

Estonia X-Road

Open Digital Ecosystem (ODE) Case Study

1. Context

Estonia, a small European nation with a population of around 1.3 million people, has emerged as an unlikely torchbearer of digital governance. Having earned its sovereignty from the USSR in 1991 at the cusp of the internet revolution, Estonia entered the internet era without the burden of cumbersome and inefficient legacy government systems. Consequently, the country was well-positioned to harness the benefits of digital technology and create an Information and Communications Technology (ICT) ecosystem that enabled social and economic development in the country. In order to do this, it adopted a three-pronged approach that focused on developing a new ICT policy, modernizing the Information Technology (IT) infrastructure, and launching programs in collaboration with the private sector to bridge the digital divide.

In the 1990s, the government released the Principles of Estonian Information Policy – a comprehensive policy document that articulated the actions to be taken by the State to develop an information society. The actions laid out were designed to assist government agencies in creating their own Information Policy Action Plan. To strengthen the IT infrastructure, government departments were provided with secure internet and intranet services. Further, to give a boost to the mass adoption of technology, computer and internet access was provided to schools, public internet access points were created, and computer skills courses were launched.

Estonia quickly leveraged the infrastructure to provide e-solutions such as e-banking and e-tax board to transform into e-Estonia, a digital society. Today, Estonia has earned the distinction of being the only country in the world to provide 99 percent of its public services online.

2. Solution

“Estonia is probably the only country in the world where 99% of the public services are available online 24/7. Only marriages, divorces and real-estate transactions are impossible online – you still have to get out of the house for those.”

Source: <https://e-estonia.com/solutions/e-governance/>.

E-Estonia is the platform through which the government provides public services digitally. The services provided span across almost every sector such as health (e-Health Records, e-Prescription), education (e-School), transportation (m-Parking), business (e-Tax board), public security (e-Police), etc. The private sector can leverage the infrastructure to create new solutions on top or provide their services through government-built portals (such as the e-government portal www.eesti.ee).

Estonia’s e-Governance Principles¹ guide the principles:

- All IT resources are intended to be open standard and open source to enable private organizations and other countries to use them freely and/ or build on them. While not every system is open source, the objective is to facilitate interoperability and sharing.
- The government maintains decentralized databases with the respective ministry or department that can communicate with each other. This enables availability of real-time data and eliminates duplication of data capture and storage efforts. The decentralized model not

only provides flexibility to the system as new databases can be built and connected but is also more secure as it eliminates a single point of failure. For example, the Ministry of the Interior is the chief administrator of the Population Register² which records the personal data of naturalized citizens and permanent residents. Every other department uses that system for name and identity (ID).

- The government recognizes the importance of data security and privacy. Accordingly, it has ensured that data exchanges are held accountable for the security of data and citizens have the right to view who has accessed their personal information and how it has been used. There are significant consequences for breach of data privacy including termination of employment, in the case of public sector employees.

The e-Estonia services have been built on two key building blocks – an e-ID system and a data exchange platform, X-Road. Citizens are provided with a digital signature using e-ID cards. This is used to authenticate identity and forms the basis of providing digital services in the areas of healthcare, law and justice, etc., to the citizens.

The X-Road platform facilitates secure exchange of information over the internet across disparate IT systems, i.e., it allows different government databases to communicate with each other. X-tee, Estonia's data exchange platform, is based on X-Road which enables the exchange of data amongst different government departments, citizens, and other private sector stakeholders. Originally developed in Estonia by the Information System Authority (RIA) in collaboration with private partners, X-Road technology is now managed by the Nordic Institute for Interoperability Solutions (NIIS), a non-profit institute. X-tee is governed by the RIA in Estonia.

X-Road has not only created an ecosystem of new and improved services for citizens, but has also made service delivery more efficient and cost-effective. Simply put, it has significantly reduced the time spent on data handling and exchange. For example, filing taxes through the e-Tax system takes about three to five minutes and is used by over 95 percent of Estonia's population.³ Similarly, the time taken to register a business takes three hours now compared to five days earlier. X-Road eliminates the need to build a central database or integrate existing data into one, thereby saving the country's resources. It also links with the database of private companies and allows them to use functions such as authentication, eliminating the need to reinvent the wheel. The use of digital signatures for enabling e-services has resulted in savings worth about two percent of the Gross Domestic Product (GDP)⁴ for the government.

In this case study, we will specifically delve into one of the biggest success stories – X-Road. Throughout the case study, we have used the term X-Road to also refer to X-tee, the Estonian data exchange platform built on X-Road.

3. Key Features and Learnings from X-Road

In this section, we describe how X-Road follows a few key principles of the Open Digital Ecosystem (ODE) approach, identify best practices, as well as areas where it can be strengthened.

3.1 Digital Platform

- **Enables interoperability across IT systems (both public and private)**

X-Road is a system through which messages are routed between the IT systems of the organizations, enabling them to exchange data. Today, over 1,000 organizations (both public and private) in Estonia use X-Road daily.⁵ X-Road uses common Application Programming Interfaces (APIs) and has adopted open standards for data exchange. This is especially valuable in a decentralized database model where different departments maintain their own databases. Open standards have improved the efficacy of X-Road by enabling functionalities such as exchange of digital documents and the ability to search through a database.

Since 2017, X-Road has been further enhanced to facilitate interoperability across databases maintained by countries. For example, discussions are underway between Estonia and Finland to enable data exchange between the Estonian Tax and Customs Board (EMTA) and the Finnish Tax Administration (VERO). This will ensure that taxation related functions such as international audits become more efficient.⁶

Principle 1: Be open and interoperable

Estonia is the first country in the world to make decentralized public and private databases interoperable at a national level.

For example, when the birth of a child is registered on the Estonian State Portal eesti.ee, the child is automatically registered for benefits and enrolled in school. This is possible only because of interoperability between the Population Registry, the IT system of the education department, and the IT system of the Social Insurance Board.

- **Built on reusable and shareable components**

X-Road comprises reusable components that can be configured by developers for application in different contexts. These components provide various functionalities such as enhancing security, monitoring transactions, and improving user experience. For example, the tool API Catalog is a web portal where the interfaces available on X-Road can be searched. It is currently being used by Finland to break data silos in providing public services. Then, there are monitoring tools such as the X-Road End-to-End Monitoring Tool (XRdE2E) that monitors the performance of the security servers of X-Road.⁷ The reusable and shareable components of X-Road lend flexibility to the system. These attributes make the system agile, enabling customization and easy upgradation with advances in technology.

- **Ensure privacy and security for data exchange**

Principle 4: Ensure privacy and security

One of the core principles of X-Road is ensuring data security, i.e., integrity, availability, and confidentiality of data.

For example, X-Road follows a two-stage process to access information. The first stage is registration. Only registered organizations fulfilling key security requirements can exchange data on X-Road. Registration with RIA is a complex process requiring an organization to have its own information system, a recognized security system, and an online certification system integrated into servers. In the second stage, the registered organization can access information only if the organizations sharing data have an agreement to share information. For example, a bank might need to access data from the population registry to establish the identity of a person. In order to do so, it will not only have to register on X-Road it will also need to have an information sharing agreement with the Ministry of the Interior.

Estonia is one of the leading countries in the world with respect to furthering practices to ensure security and privacy of data. The security of the system and of the data on X-Road has been ensured through the adoption of ‘Privacy by Design’ (PbD) principles and by incorporating appropriate security features in the platform design. These have helped maintain integrity, confidentiality, and security of data. First, the principle of minimal data is followed by (i) collecting minimal data for ID issuance, (ii) requiring citizens to share their data only once with the government, and (iii) permitting only minimal data to be shared with the requesting system for service delivery.⁸ Second, access control is established by allowing a system to access data only after authorization and authentication (authentication verifies the identity of the system while authorization allows only those data fields to be shared that have been approved by the governing authority for the specific purpose) has been completed.

Third, standard methods such as encryption, digital signatures, digital stamping, and timestamping are followed to maintain the security of data. Fourth, transactions are automatically logged for monitoring and establishing accountability. For example, individuals have access to a Personal Data Usage Monitor, an Artificial Intelligence (AI)-enabled software that allows them to view logs of all instances of their personal data being used by the government. They can use these logs to identify any unauthorized usage or data breaches. The only exception is a court warrant, say for national security monitoring. In this case, data access is logged and available only to the judge that issued the warrant – to maintain integrity. Finally, they have the choice to opt out and transact with the government manually. However, few end up doing so.⁹

Estonia has also developed capabilities and cyber security solutions to prevent and manage cyberattacks. However, in 2007, Estonia faced a three-week long government cyberattack in which the majority of the services of banks, government offices, and media were taken down. In 2017, another security threat was identified from a faulty chip in the digital ID card. It could have affected over 700,000 national ID cards. The 2007 attack led to the development of the concept of Data Embassy. In 2017, Estonia created the world’s first data embassy in Luxembourg, i.e., stored data in data centers owned by the Luxembourg government. By

creating a backup of critical data and services, the Estonian government ensured that potential future digital disruptions would not lead to a complete shutdown. However, the implementation of data embassy encountered several challenges related to technical design and legal agreements between the two countries to ensure security and confidentiality of the data. While data embassy helps manage cyber risk by protecting data and services, additional measures are required to proactively prevent future cyberattacks.

- **Adoption of agile development methodology**

The NIIS, which has been managing the development of the core X-Road technology since 2018, follows an agile development approach both for developing new functionalities and testing it with the objective of detecting and fixing errors quickly.¹⁰ For example, the NIIS tests the projects continuously during the development phase rather than having a separate testing phase - typical of waterfall methodology. This ensures that NIIS is able to detect bugs in the code faster and reduce manual effort by automating the testing processes.

3.2 Community

- **Facilitates co-creation and innovation**

X-Road was initially built to facilitate communication amongst government agencies. However, it now facilitates interoperability across various public and private sector information systems, enabling the delivery of user-centric solutions across a variety of sectors such as health, education, transport, etc. For example, the ability to exchange data across multiple entities has transformed the health system in Estonia. Estonia's Health Information System is underpinned by e-Health Records which functions as a nationwide database integrated across different healthcare providers, using the secure data exchange layer X-Road. This allows doctors to easily view a patient's medical history, ongoing treatments as well as test results, and can be especially useful during emergencies to access time-critical information. An additional solution, e-Ambulance, is also linked to the X-Road. It allows paramedics to access patient medical records en route to the hospital as well as pre-register the patient so that medication, tests, etc., can be prepared before the patient's arrival. In parallel, Estonia has also developed a Digital Prescription Centre (DPC) under the control of the Estonian Health Insurance Fund. Health care providers can upload prescriptions to the DPC (using X-Road) and pharmacists can access these online prescriptions to dispense the required medicines. Pharmacists charge individuals only the preferential rate of the medicines and receive the remaining amount from the Health Insurance Fund.^{11,12,13}

NIIS is also undertaking initiatives to facilitate participatory design and co-creation. For example, NIIS has identified X-Road technology partners who can assist in the deployment of X-Road, provide services such as develop extensions and integrate information systems to implement X-Road in different countries. It has also created a global X-Road community of developers, users, service providers, etc., who help test and improve the code.

Principle 8: Cultivate a network of innovators

X-Road is the backbone of Estonia's digital infrastructure and the government has undertaken numerous initiatives to support organizations and developers in the effective usage and successful implementation of the platform.

For example, to facilitate the participation of small institutions, Mini Information Service Portal (MISP) has been made available to allow access to X-Road services via an ordinary internet browser. Further, the RIA has developed training materials hosted on Moodle for developers of X-Road interfaces. The modules act as a guide, providing a vast array of information ranging from steps on how to join the production environment of the platform to server installation, registration, and providing data services.

3.3 Governance

- **Accountable institution to manage and regulate the data exchange ecosystem**

The RIA of Estonia under the Ministry for Economic Affairs and Communications (MEAC) is the department responsible for developing and managing X-Road, while the legislative roles fall under MEAC. The RIA was housed under the Government Office and then shifted to the Ministry of Transport and Communication before being moved to the MEAC in 2011. This was in line with the MEAC being the main legislative and implementing organization of the country's IT strategy.

The MEAC, along with the Chief Information Officer's (CIO) office, is responsible for developing legislations, processes, and policies such as the Estonian Information Society Policy, the State IT policy, the IT procurement procedures, the Interoperability Framework, etc.

RIA plays the role of the coordinator and the implementer by managing the functioning of X-Road. Specifically, it registers new members, documents data exchange between members, and supervises the security of the information systems. For example, RIA verifies and registers trust service providers - critical participants on X-Road. These are commercial third-party vendors that provide services such as certification, Online Certificate Status Protocol (OCSP), and timestamping. RIA is also responsible for registering members on X-Road after the requirements with respect to security measures, data description, etc., have been met.¹⁴ RIA also plays the role of a watchdog, i.e., it collects statistical information about data transfer through X-Road to oversee the ecosystem and manage any risks that may arise.

This model separates the strategy and implementation roles, establishing accountability while housing both departments under the same ministry to facilitate coordination. Secondly, having a single point of accountability to manage the various stakeholders enables effective management.

- **Robust data governance mechanisms**

Estonia has stringent regulations governing the security of systems, data, and cross-border exchange of information. For example, the Cybersecurity Act that came into force in 2018, aims to strengthen the security of digital systems. Around the same time, another regulation was enacted that governed cross-border exchange of information in the health sector.

Estonia adopted its Personal Data Protection Act (PDPA) in 2018 which came into force in 2019. The PDPA has a robust framework that focuses on user consent for processing personal data. It mentions that consent must be obtained after clearly stating the data to be processed, the intended use of the data, and people who would have access to data. The Act further states that silence and inactivity are not consent.¹⁵ Citizens, by using their e-ID to login into the system, can also view who is accessing their personal information and what information has been accessed. They have the right to withdraw consent for the use of their personal data at any time and even request for deletion of data. In these ways, the PDPA has incorporated agency and transparency in the use of personal data.

The Data Protection Inspectorate (DPI), an independent organization, has been appointed to supervise the implementation of and compliance with PDPA. The DPI has the power to prohibit the processing of personal data and demand its deletion. It is responsible for examining the complaints received from users in case of rights violation. The DPI is also empowered to conduct an audit of public sector agencies and levy fines for the violation of PDPA.

As illustrated above, a strong legal and regulatory framework underpins e-Estonia. The regulations are designed to uphold citizens' rights with respect to data privacy and incorporate appropriate grievance redressal mechanisms, ensuring that citizens view the system through a lens of trust and dependability.

- **Private sector capabilities to support the development and enhancement of X-Road**
The development and deployment of X-Road has been undertaken with extensive support from the private sector. The IT sector has been an integral part of the X-Road build since inception and continues to contribute in the running the platform.

Through the Estonian ICT cluster, a collaborative platform for companies in the IT sector, the government has been able to leverage private sector expertise in developing not just X-Road but other solutions as well. For example, the government partnered with Cybernetica, a technology company renowned for its research and development capabilities, to develop the first version of X-Road that was launched in 2001. Cybernetica has since been involved in continuous development of the platform. The company has also been a critical player in developing the ID card and the i-voting solution.¹⁶

Private sector companies have also proved to be valuable partners, serving as trust service providers (TSPs) and helping in the effective running of X-Road. TSPs are commercial third-party vendors that provide services such as certification, OCSP, and timestamping. These services are mandatory for organizations seeking registration on X-Road and are important from a security point of view as they help maintain integrity of the data exchanged on X-Road.

Principle 14: Ensure the right capabilities

The Estonian ICT cluster is a collaborative platform that brings together public and private enterprises to create solutions together. Most of the e-solutions in Estonia have been created with ICT cluster partners.

For example, the government sought the expert capabilities of Aktors, a software company with competence in creating eGovernment infrastructure, to develop and maintain the MISIP which is a portal for small organizations to access X-Road.

Source: <https://e-estonia.com/wp-content/uploads/eestonia-guide-2018.pdf>.

4. Conclusion

The success of X-Road has encouraged many other countries to adopt a similar approach. Denmark's national eHealth system and New Zealand's Integrated Data Infrastructure are examples of other countries that have successfully adopted this approach. Further, Finland, Iceland, Faroe Islands, etc., have adopted the X-Road platform for their e-Governance initiatives as well. X-Road is a strong example of the adoption of ODE principles in its technological and governance framework. The key successes of X-Road can be attributed to the following factors.

- X-Road has found strong support from the senior most leadership of the Estonian government, including successive prime ministers. This has helped in building trust in the national digital system and, hence, increased adoption. The commitment of the government is evident in the Prime Minister's initiative to personally host the Tallinn Digital Summit 2018, inviting top ministers from other countries and sharing with them Estonia's digital experience and learnings.
- The X-Road project also has a strong business case. While the vision of the project is to enable continuous access to government databases, the metrics validate a substantial economic benefit to the country – with savings equivalent to about two percent of the GDP. The economic benefits make a compelling argument in favor of X-Road.
- X-Road is based on both social and economic values that are important for all stakeholders – the government, citizens, and businesses. It is commonly said that necessity is the mother of invention. When Estonia gained sovereignty, it started at ground zero with neither the benefit nor the baggage of existing governance institutions or systems, a poor infrastructure, and low digital skills. In such a backdrop, building a national digital infrastructure such as X-Road became a social and economic imperative for the country.

¹ E-Estonia. (n.d.). *E-Estonia Guide*. Retrieved from <https://e-estonia.com/wp-content/uploads/eas-eestonia-vihik-a5-180404-view.pdf>.

² Ministry of the Interior. (n.d.) *Population Register*. Retrieved from <https://www.siseministeerium.ee/en/population-register>.

³ Hoe, W. (2017). *E-stonia: One Small Country's Digital Government Is Having a Big Impact*. Retrieved from <https://www.innovations.harvard.edu/blog/estonia-one-small-country-digital-government-having-big-impact-x-road>.

⁴ E-Estonia. (n.d.). *E-Estonia Guide*. Retrieved from <https://e-estonia.com/wp-content/uploads/eas-eestonia-vihik-a5-180404-view.pdf>.

⁵ E-Estonia. (n.d.). *Interoperability*. Retrieved from <https://e-estonia.com/creating-next-generation-of-digital-state-developers/>.

⁶ Plantera, F. (n.d.). *Case Study – Estonia and Finland heading towards real-time data exchange on taxation*. Retrieved from <https://x-road.global/case-study-tax-boards>.

⁷ GitHub. (n.d.). *X-Road Components*. Retrieved from <https://github.com/nordic-institute/X-Road-code-samples/blob/master/COMPONENTS.md#x-road-end-to-end-monitoring-tool-xrde2e>.

⁸ World Bank. (2018). *ID4D Privacy by Design Current Practices in Estonia, India and Austria*. Retrieved from https://id4d.worldbank.org/sites/id4d.worldbank.org/files/PrivacyByDesign_112918web.pdf.

⁹ Ellex, R. (2019). *Data Protected – Estonia*. Retrieved from <https://www.linklaters.com/en/insights/data-protected/data-protected---estonia>.

¹⁰ Kivimaki, P. (2018). *X-Road Core Software Testing*. Retrieved from <https://www.niis.org/blog/2018/7/9/x-road-testing>.

¹¹ CEF Digital (n.d.). *Estonian Digital Prescription*. Retrieved from <https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/2019/07/26/Estonian+Digital+Prescription>.

¹² E-Estonia (n.d.). *e-Health Records*. Retrieved from <https://e-estonia.com/solutions/healthcare/e-health-record/>.

¹³ Heller, N. (2017). *Estonia, the Digital Republic*. Retrieved from <https://www.newyorker.com/magazine/2017/12/18/estonia-the-digital-republic>.

¹⁴ Moodle. (n.d.). *How X-Road works and participants on X-Road*. Retrieved from <https://moodle.ria.ee/mod/book/tool/print/index.php?id=335#ch151>.

¹⁵ Riigi Teataja. (n.d.). *Personal Data Protection Act*. Retrieved from <https://www.riigiteataja.ee/en/eli/512112013011/consolide>.

¹⁶ Cybernetica. (n.d.). *Case Studies – Estonian Interoperability Framework X-Road*. Retrieved from <https://cyber.ee/products/secure-data-exchange/case-studies/#estonian-interoperability-framework-x-road>.