS is looking for possibilities to enhance cooperation beyond European borders, to connect to countries outside of the EUCARIS network that do not align with European data protection standards (Interview 7). Moreover, possibilities are being assessed to connect EUCARIS to other European data-exchange systems, such as e-CODEX or the Single Digital Gateway

Figure 13. European countries using EUCARIS cross-border data exchange solutions. (Source: The Authors)

(Interview 7). In future, EUCARIS envisages expanding its scope within the mobility sector by looking into functionalities connected to drones and large sailing ships, etc. (Interview 7). A potential future scenario within the next ten years could be the development into a general European system in the field of mobility (Interview 7).

Table 9. EUCARIS cross-border data exchange solution specifications.

Specifications	Criterion	EUCARIS
Legal Specifications	Legal background	Multilateral EUCARIS Treaty Bilateral agreements Council Decision 2008/615/JHA (EU Prüm Council Decisions) 3rd Driving Licence Directive 2006/126 Directive (EU) 2015/413
Business Specifications	Solution vision, description, and objectives, key principles	EUCARIS enables cross-border data exchange on vehicle registration, driving licenses, and other transport related data. The objective is to combat criminal offences related to road safety across national borders, such as car theft, document fraud, or speeding.
	Solution's governance	EUCARIS General Assembly
Technical Specifications	Data exchange model	Four-corner model
	Data transmission communication type/method	Synchronous and asynchronous are supported
	Data exchange solution network usage	Closed

	Data-exchange solution standards and specification	Proprietary solution, standards-based technology
	Data exchange solution specialization	Vertical

4.1.8 EHDSI –THE EHEALTH DIGITAL SERVICE INFRASTRUCTURE

Cross-border data exchange in the health domain is envisaged by the Directive on patients' rights in cross-border healthcare (Directive 2011/24/EU, 2011), which aims to establish a network of national contact points (NCP) for eHealth, and to establish conditions under which EU citizens may travel to another EU country and receive treatment.

To support the implementation of the directive and enable cross-border eHealth services, the EU has been developing the infrastructure for data exchange in the eHealth domain. The eHealth digital service infrastructure (eHDSI) enables data exchange within the EU in cross-border
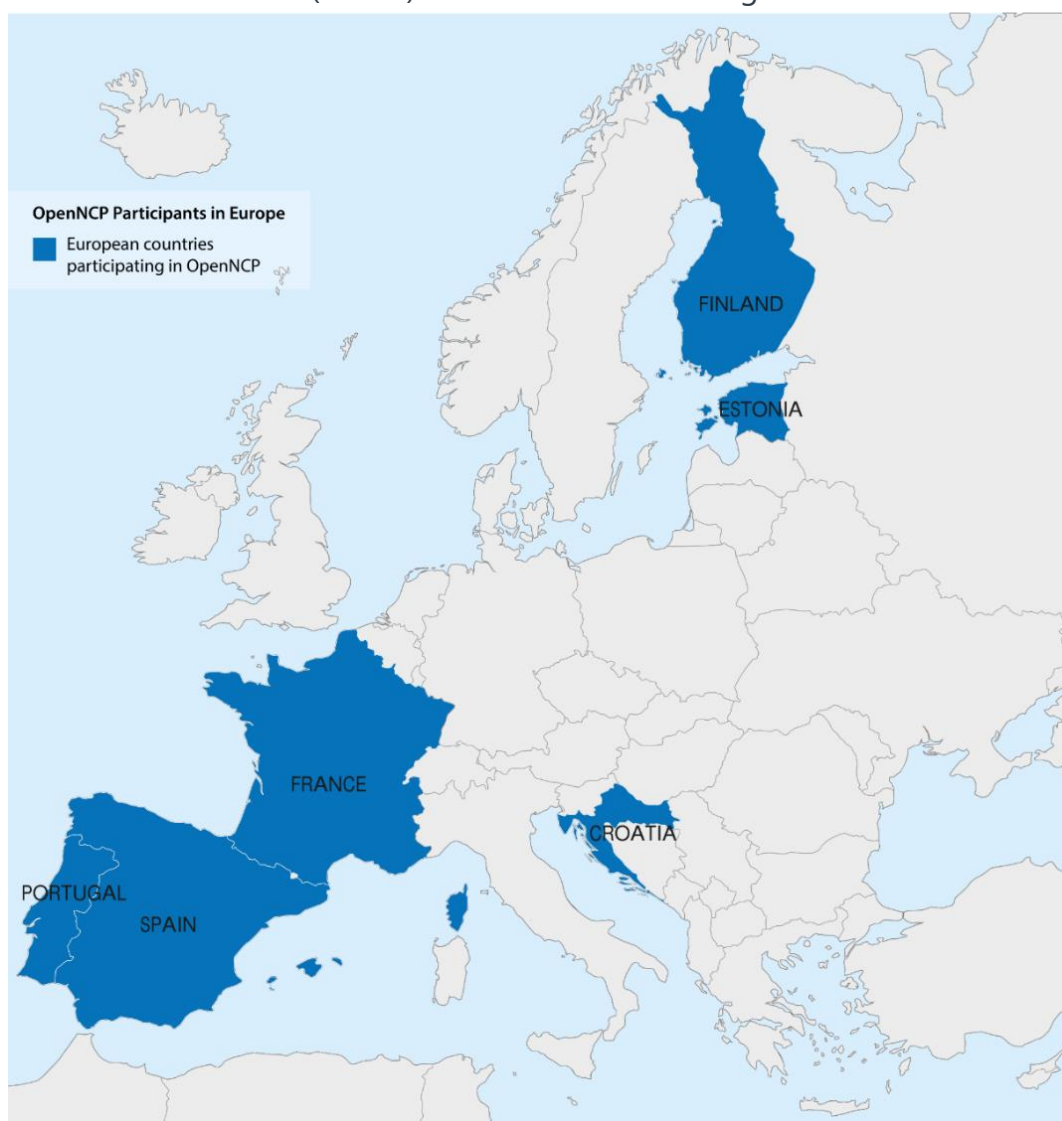
Figure 14. European countries using eHDSI cross-border data exchange solutions. (Source: The Authors)

environments in a secure, efficient, and interoperable manner in the health domain (European Commission, n.d.-b). eHDSI is based on the LSPs such as ePSOS and e-SENS, which provided specifications for the reference architecture of the OpenNCP (sometimes referred to as NCPeH technical gateway) solution (Katehakis et al., 2017). The OpenNCP solution was developed to help and support national public administrations in implementing the eHealth infrastructure to support the secure exchange of health data across the borders. Furthermore, the OpenNCP framework

facilitates the integration of heterogenous e-Health infrastructures that are common in cross-border settings (Fonseca et al., 2016).

The governance of the eHDSI solution contains EC DG SANTE, which provides a common ICT infrastructure, the eHDSI EU countries Expert group (eHDSIEG), which is responsible for the implementation of the OpenNCP and implementation of the cross-border eHealth infrastructure, the eHealth Operational Management (eHOM) board composed of representatives of EC and Expert Group which oversees the provision of services and takes tactical and operational decisions on eHDSI (European Commission, n.d.-c) into consideration.

One of the main principles of the eHDSI is not to alter the existing eHealth information system in EU countries, thus providing a four-corner data exchange model (European Commission, n.d.-b). Corners one and four represent national infrastructure, while corners two and three represent the OpenNCP infrastructure (Katehakis). Within the data transmission type, communication between data providers and data consumers occurs asynchronously, only when there is a data and service request. eHDSI also uses a closed network sTESTA such as the EUCARIS solution. Furthermore, this solution provides vertical integration in the health domain across Europe.

OpenNCP solution uses some existing eDelivery specifications. However, it does not use an AS4 access point but has its own NCP connector. The standards and specifications of eHealth data exchange solution are based on the Integration HealthCare Interoperable profiles[3]. The eHDSI DSI has an open access to its interoperability technical specifications on the eHDSI website[4]. Thus it can be considered a different solution than the CEF eDelivery building block (Katehakis , 2017; Interview 4).

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[3] For further details please see https://www.ihe.net/

[4] For futher details please see
https://webgate.ec.europa.eu/fpfis/wikis/pages/viewpage.action?pageId=888398574&preview=/888398574/888398592/eHDSI_NCPeH_Components_Specification_v3.0.0_OR.pdf

Currently, two services are provided through (eHDSI), cross-border data exchange of patient summaries and electronic prescriptions.
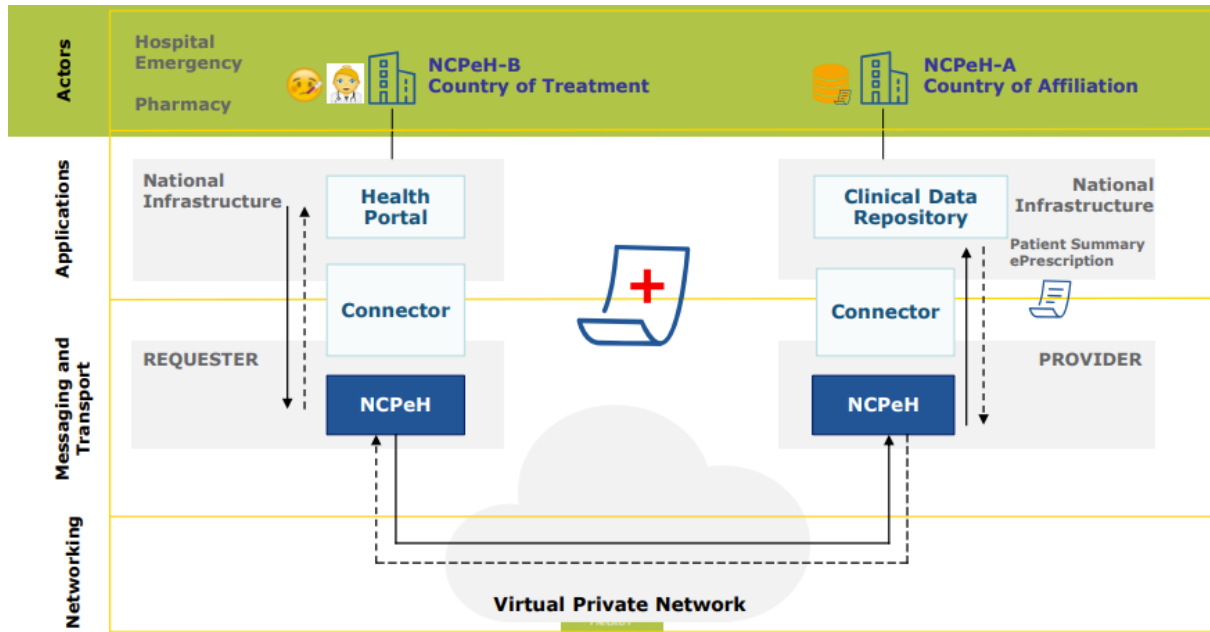
Figure 15. eHealth architecture model (Source: (Piha, n.d.))

In the case of the cross-border data exchange for e-prescription, countries that have implemented eHDSI and are involved as data consumers or data providers are Croatia, Estonia, Finland and Portugal (European Commission, n.d.-b). In addition, the countries that are able to access patient summaries either as data consumers or data providers are the Czech Republic, Malta, Portugal, Croatia, Spain, Luxembourg and France.

Table 10. eHDSI cross-border data exchange solution specifications.

Specifications	Criterion	eHDSI
Legal Specifications	Legal background	Directive on Patients' Rights
Business Specifications	Solution vision, description, and objectives, key principles	eHDSI is a digital service infrastructure that enables data exchange across borders within the EU in the health sector.
	Solution's governance	EC, eHDSIEG, eHOM)
Technical Specifications	Data exchange model	Four- corner model
	Data transmission communication type/method	Asynchronous
	Data exchange solution network usage	Closed network - sTESTA
	Data-exchange solution standards and specification	eHDSI DSI Interoperability Open Specification
	Data exchange solution specialisation	Vertical

4.2 Other Solutions

4.2.1 GAIA-X

The Gaia-X is an initiative intended to create an open, transparent, and secure ecosystem for infrastructure and data services (Gaia-X Association, 2020), coherent with European values and standards. This goal is achieved by developing open software for ecosystem control, establishing common governance mechanisms, offering technical tools, and introducing shared rules and policies that individual platforms or participants follow in order to work together (Gaia-X Association, 2020). It is a project primarily focused on industry (Interview 8), and pays attention to cloud infrastructures (Interview 8). Gaia-X is based on European values for data security, openness, transparency, interoperability, fairness, inclusion, and sovereignty (Bonfiglio, 2021).

Gaia-X consists of two main parts: the infrastructure and data ecosystems. Both of them must still be operationalized and deployed in practice (Interview 8). The infrastructure ecosystem includes the technological infrastructure and services required to enable activities relating to capturing, storing, exchanging, and processing data (Gaia-X Association, 2020). As Gaia-X includes service providers in the ecosystem, infrastructure services may vary among cloud services, sector-specific clouds, high-performance computing, edge clouds, interconnection, network providers, etc. (Gaia-X Association, 2021). On the other hand, the Gaia-X data ecosystem introduces the necessary rules and governance mechanisms to ensure that participants' data-use rights and conditional agreements are enforced at different stages in the data value chain (Gaia-X Association, 2021). An example could include agreements between parts determining how data will be processed and under what conditions third parties can (or cannot) access the data sets.

Gaia-X promotes federation as a model for cloud data exchange (Interview 8), which is relatively different from existing models that centralise data storage into one single place (Gaia-X Association, 2022a). Here, data can be collected from different domains and industries; distance and geographical locations do not restrict it; it is stored at the source and shared when necessary (Gaia-X Association, 2022). Federation in Gaia-X is enabled through federation services, including the Federated catalogues, Identity and trust, Data sovereignty services, Compliance, and Gaia-X portals and API (Gaia-X Association, 2020). They are provided through an open-source reference implementation (Gaia-X Association, 2020). Data sovereignty services enable ecosystem participants to exchange and share data with other parties while maintaining self-determination

of the data. Before the transfer takes place, the data provider and the data consumer must negotiate a data-exchange agreement. Both sides must agree on Usage Policies and other terms for the data transfer (Gaia-X Association, 2021c). Only then may the transaction occur. A data log message will stimulatingly be generated to record the exchange, prove that data has been sent/received, and keep track of rules, obligations, and possible parties involved in the transfer (Gaia-X Association, 2021c). This information is then stored and can be requested by the parties involved in the transaction.

Gaia-X supports four modes of transmitting data: pull, stream, push, and publish/subscribe (Gaia-X Association, 2021b). Pull mode presents scenarios where data providers define the endpoint where data consumers can download the data asset directly. In stream mode, data providers define the endpoint as where data consumers can continuously download data. Push mode presents scenarios where data providers submit data in endpoints that consumers require. And lastly, the publish and subscribe model offers cases where data providers frequently update data in endpoints that the consumer requests. This shows that the solution that facilitates the transfer or exchange of Data Assets in the Gaia-X ecosystem is missing (Gaia-X Association, 2022b). Data exchange solutions or connectors were outside the scope of the Gaia-X materials and documents, but later publications are expected to clarify this matter further (Gaia-X Association, 2022b).

The Gaia-X initiative is still in at an emerging state of development. It was initially commenced by the French and German economic Ministers to support Europe's digital sovereignty. In 2020, the non-profit Gaia-X European Association AISBL was established as the central organisation responsible for developing the technical framework and operating Gaia-X Federation services (Gaia-X Association, 2021). The Association has established a five (5) year strategic plan, which starts with pushing Gaia-X deliverables into the market (reference architecture, federated services, data space services etc.) and shifts towards scaling up, making the EU an important player in the global data economy (Bonfiglio, 2021). However, there are different ongoing debates regarding Gaia-X in public. By February 2022, the German Federal Ministry of Economics and Technology promised 117.4 million EUR in funding for eleven (11) supra-regional projects in education, finance, health, the public sector, etc. This changed recently, as this funding is most likely to be reallocated to other activities (Von Hannah, 2022).

The Gaia-X numbers over 300+ members, 70+ use-cases in 10+ sectors, and it includes members from 28 European and non-European countries (Gaia-X Association, 2022c). Most of the developments are taking place in the context of Data Spaces. They focus on agriculture, finance,

geoinformation, health, industry 4.0/SME, mobility, public sector, smart city/smart region, education etc. (Gaia-X Association, 2022c). Given the diversity of domains, Gaia-X enables flexibility and different requirements across different use-cases - i.e., it could support private internet for sensitive domains such as healthcare & social assistance relief but support public internet for travel or transportation domains.

4.2.2 IHAN

IHAN is a Finnish project by Sitra - the Finnish Innovation Fund, which lasted from 2018 to 2021 (Sitra, 2022b). IHAN does not provide a cross-border data-exchange solution; but instead, it enables the first steps of a fair data economy and contributes to balancing the interests of individuals, businesses, and society. The aim of IHAN was to create a method for data exchange and define governance frameworks, architecture definitions, and requirements necessary to build components that support seamless and secure data flows (Sitra, 2020). The goal is to support fair value exchange for all parties involved in service delivery and indicate a route towards fair data usage for addressing the issues emerging from the current data monopolies. In addition to service providers, IHAN encourages compensating other stakeholders that participate in creating services, especially data providers storing and making data available (Sitra, 2020).

The data exchange method that IHAN builds is based on consent and data productisation using API's and existing technical solutions and standards (Interview 9). The usability of this method was tested nationally and internationally in the context of IHAN's pilot projects. No significant barriers were identified to hinder the implementation of this method in cross-border aspects either (Interview 9). Work in pilot projects also supported participants in building technical solutions based on IHAN principles and creating businesses with data that accelerate the development of the fair data economy (Sitra, 2022). Pilots primarily covered topics supporting human-centricity in data usage and placing end-users in full control of their data.

IHAN puts forward five concepts to support the shift towards data economy, including consent, data transfer, identity, logging, and service. Particular data transfer (exchange) solutions are outside this project's scope, but different mechanisms could be used in the IHAN ecosystem. Therefore, both X-Road and eDelivery solutions are supported in IHAN ecosystems and could be used if data and service providers prefer them (Interviewer 9). On the other hand, the architectures of IHAN and Gaia-X (IDSA) are based on the same elements and roles (data providers, service

providers). One of the key differences between the two is how personal data is managed, where IHAN puts end-users first, while for Gaia-X, there is more flexibility in this context (Interviewer 9).

Since the project ended in 2021, the main objective has been to use lessons learned and utilise the Fair Data Economy Rulebook and IHAN Blueprint 2.5 for further advancement in the domain of fair data economy.

4.2.3 NORDIC SMART GOVERNMENT

Nordic Smart Government (NSG) is a collaboration between five Nordic countries – Denmark, Finland, Iceland, Norway, and Sweden. The program is currently undergoing its fourth phase, where it provides a strategic roadmap defining the steps and milestones which must be realised by 2027. The vision of NSG is to reduce barriers for businesses in the Nordic region by making business data accessible and useful for innovation in an automated, consent-based, and secure way (Nordic Smart Government, 2022b). It intends to reduce burdens for businesses, automate reporting processes, and reduce manual interventions through standardisation and structuration of business data (Nordic Smart Government, 2022b). Hence, to support digital development and regional integration by aligning technological infrastructures between relevant parties and enable Nordic businesses to operate freely across the region (Interview 10) while fulfilling the necessary legal and business requirements (Nordic Smart Government, 2021). By 2027, the goal of NSG is to make Nordic countries one of the most integrated neighborhoods in the world (Nordic Smart Government, 2021).

The NSG program focuses on six solutions: digital business documents, open accounting, digital product information, reliability, and data quality, generated digitally, simplified reporting, and reliability of data quality (Nordic Smart Government, 2022c). NSG focuses on both horizontal and vertical activities to support fields of solutions while also synchronising developments among participating countries (Nordic Smart Government, 2022a). The NSG program is governed by the Programme Manager while collaborating with the five designated National Teams and Operations Office. External stakeholders are also involved whenever it is deemed necessary.

To achieve NSG objectives, the Nordic public administrations depend on eDelivery and other European solutions that provide a technical basis (i.e., OpenPeppol, BRIS, SDGR, etc.). The business registers, tax authorities, and other relevant authorities that are involved in cross-border data

exchange activities already utilise eDelivery or some variants of it. This work is taking place under EU projects, independently by the authorities, as Nordic cooperation (including but not limited to the activities coordinated by the Nordic Council). And then, also through NSG, which is the most extensive initiative bringing everything together under the vision of Nordic real-time economy (business ecosystem). Although the primary role of NSG is not to develop new technologies, but to agree on principles and formats and to reuse existing solutions as much as possible, it cannot always avoid developing or adopting some technical components either.

5   Status-Quo: Cross-border Data Exchange in Europe

The cross-border data exchange infrastructure in the EU is highly heterogenous, and it represents one of the barriers to successful digital public service delivery across national boundaries (Krimmer, Dedovic, et al., 2021). In this report, we have presented three main cross-border data-exchange solutions. The first type of data-exchange solution is the national infrastructure solution, such as X-Road, that supports cross-border data exchange. The second type is solutions developed within the EU LSP, such as the OpenNCP and eDelivery building blocks (including EESSI, BRIS, OpenPeppol). The third type is the MS driven cross-border solution EUCARIS. Although all these data-exchange solutions offer the capacity to exchange data across borders, there are a few points that should be addressed, following the framework developed by this report.

The structure of this chapter is based on the framework developed for this report, that only addresses these solutions for the purpose of the cross-border data exchange. It involves legal specifications, which discuss legal aspects, business specifications, and technical specifications of cross-border data exchange solutions.

5.1   Legal specifications

Cross-border data exchange solutions depend not only on the technical feasibility to exchange data but more often, may also depend on legal support to exchange data across borders. The legal support for the solutions described in the EU varies. Bearing in mind that the EU is a supranational entity, the EU laws and legislations greatly impact the cross-border data exchange solutions and their use. This can be seen in cases of the EU supported cross-border data exchange solutions, such as OpenNCP and solutions based on the CEF eDelivery building block, such as BRIS, OpenPeppol, EESSI. These solutions have been supported by specific EU legislation (see Tables 4,5,6,7), which defines the requirements for using such a solution, and thus should be integrated within the national legislation. In addition, EUCARIS as one of the most successful and widely-used solutions in the EU – but also outside the EU – has been initiated in a bottom-up manner by MS and has also been supported by EU legislation to enable cross-border data exchange. However, as we can see, all of these solutions are based on the domain-specific legislation which aims to enable cross-border data or document exchange in the EU. Whereas these legislations support domain-specific cross-border data exchange, the SDG regulation aims

to enable cross-border data exchange in multiple domains as part of the SDG OOTS. Nonetheless, regulation of SDG supports interconnection of the information systems, but not the personal data transfer itself. Thus, transferring personal data is only possible following GDPR, after consent has been given by the data subject. In addition to managing and recording the data subjects' consent, SDG OOTS needs to provide a preview of the data to be used, which further complicates the use-case. On the other hand, solutions such as the X-Road, primarily a national data exchange solution that supports cross-border data exchange, do not have any support from EU-level legislation. This also affects the use of such cross-border solutions, as there is a specific need for agreements between interested parties. The use-case of X-Road presented in this paper shows the importance of existing mutual collaboration and legal requirements, to set up the initial data exchange in specific domains. Also, in this case, we can see that mutual agreements are based on domain-specific needs, such as business registers and population registers. These situations in the legal sphere show the importance of regulating and supporting cross-border data exchange within multiple domains, and this legislation could act as the primary enabler for cross-border data exchange. Another primary enabler of cross-border data exchange is the business and governance level.

5.2   Business specifications

Business needs for cross-border data exchange, as demonstrated in this report, are a crucial enabler for the implementation and usage of the solution. The data exchange solutions presented in this report have been associated and started as the primary business needs of involved actors. In the case of the CEF eDelivery building block, the solution was developed to provide standards and specifications for MS to enable cross-border data exchange between heterogeneous infrastructures. In addition, solutions based on CEF eDelivery, such as BRIS, OpenPeppol and EESSI, have been initiated based on the needs of citizens and businesses for cross-border data exchange. More specifically, in the domains of business, procurement, and social security. Similarly, other European solutions such as OpenNCP have also been recognised as crucial infrastructure to enable cross-border access to eHealth, thus the solution that enables interconnection between different information systems in the health domain. Furthermore, the main business needs as an initiator of the cross-border data exchange solution have been identified in vehicle registration cases, more specifically in the EUCARIS solution. From the governance perspective, as is shown in the report, most of these solutions have structured governance and roles. Although different types of governance, many of these solutions involved the representatives of MS within the EU. On the

other hand, for the X-Road solution, as previously mentioned regarding its governance body, NIIS, three countries are primarily involved as members, Estonia, Finland and Iceland.

5.3   Technical specifications

In addition to the legal and business aspect, another important feature of cross-border data exchange solutions is the technical level. From a technical perspective, most of the current solutions are based on the CEF eDelivery standards and specifications and thus mainly support similar technical specifications. However, despite of the similarity, not all the specifications are compatible with each other, e.g., OASIS SMP vs Peppol SMP. We can observe that the main approach of these solutions for the data exchange messaging model is based on the four-corner model, asynchronous communication, and open source, using a public network. In addition, OpenNCP, which does not use the CEF eDelivery building block, provides asynchronous communication and is similarly based on the four-corner model. On the other hand, EUCARIS is based on different specifications. As one of the longest and most widely used solutions for cross-border data exchange, EUCARIS, which is a proprietary solution, is based on three corner model, supports both synchronous and asynchronous communication, and uses a closed sTESTA network. X-Road as a national open-source data exchange solution is also based on a four-corner model, supports synchronous communication, and uses a public network, and as well can technically support private network. Technically, these solutions enable cross-border data exchange; however, it is mainly based on specific domain data exchange. Based on the initial development for specific purposes, the solutions such as OpenNCP and CEF eDelivery based solutions, such as BRIS, EESSI and OpenPeppol, cannot integrate with each other and thus exchange data within different domains. The technical solution that enables data exchange within multiple domains is the SDG OOTS; however, the implementing act for such a technical solution has yet not been adopted, although initial plans for the implementing act on technical solutions were made in June 2021. As we can see in this report and from the implementing act, there are initial plans to interconnect the EUCARIS solution with SDG OOTS and BRIS. X-Road, as the technically most advanced solution for data exchange, does support data exchange between multiple domains; however due to legal aspects, data exchange is still on a single domain level.
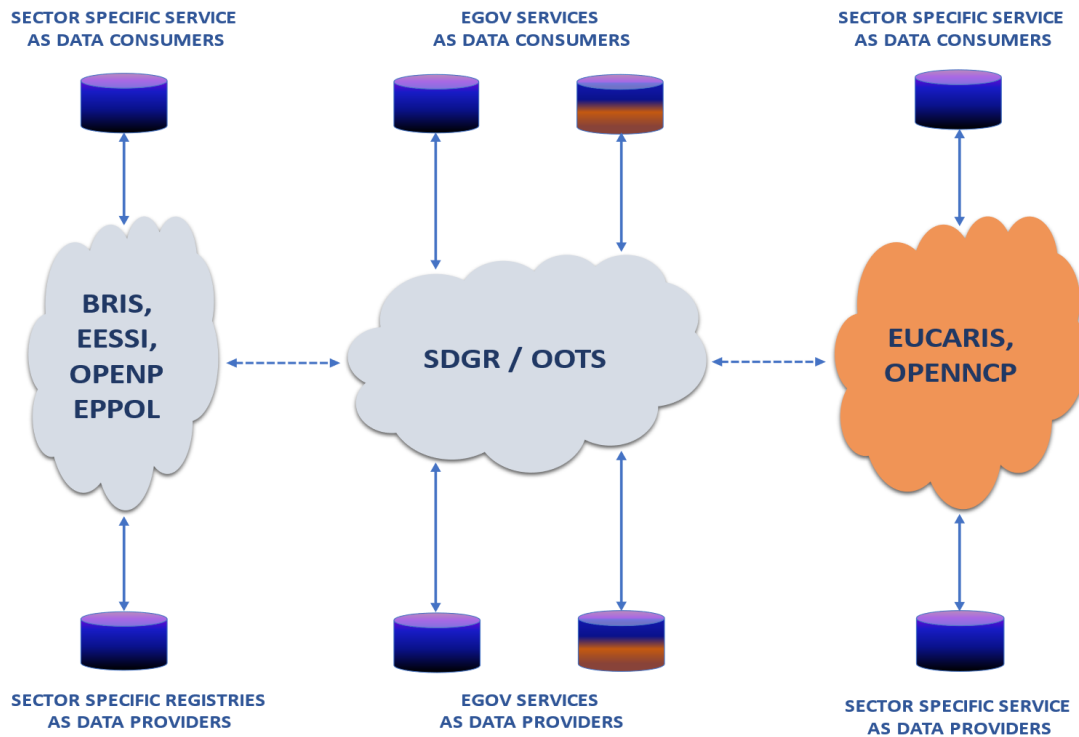
*Figure 16. Cross-border European solutions (Source: The Authors)*

5.4   Summary of the analysis

The current status-quo of cross-border data exchange solutions is a heterogeneous landscape with domain-specific data exchange. Following the Layne and Lee (2001) model of evolution stages in digital government, the current landscape on the European level shows that most of the presented solutions enable vertical integration of cross-border e-services. Developments of the cross-border data exchange solutions based on the business needs with the support of specific domain legal acts show that the future of cross-border data exchange will be based on domain-specific vertical integrations. The SDG OOTS solution aims to enable horizontal integration by using eDelivery standards and specifications,. This solution also aims to interconnect existing domain specific solutions such as EUCARIS thus enabling horizontal integration. , Currently, this solution is not in production mode, as an implementing act of SDGR has not been adopted, although the envisioned date for the implementing act was June 2021. A graphical representation of such developments on the EU level can be seen in the Figure 16 (see below).

X-Road, as one of the most developed technical data exchange solutions in the cross-border setting, also enables vertical integration, although nationally it supports horizontal integration and data exchange within multiple domains. (please see Figure 17 below). In the cross-border settings, X-Road currently enables vertical integration and data exchange within the same domain, such as, inter alia, population registry and business registries. Several challenges in the cross-border data exchange for X-Road have been identified. The lack of support in the legal framework for cross-border data exchange on the EU level using X-Road solution and cross-border governance and organisational framework presents a challenge for further use of the X-Road solutions cross-border data exchange solution.

For example, joining the X-Road federation for cross-border data exchange is based on a one-to-one trust federation with a need for multiple agreements on specific legal and business needs. This creates a multiplicity of agreements and multiple potential interconnections with each new user, as shown in Figure 18 below. Therefore, the lack of support in EU legal framework, governance model, organisational structure and involvement of MS representatives, may be a barrier to the usage of the highly advanced X-Road solution for cross-border data exchange within the EU.
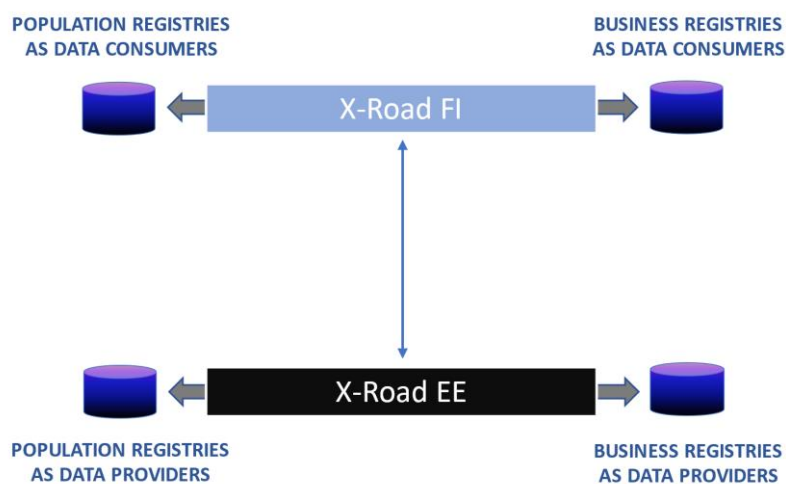
Figure 17. Estonia and Finland X-Road Federation
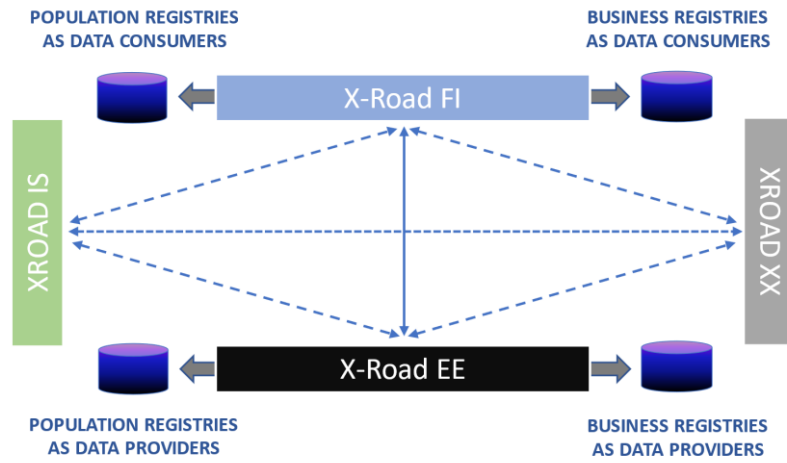*(Source: The Authors)*

Figure 18. X-Road Federations (Source: The Authors).

7 A Future Outlook for Cross-Border Data Exchange in Europe

In a broad sense, cross-border data exchange is all about enabling seamless, well-functioning, and accessible digital services across (*national*) borders, as well as improving interactions between governments, businesses, and citizens. With the growing mobility of people and businesses across Europe, the demand for secure and reliable cross-border data-exchange solutions will continue to increase. Therefore, this section provides a future outlook of key developments we anticipate in three domains: legal, business, and technical specifications.

As part of legal specifications, we can see that further work must be completed at the EU level. The lack of a common legal basis prevents a MS from recognising and accepting solutions or data issued in another MS. The current landscape indicates that cross-border data exchange and interoperability remain sensitive topics. Sufficient cross-border interoperability, especially of electronic identification schemes issued, enables citizens and businesses to benefit fully from a digital EU. Therefore, in the following years, we anticipate more work on:

1. Harmonisation of legal frameworks at the national level.
2. Filling gaps in the existing European eID framework.
3. Amending the data protection regulation with a focus across the EU borders.
4. Implementation of specifications for technical and operational systems for OOP.

Regarding business specifications, European solutions are currently oriented more towards vertical integration. In the coming years, this will presumably change, and the European data-exchange landscape will also evolve towards horizontal integration. This study did not identify any European one-size-fits-all solutions for cross-border data exchange. Different solutions cater to different needs and complement each other to a certain extent. However, organisations that operate at the national level and want to link to cross-border data exchange solutions must be prepared to be connected to more than one solution in the same domain. Cross-border data exchange solutions can co-exist, although they use different approaches for data exchange. In this sense, they differ from fax machines or modems, where everything is based on one global standard. For this reason, further research is required to understand why each data-exchange approach is needed and how they complement each other.

In the service delivery domain, cross-border data exchange solutions are part of complex institutional infrastructures that enable institutions to deliver services across borders. For this very

reason, standardisation and enactment of a solution tend to occur in a very complex environment and require competencies/resources that transcend technical aspects. Moreover, we see that the exact solutions that are thriving have sustainable governance models and solid political backing to address a business need. Hence, they incorporate values (i.e., security, privacy, sovereignty, etc.) and show the importance of further engaging relevant actors to develop the solutions. That is, solution owners can organise further forums for datathons, allowing countries to connect with each and test their cross-border exchanges.

The technical specifications of cross-border data exchange are likely to continue developing and evolving, and will support existing solutions for expansion with new features. For example, the majority of European cross-border data exchange solutions could support both synchronous and asynchronous communication. However, drastic changes in technical specifications are complex. Changing existing specifications that are already in use is difficult because data exchange solutions often serve as backbone infrastructures to support communication and are embodied in complex national and cross-border information system networks (Interview 1). For this reason, stability is often considered critical, and changes are associated with various switching costs and losses of past investments. However, extending specifications with new features and characteristics that doesn't affect existing implementations is easier, i.e., extending AS4 based eDelivery building block with a REST profile. The potential of new emerging technologies to transform cross-border data exchange should also be considered. Technologies such as the cloud and blockchain can give rise to new approaches. For this reason, they should be monitored more closely and studied further.

New types of cross-border data exchange solutions might also be developed in the course of the next five to ten years. These solutions can make use of different emerging technologies (i.e., blockchain; EBSI), adopt new approaches to control data (i.e., eIDAS II Wallet), or adopt complementary principles on how data is handled in general (i.e., IHAN). For the existing solutions, we anticipate that the number and quality of transactions will increase as they mature. Also, the development of seamless cross-border digital services will continue to be a digital government priority in Europe. For this reason, it is very important to keep track of recent developments, review progress regularly, and understand the type of data required to assess cross-border data exchange solutions. This would also help develop future benchmarks and keep track of advances in terms of technical specifications, rules, mechanisms, frameworks, etc., for cross-border data exchange.

6 Conclusions

A first result of analysing the different projects and solutions was discovering that in areas where a solid legal basis exists, the gaps in digitalisation are smaller than in fields with no or with only a weak legal framework. Secondly, we also demonstrated that implementation of a sound legal basis (e.g. SDGR, BRIS) boosts related technological developments, especially in a cross-border context. Furthermore, with X-Road we have shown that a solution can perform well in its primary purpose as a secure national/regional data exchange layer but can cause compatibility issues on a supra-national level. It was also recognised that the different variations of standards used by the sector specific solutions (e.g. OpenPEPPOL) increases the technical complexity for such a solution as X-Road to develop different interfaces to be interconnected with the different solutions. Besides that, the interviews with the experts as well as desk research highlighted the need for amendments to existing legal frameworks, e.g., the eID framework, data protection legislation etc.

The analysis above has not only underlined that piloting on a large scale is an appropriate instrument for bringing stakeholders together, developing technical solutions and identifying open issues. It has also shown us that this is a very useful approach for testing the transformation process on a national and supranational level. Furthermore, the solutions showed us that most participating countries and/or organisations are in or are in-between phases 2 and 3 of the Layne & Lee (2001) model. Consequently, it may be considered worthwhile to propose new initiatives that focus on and have a new thematic context, and also to add a new dimension from the organisational side. This should reflect the perception that it is crucial to continue and extend the involvement of vertical networks to test the cross-sector interoperability of cross-border solutions. Besides which, further efforts should be spent to investigate how the organisational structure of existing solutions can be institutionalised, further professionalised, and thereby sustained.

Future research should focus on the key solutions and further investigate how they could be sustained and extended. As user-centricity is a key element of Europe's digital future, additional attention could be paid and resources diverted towards examining, e.g., data ownership, data reorganisation, and data responsibilities.

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8 Appendixes

8.1 Appendix A. European Cross-Border Interoperability Policy Overview 2000 – 2030 (Source: The Authors)

	2000	2005	2010	2015	2020 - 2030
Declarations & Frameworks	30.11.2001 Brussels Declaration 25.06.2003 Como Declaration	24.11.2005 Manchester Declaration 19.09.2007 Lisbon Declaration 16.11.2009 Malmö Declaration		6 Oct 2017 Tallinn Declaration	8 Dec 2020 Berlin Declaration 1 June 2021 Lisbon Declaration
Frameworks	2004 EIF 1.0 - European Interoperability Framework	2007 - 2013 CIP - Competitiveness and Innovation Framework Programme	2011 EIF 2 - European Interoperability Framework	2017 New EIF - New European Interoperability Framework	
EU Policies	2001 - 2002 eEurope 2002 2003 - 2005 eEurope 2005		2011 - 2015 eGovernment Action Plan 2011-2015 2014 eIDAS Regulation	2015 Digital Single Market Strategy for Europe (DSM) 2016 - 2020 eGovernment Action Plan 2016-2020 2018 Single Digital Gateway	2023 Single Digital Gateway Procedures 2020 - 2024 Digital Europe for All (DE4A) 2021 Proposal to update eIDAS

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EU Programmes				
			Regulation (SDGR)	2021 - 2030 Digital Compass: The European Way for the Digital Decade
1999 - 2004 IDA II programme - Interchange of Data between Administrations II	2005 - 2009 IDABC programme - Interoperable Delivery to public Administrations, Businesses and Citizens	2010 - 2015 ISA programme - Interoperability Solutions for European Public Administrations	2016 - 2020 ISA² programme - Interoperability Solutions for European Public Administrations² / EIRA

2014 - 2020 CEF - Connecting Europe Facility Programme
2014 - 2020 Horizon 2020 research and innovation funding programme | 2021 - 2022 Interoperable Europe programme

2021 - 2027 CEF Digital - Connecting Europe Facility Programme
2021 - 2027 Horizon Europe

2021 - 2027 Digital Europe Programme (DEP) |

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8.2   Appendix B. EU Large Scale Pilots (2008 – 2021) (Source: The Authors)

	2005	2010	2015
Large Scale Pilots	2008 - 2012 PEPPOL - The Pan-European Public Procurement Online 2008 - 2014 STORK/STORK 2.0 - Secure Identity Across Borders Linked 2008 - 2015 epSOS - European Patients Smart Open Services 2009 - 2012 SPOCS - Simple Procedures Online for Cross-border Services	2010 - 2016 e-CODEX e-Justice Communication via Online Data EXchange 2013 - 2017 e-SENS Electronic Simple European Networked Services	2017 - 2021 TOOP - The Once-Only Principle Project

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8.3 Appendix C. Solution Specific Regulation on European Cross-Border Interoperability (2000 – 2020) (Source: The Authors)

	2000	2005	2010	2015	2020
Solution Specific Regulation	2000 EUCARIS: Multilateral EUCARIS Treaty	2005 EUCARIS: Prüm Convention	2011 eHDSI: Directive 2011/24/EU	2015 eDelivery: Regulation (EU) 2015/1986 ('eForms')	2020 eDelivery: Commission Delegated Regulation (EU) 2020/473
	2004 EESSI: Regulation (EC) No 883/2004	2006 EUCARIS: 3rd Driving Licence Directive 2006/126	2014 eDelivery: Regulation (EU) 910/2014	2015 EUCARIS: Directive (EU) 2015/413	2020 BRIS: Regulation (EU) 2020/2244
		2008 EUCARIS: Council Decision 2008/615/JHA	2014 OpenPEPPOL: Directive 2014/55/EU	2016 X-Road: Joint Declaration Finland Estonia	Forthcoming OOTS: Implementing Acts (to set out the technical and operational systems)
		2009 EESSI: Regulation (EC) No 987/2009		2016 SDG/OOTS: Regulation (EU) 2016/679 (and repealing Directive 95/46/EC)	
		2008 EUCARIS: Council		2017 BRIS: Directive 2017/1132/EU	

		Decision 2008/615/JHA			
				2018 SDG/OOTS: Regulation (EU) 2018/1724 2018 eDelivery: Council Decision (EU) 2018/1926	