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Cross-Border Data Exchange in the Nordic-Baltic Region: Data Intermediaries, Interoperability, and e-Services Orchestration

Eric Blake Jackson

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ERIC BLAKE JACKSON

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TALLINN UNIVERSITY OF TECHNOLOGY
School of Information Technologies
Department of Software Science

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Supervisor: Assoc.-Prof. Dr. Ingrid Pappel,
Next Generation Digital State Research Group
Department of Software Science,
School of Information Technologies,
Tallinn University of Technology
Tallinn, Estonia

Co-supervisor: Prof. Dr. Dirk Draheim,
Department of Software Science,
School of Information Technologies,
Tallinn University of Technology
Tallinn, Estonia

Co-supervisor: Prof. Dr. Sadok Ben Yahia,
SDU Center for Industrial Software,
Faculty of Engineering
Southern Denmark University
Odense, Denmark

Opponents: Prof. Dr. Nitesh Bharosa,
TU Delft
Delft, Netherlands

Dr. Anastasija Nikiforova,
University of Tartu
Tartu, Estonia

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Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology, has not been submitted for any academic degree elsewhere.

Eric Blake Jackson ______________________________
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Piiriülene andmevahetus Põhja-Balti regioonis: andmevahendajad, koostalitlusvõime ja e-teenuste orkestreerimine

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Contents

List of Publications

The present Ph.D. thesis is based on the following publications that are referred to in the text by Roman numbers.

I E. B. Jackson, R. Dreyling, and I. Pappel, "A historical analysis on interoperability in estonian data exchange architecture: Perspectives from the past and for the future," in *Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance*. Association for Computing Machinery, 2022, p. 111–116

II M. Weck, E. B. Jackson, M. Sihvonen, and I. Pappel, "Building smart living environments for ageing societies: Decision support for cross-border e-services between estonia and finland," *Technology in Society*, vol. 71, p. 102066, 2022

III E. B. Jackson, R. Dreyling, and I. Pappel, "Challenges and implications of the who's digital cross-border covid-19 vaccine passport recognition pilot," in *2021 Eighth International Conference on eDemocracy & eGovernment (ICEDEG)*. IEEE, 2021, pp. 88–94

IV E. B. Jackson, P. Kivimäki, I. Pappel, and S. B. Yahia, "Exploring eu e-delivery integration for enabling interregional innovation through the silverhub platform," in *Proceedings of the 24th Annual International Conference on Digital Government Research*. Association for Computing Machinery, 2023, p. 172–179

V E. B. Jackson, M. Weck, and I. Pappel, "The role of data intermediaries for small- and medium-sized enterprises in the innovation ecosystems of the nordic-baltic silver economy," in *2024 International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences (AHFE)*. AHFE Open Access, 2024

Author's Contributions to the Publications

I The thesis author was the lead and corresponding author of the publication. The author conducted the interviews, was responsible for a majority of the content, as well as the research design, questions and methodological choice guiding the article.

II[1] The thesis author was responsible for analyzing the collected data, writing a majority of the content as well as collaborating with the primary author on the research design, questions, and methodological combinations guiding the article.

III The thesis author was the lead and corresponding author of the publication. The author participated and conducted the stakeholder workshops, was responsible for a majority of the content, as well as the research design, questions and methodological choice guiding the article.

IV The thesis author was the lead and corresponding author of the publication. The author facilitated workshop discussions and was responsible for a majority of the content, architectural model, as well as the research design, questions and methodological choice guiding the article.

V The thesis author was the lead and corresponding author of the publication. The author conducted the document analysis, was responsible for a majority of the content, as well as the research design, questions and methodological choice guiding the article.

[1] This publication won TalTech's research article of the year award in the social sciences and humanities category.

Abbreviations

CGN	Collaborative Governance Network
MCDM/A	Multiple-criteria Decision-making/Analysis
DEMATEL	Decision-making and Trial Evaluation Laboratory
DGA	Data Governance Act
DNS	Domain Name System
DSM	Digital Single Market
EU	European Union
EIF	European Interoperability Framework
G2G	Government-to-Government
G2C	Government-to-Citizen
G2B	Government-to-Business
JSON	JavaScript Object Notation
NIIS	Nordic Institute for Interoperable Solutions
PSM	Problem Structuring Methodology
QH	Quadruple-Helix
RDF	Resource Description Framework
RQ	Research Question
RSSLS	Regional Smart Silver Labs
SML	Service Metadata Locator
SMP	Service Metatdata Publisher
SQ	Sub-question
SSL	Smart Silver Labs
WHO	World Health Organization
XML	Extensible Markup Language

Terms

Collaborative Governance Network	Is a network in which multiple stakeholders, including government agencies, private sector entities, non-profit organizations, and community groups, collaborate together to achieve common goals.
Data Intermediation	"Allow for the establishment of a relationship (commercial or non-commercial) between data subjects and/or data holders, on the one hand, and data users on the other hand."[2]
Interoperability	"The ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems."[3]
Silver Economy	"The economic opportunities arising from public and consumer expenditure related to population ageing and the specific needs of people aged over 50."[4]
Quadruple Helix Stakeholders	"An innovation and collaborative model involves representatives from all members of society; public authorities, industry, academia and citizens."[5]

[2] EU Science Hub
[3] New European Interoperability Framework
[4] Interreg Europe
[5] Interreg North Sea Region

Summary

The structure of this research summary is as follows. Sect. 1 introduces the context of EU cross-border data exchange, interoperability, and data intermediaries in the Nordic-Baltic region and conducts problem-framing. Sect. 2 presents the focus and aim of the research compilation through elicited research questions and corresponding justifications and elaboration. Sect. 3 examines the theoretical background anchoring this thesis. Sect. 4 describes the interdisciplinary nature of this work and the methodological approach deployed in the publications. Sect. 5 summarizes the results of the five publications contained in this compilation. Lastly, Sect. 6 entails the limitations of this thesis compilation and the implications for future research, concluding the research summary.

1 Introduction

Data is power. It is the foundation of our data-driven economies, transcending borders and boundaries. Projections show a 530 percent increase in global data production to 175 zettabytes by 2025 [6]. Adding fuel to the fire is the rise of artificial intelligence, big data, IoT devices, and blockchain technologies, which has intensified the value of data as an asset for both public and private sector organizations. Nowadays, organizations exchange data across borders to catalyze innovation [7], deliver e-services [8], and tackle global challenges [9], amongst other objectives.

In the European Union, there is a recognition that non-personal data must flow freely and unhindered by borders, infrastructure, organizational silos, and legal barriers to sustain the digital era's data-driven economies [10]. Thus, cross-border interoperability, or the ability of different organizations to share and use data with one another regardless of national borders, has emerged at the forefront of digital transformation for European public administrations and is a promised cornerstone of the European Digital Single Market (DSM).

From an e-government perspective, cross-border interoperability between government-to-government (G2G) information systems increases the efficiency and efficacy of cooperation between national public administrations and the delivery of cross-border e-services between government-to-citizens (G2C) in transport, healthcare, education and training, the environment, and other various public policy intervention areas [8]. A successful cross-border e-service use case is the recognition of e-prescriptions among EU member-states, ensuring citizens have access to the medication they require regardless of location [11]. Politically, a concrete example of a cross-border interoperability initiative is when the Nordic Council of Ministers declared the Nordic-Baltic region aiming to be "cross-border by default" in terms of public service delivery by 2030, emphasizing study mobility, healthcare service provision, and inter-regional legal database harmonization [12]. Cross-border interoperability between government-to-business (G2B) is also necessary for streamlining administrative tasks, making business registration processes more convenient and user-friendly [8].

Beyond purely public sector administrative applications, the EU's regulatory premise is an economically integrated Digital Single Market. It also envisions creating a Digital Single Market for data under the European Data Strategy [10], the basis of which is free-flowing cross-sectoral data conforming to European law on data protection, privacy, and fair competition. Subsequently, many high-level EU political initiatives and regulatory actions shape and foster cross-border interoperability governance and implementation, such as the eIDAS Act, Digital Single Gateway Initiative, Interoperability Act, Data Governance Act, Digital Services Act, Digital Markets Act, Data Act, and the AI Act. In aggregate, these policy instruments regulate the fair use and reuse of data sharing and limit asymmetrical data capture seen in Big Tech monopolies while safeguarding AI usage and ultimately providing regulatory frameworks and governance principles for the free movement of non-personal data.

The emergence of collaborative ecosystems corresponds to the transition to the European DSM and envisioned EU cross-border public e-services. In his seminal work, Moore [13] famously declared "the death of competition" and, from the ashes, the rise of business networks and ecosystems where collaboration and cooperation transcend competitive inclinations and national borders. Although Moore came from a private sector perspective, the ecosystem metaphor manifests through different cross-border paradigms expected to address complex transnational public policy problems affecting the European Union, like collaborative cross-border governance networks (CGN) [14][15], and spur next-generation technology and products, like innovation ecosystems [16][17]. The impact of network and ecosystem emergence is widening engagement, complementarities, participation, and tension between various government, academic, industry, and societal actors, referred to as Quadruple Helix (QH) stakeholders [17]. Consequently, the myriad of cross-sectoral, collective problems facing the EU, like the environment, pandemics, war, migration, and population aging, for instance, has expanded bi-directional data exchange participation to include non-governmental QH organizations.

A significant transnational public policy problem of focus for this research is population aging. Europe's population is getting older at a rapid rate, with over one-fifth of the current population over the age of 65 [18]. Higher life expectancy and low birth rates are contributing to population decline, which will profoundly impact European societies in the future. A shrinking labor market and higher social spending on an expanding retiree population will increase the pressure on European governments to provide innovative responses and services, in which information communication technologies will play a critical role [15] [19]. Encapsulating these trends is the "Silver Economy," which is the economic market for products and services intended for those over the age of 50 [20]. The Silver Economy encompasses healthcare, mobility, insurance, education, service robotics, financial services, and more. Moreover, the increase in the older adult population will lead to new market opportunities and a growing consumer base estimated to reach 5.7 trillion Euros in baseline value for products and services by 2025 [21].

Particularly in the Nordic-Baltic region, which has a higher threat of demographic vulnerability, population aging is and will have acute effects in this region, requiring a coordinated regional response. The author participated in a cross-border CGN, OSIRIS Interreg Baltic Sea Region, comprising five countries from the Nordic-Baltic region (Denmark, Estonia, Finland, Latvia, Lithuania) with representatives from small and medium enterprises, public sector organizations, citizens, non-governmental organizations, and academia. The author researched cross-border e-services mainly related to the Silver Economy, which has high cross-sectoral, cross-border collaboration characteristics and social value function.

Ultimately, collaborative cross-border governance networks and innovation ecosystems inherently require some form of public-private partnership [14], and in a data-centric world with intersectional problems, decision-making or product creation and service provision can no longer occur in a vacuum. Therefore, leveraging private and public sector data to achieve a shared objective in a governed environment between different QH institutional and economic stakeholders, as well as society (who are ultimately, the end-users), can play a catalytic role in producing innovation and addressing broader regional social challenges, like the Silver Economy, through leveraging interdependencies and data-driven insights organizations would otherwise not be able to achieve on their own [22].

However, interoperability is a complex and multidimensional endeavor, especially in cross-border contexts where different legal systems, organizational management practices, and levels of e-governance maturity impact implementation [23]. It requires technical capabilities like open APIs, database connectivity, semantic harmonization, organizational leadership, policies and business process alignment, and last, but certainly not least, an assortment of legal agreements [23]. Many organizations, primarily micro, small, and medium-sized, need more incentives and digital capacities to participate in cross-border data exchange [10]. Particularly when it comes to protecting data and the ingenuity of modern cyberattack vectors, there is an elevated risk and liability when data is exchanged between organizations, even if they trust one another. From the private sector side, organizations are cautious about providing third-party access to data as it may go against their commercial-driven interests [7].

Thus, to alleviate these challenges, data intermediaries have become prominent in decreasing the friction of cross-border data exchanges between European public administrations and between public and non-governmental organizations. Data intermediaries are typically neutral third-party mediators for providing trustworthy and secure data exchange infrastructure, data processing, and governance models through varying technical architectures [24]. Instead of relying purely on internal organizational capacity and direct integration, secure data exchange is now commonly an outsourced trusted functionality for various public and private objectives.

A primary data intermediary of focus for this research is the X-Road data exchange platform in the Nordic-Baltic region. The X-Road open-source software was developed by a private-public consortium in 2001 to operationalize Estonian internal interoperability between government ministries [I]. Over time, the X-Road has scaled to numerous private and public organizations beyond Estonia that use X-Road software for secure internal data exchange between information systems, not only for G2G applications but also for establishing collaborative ecosystems. In general, the X-Road fosters interoperability between organizations through a combination of data encryption, REST or SOAP API recognition, shared protocols, public key infrastructure (PKI), security servers, the public internet, and legal agreements via a centrally governed but distributed platform approach [I]. Crucial to X-Road's operational longevity and development has been the incorporation of high-level requirements related to the confidentiality, integrity and availability (CIA) triad. As the X-Road facilitates different queries and responses between public sector ministries, the private sector, and citizens, highly specified access controls are embedded in the software, including a central directory of verified network participants via DNS-SEC. National public key infrastructure ensures the integrity of data through hardware-protected keys and digital signature validation conducted through combining Online Certificate Status Protocol (OCSP) and time-stamping functionalities[25].

Each X-Road organization maintains and operates a security server, which acts as a signature device. Security servers can be considered as the cybersecurity and operational "backbone" of the X-Road ecosystem. While the public internet serves as the information highway between data exchange participants, the security server encrypts and decrypts messages exchanged between X-Road organizations, while also serving as the communication gateway between organizations. It ultimately acts as an "organizational VPN" without extensive networking arrangements, while also enabling payload encryption[26]. Security servers contain the full historical log of data exchange activities, is responsible for time-stamping, digitally signing outgoing SOAP or REST API messages and verifying incoming digital signatures. In the end, X-Road participants communicate with one another through distributed security servers and a few centralized services related to time-stamping, secure directory management and dispute resolution[26].

Organizationally, the Nordic Institute for Interoperable Solutions (NIIS) is the non-profit governing body of the X-Road community and is in charge of maintaining and testing the source code [27]. The governing composition of NIIS is composed of three nation-state members (Estonia, Finland, Iceland) and three official partners (Ukraine, Faroe Islands, and the Government of Åland) [28]. Most crucial for this research is the X-Road has cross-border data exchange capability through trust federation, meaning X-Road member organizations can connect national X-Road instances to exchange data between secure access points for establishing e-services and streamlining administrative processes [28]. For example, Estonia and Finland exchange data through a trust federation between population registries, business registries, and tax authorities, aiming to streamline cross-border administrative functions effectively [29]. Furthermore, during the COVID-19 pandemic, a lightweight X-Road-based architecture was proposed for recognizing vaccine passports globally under the initiative of the World Health Organization [III].

In addition to the X-Road, eDelivery is an EU-level data intermediary in the cross-border interoperability space that NIIS also enables through maintaining open-source components. eDelivery is a Connecting European Facility building block with functionality similar to the X-Road, but it is connected to the European Commission and has different governance principles and stakeholders. Ultimately, their mission description is enabling "cross-border and cross-sectoral public services" typically through a four-corner, payload agnostic network model in a specific policy domain [30]. eDelivery utilizes the Domibus software, Service Metadata Publisher (SMP) and Service Metadata Locator (SML) open-source digital building block software developed by the European Commission. In this case, eDelivery leverages "Access Points" for the exchange of messages between eDelivery network participants through ebMS3 (ebXML Messaging version 3.0) and AS4 OASIS standardized message exchange protocols that can handle messaging asynchronously. Thus, the backends of eDelivery organizations do not have to directly communicate with one another. Similar to the X-Road security server, when an organization wants to exchange data with a receiver, the Access Point has a digital certificate enabling the signing of data/documents and can encrypt them as well. Once the receiving Access Point verifies the sender's digital signature, it uses its digital certificate to decrypt the data and then digitally signs an acknowledgement to the sending Access Point[31].

During the messaging process, for a data sender to dynamically find the receiving party's information details, a query is sent to a centralized SML, which points the sender to the correct SMP location through the internet's Domain Name System. Thus, the Access Point is guided towards the correct SMP through the SML, and the SMP contains the IP address of the receiver along with the receiver's message exchange capabilities[32]. Generally, these SMPs have distributed architecture. From a cryptographic perspective, eDelivery Access Points use two-way Transport Layer Security (TLS) for encrypting communications between sending and receiving parties.An eDelivery organization can use "connectors" as well that is software connecting Access Points with local organizational backends. There is also a relationship between the X-Road and eDelivery, as NIIS in its data intermediating portfolio is Harmony eDelivery Access, which provides organizations with open-source components for accessing an eDelivery policy domain[33].

More recently, the establishment of cloud-federated Common European Data Spaces in fourteen sectors ranging from mobility to the environment has entered the cross-border interoperability realm. Common European Data Spaces encompass a broad spectrum of elements, including data models, datasets, ontologies, data sharing agreements, and specialized management services. These services, often provided by entities like data centers, stores, or repositories, may be housed individually or within larger constructs. Additionally, Data Spaces involve softer capabilities, such as governance, social interactions, and business process management. The merging of these competencies is supposed to foster a data exchange ecosystem enabled by a cloud federation with a high computing and edge computing technology stack[34]. In policy terms, Common European Data Spaces represent a coordinated political response to Big Tech asymmetrical powers in capturing personal and non-personal data. The objective is to combine standardized data infrastructures and governance frameworks to accelerate interoperable data pooling and sharing between European public and private organizations. Bolstered by recent EU regulations related to data governance, quality, management and the recognition of high-value data sets, Data Spaces seeks to facilitate cross-sectoral data access, sharing, pooling and use across the European Union. Data intermediaries thus play an important role in this data sharing ecosystem.

While each Data Space has its own unique qualities and stakeholders, stakeholders will have to use standardized data exchange infrastructure and governance mechanisms. The technical centerpiece for Data Spaces is the open-source smart cloud-to-edge middleware platform (Simpl). The European Commission plans for a minimum viable platform by the end of this year. During the time of this research, Data Spaces was still in development and thus was not a subject of focus for this research. Still, as of the writing of this research summary, there is an initial road map for X-Road to be Data Space-compliant, but it is beyond the scope of this research summary.

1.1 Problem framing

However, despite numerous regulations, growing momentum, and high aspirations for achieving European cross-border interoperability and the DSM, and even already established data intermediaries solutions like the X-Road, eDelivery, and common European Data Spaces, the expected results of cross-border data exchange is still at a low level in practice in the Nordic-Baltic region and the EU overall.

In terms of G2G cross-border data exchange between national administrations, Krimmer et al. [23] point to the EU's high heterogeneity and fragmentation in data exchange infrastructure in the EU, hampering cross-border interoperability capability between public administrations and, in effect, creating siloes between countries' information systems. There are also vast political-institutional challenges concerning cross-border interoperability. The byproduct of national sovereignty and lack of uniformity in EU administration processes are fundamental differences in culture, language, and organizational practices that are difficult to ameliorate when implementing cross-border data exchange for e-services [35]. Legal incompatibility between EU nation-states makes harmonization related to data protection, commercial law, and liability challenging to achieve [35].

The myriad top-down regulations passed by the European Commission for fostering cross-border interoperability have also created legal uncertainty and unclear transaction costs. Institutions are complex, and the EU's unique political dynamics of collectively passing regulations on a supranational level and leaving implementation up to member states can lead to disjointed approaches to cross-border interoperability. The responsibilities and accountabilities of institutions are often opaque and not well defined. Thus, if viewed through New Institutional Economic Theory [36], the "rules of the game" in relation to cross-border interoperability, data exchange, and data intermediation have been defined via EU regulations. However, "how the game is played" varies by member-state capacity, capabilities, and willingness, leading to fragmented implementation.

According to the OECD's cross-border data policy, the EU has relatively strict data localization laws inhibiting cross-border data transfers [37]. By the EU's admission, there are deficiencies in private organizational data management practices inhibiting cross-border data flows [38]. Sceri et al. [27, pg 351] aptly summarize the EU's cross-border data exchange environment: "The most pressing inter-organizational concern remains the lack of valuable and trustworthy data sharing ecosystems that inspire immediate large-scale participation. Primary causes include the lack of robust legal and ethical frameworks and governance models, and trusted intermediaries that guarantee data quality, reliability, and fair use. This is compounded by the lack of widespread adherence to emerging best practices and standards (e.g., interoperability, provenance, and quality assurance standards), whose maturity pace also continues to fail expectations".

Consequently, the prerequisites for establishing interoperability for collaborative and innovation ecosystems and for providing cross-border e-services are still limited, leading to an absence of development. Even though data intermediaries are already available for cross-border data exchange in the Nordic-Baltic region, their role in fostering interoperability for collaborative ecosystems and innovation networks in the Silver Economy still needs to be included and investigated.

Research on the Silver Economy has mainly focused on the demand side of service provision [39]. As a result, there is a lack of supply-side research regarding cross-border e-services and innovation capacity from those who deliver services, create products, or derive data-driven insights. As a result, the role of data intermediaries in the Silver Economy has been unexplored as a medium for facilitating data exchange between actors in this economic market to produce services, products, and innovations targeted at older adults. There is a critical gap in understanding how different data intermediary architectures impact cross-border interoperability in the context of multinational collaborative governance ecosystems and innovation networks for the Silver Economy.

Subsequently, the author's research investigates the intersectionality of cross-border interoperability enabled by data intermediary technical architectures and their governance capability for enabling cross-border e-services, fostering innovation and collaborative governance activities for bolstering the Silver Economy, and preparing QH stakeholders for tackling population aging-related issues through digital technologies and e-services in mobility healthcare, the labor market, active and healthy aging, among other use-cases.

2 Focus and Aim

Based on the identified problem framing, this thesis seeks to explain the phenomena of cross-border data exchange through the lens of interoperability, data intermediation, and e-service orchestration from a traditional G2G perspective and between cross-boundary QH stakeholders participating in innovation networks and collaborative governance ecosystems. For a majority of the publications, the author selected the Nordic-Baltic region as the geographical unit of analysis due to its political prioritization of cross-border integration, established data intermediaries like the X-Road, and high levels of cross-border mobility. The author selected the Silver Economy for most research articles to explain cross-border interoperability dynamics between a vast network of cross-sectoral and multinational QH stakeholders engaging in age-related innovation and cross-border e-service provision. Based on the identified problem framing, the thesis author presents the following research questions with justifications and the corresponding publications that address the research questions.

2.1 Research Questions

- *RQ1* How do different data intermediary architectures impact interoperability and governance for cross-border data exchange and e-service orchestration in the Nordic-Baltic Region?
  - *SQ1.1* What are the main challenges and barriers to cross-border e-services provision in the Nordic-Baltic Region (Estonia + Finland)
  - *SQ1.2* Which types of cross-border e-services for the Silver Economy are viable in the Nordic-Baltic Region? (Estonia + Finland)
- *RQ2* How does organizational digital transformation impact cross-border data exchange? (Case of the World Health Organization)
- *RQ3* What is the role of data intermediaries for interoperability in innovation networks?
  - *SQ3.1* What are the implications for Nordic-Baltic SMEs regarding the Data Governance Act on cross-border data exchange for the Silver Economy?

RQ1, delves into the heterogeneity of data intermediary architectures in the Nordic-Baltic region. It explores how these unique characteristics impact interoperability and e-service delivery between QH stakeholders participating in a cross-border collaborative network for the Silver Economy. The premise is that different data intermediary architectures will have distinct implementation characteristics and processes for cross-border data exchange and e-service delivery. To harness the potential of data intermediaries, QH participants must align with the governance and technical architectures of data intermediary organizations, such as NIIS in the case of X-Road and the European Commission for eDelivery.

SQ1.1, a question of pragmatic importance, focuses explicitly on the core challenges and barriers to cross-border e-services in the Silver Economy between Estonia and Finland from a QH service provider perspective. This question encapsulates the complexity of delivering cross-border e-services, as there are a myriad of socio-technical factors inhibiting provision. Understanding these challenges and barriers in-depth provides service providers with valuable insights into frictions and potential amelioration, enhancing their ability to navigate the cross-border e-service landscape effectively. SQ1.2 sets the stage for Silver Economy e-service identification, specifically between Estonia and Finland, due to existing cross-border data exchange flows enabled by the X-Road. This research sub-question expands e-service delivery to encompass different QH stakeholder partnerships in eight domains with accompanying e-service descriptions.

RQ2 looks into internal organizational digital transformation processes for enabling cross-border data exchange. This research question takes the case of the WHO's global vaccine passport initiative as a use case. As the X-Road data exchange platform was a potential candidate as a worldwide data intermediary for this initiative, this research question inquires into the internal digital transformation processes the WHO would undergo to implement X-Road architecture on a global scale. Since the WHO was the project's primary stakeholder, coordinator, and implementer, it was critical to understand how the WHO internally transforms to facilitate global vaccine passport recognition through a lightweight X-Road instantiation.

RQ3 dives into data intermediaries' role in innovation ecosystems in the Nordic-Baltic region. The outsourcing of data exchange has been growing in recent years. As data is a crucial enabler for innovation activities and input for novel technologies like AI and Big Data, this question asks what part data intermediaries can have in this interplay in the Nordic-Baltic region. SQ3.1 scrutinizes the EU's Data Governance Act as a key regulation affecting the use and functioning of data intermediaries for cross-border data exchange in the Nordic-Baltic Silver Economy. This sub-question focuses on the perspective of small and medium enterprises in Nordic-Baltic innovation ecosystems, as they will have to navigate this top-down regulation in a bottom-up manner. Table 1 presents a mapping of each research question corresponding to the relevant publications presented in this research summary.

Table 1: Mapping of associated RQs and publications.

Research Question	*Publications*
RQ1	[I], [II] [IV]
SQ1.1	[II]
SQ1.2	[II]
RQ2	[III]
RQ3	[V]
SQ3.1	[V]

3 Theoretical Background

This section describes the theoretical underpinnings of this research summary. It seeks to anchor cross-border data exchange through the European Interoperability Framework (EIF) and organizational digital transformation theory, which informs the collection of publications behind this thesis compilation.

3.1 European Interoperability Framework

A core practical tenet of this research connected with cross-border interoperability, e-services, and data intermediation is the New European Interoperability Framework (EIF) developed by the European Commission. The EIF contains 12 guiding principles, 47 recommendations, and a top-down, bottom-up conceptual model for European public administrations to become more interoperable for delivering cross-border e-services in practice [40]. It also defines interoperability as "the ability of organizations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their ICT systems" [41]. Compared to traditional definitions of interoperability, the EIF emphasizes business process compatibility between organizations while focusing explicitly on the public sector, collaboration, and user engagement for designing and implementing cross-border e-services.

Conceptually, the EIF segments interoperability into four interconnected layers for forming integrative public services: technical, legal, semantic, and organizational. The technical layer comprises digital infrastructure, applications subsystems, information systems, APIs, and technical standards concerning hardware and software components that enable data exchange, integration, and sharing. The semantic layer focuses on creating shared data meanings, vocabularies, and standardized data syntax between organizations. The premise is that data must be understandable to all parties participating in an exchange, regardless of language differences and internal organizational practices. Thus, organizations should maintain the meaning of data during exchange and be understandable to all parties involved. Practically speaking, organizations may implement semantic tools like data glossaries to facilitate shared understanding and meanings of data.

The legal layer comprises EU regulations, national law, and data protection legislation forming the legal environment dictating how data is exchanged between providers and consumers. Establishing cross-border data exchange and e-services often requires new legislation or legal harmonization processes. Consequently, the EIF recommends conducting ex-ante "interoperability checks" regarding existing legislation to identify geographical and cross-sectoral restrictions for storing and using data, ambiguous licensing models, asymmetrical technical determinism, and inconsistent demands for identical or comparable business processes.

Lastly, the organizational layer focuses on public administrations aligning their business processes or identifying and establishing new ones. Legal instruments such as Memorandums of Understanding and Service Level Agreements defining responsibilities, liabilities, and formalized data exchange processes for providers and consumers of data can facilitate inter-organizational relationships in a collaborative network. From a cross-border perspective, the EIF recommends multilateral agreements, treaties, and declarations between member states on an organizational level. Although implementing the EIF is not a legal requirement for EU member states, the Interoperability Act most recently bolstered it at the beginning of 2024.

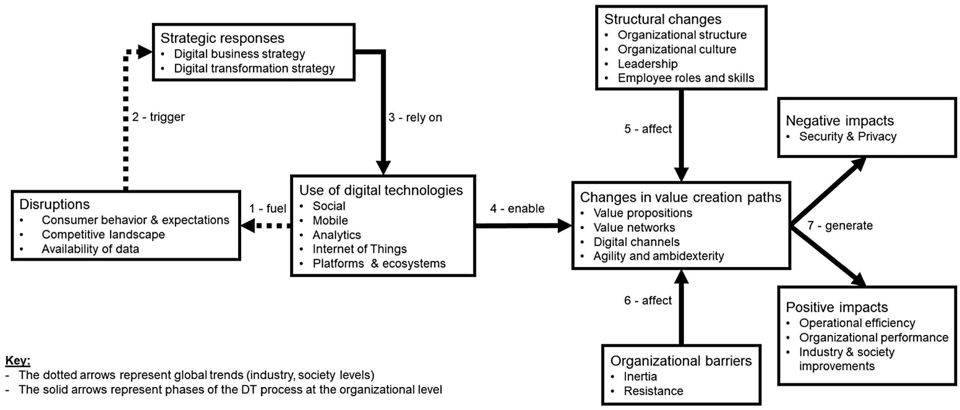

Figure 1: Vial Organizational Digital Transformation Theory [43]

3.2 Organizational Digital Transformation Theory

An additional theoretical lens informing this research summary is organizational digital transformation theory, presented by Gregory Vial [42]. Publication [III] explicitly incorporates Vial's digital transformation theory from an organizational perspective for a global data exchange use-case under the initiative of the World Health Organization. In the context of this research compilation, for an organization to become capable of performing cross-border data exchange, it must undergo a process of internal digital transformation from analogue processes to digital ones if it does have the prerequisite cross-border data exchange capability. Vial maps an internal organizational digital transformation process through a comprehensive analysis of 282 papers to formulate a framework consisting of eight building blocks and corresponding process flows presented in Figure 1.

The first building block encapsulates the organizational use of novel digital technologies. As digital transformation inherently requires the implementation of digital technologies for an organization, it is a natural starting point. Vial cites social media, IoT, mobile, analytics, platforms and ecosystems as digital technologies that "fuel" three types of disruptions. The first is related to consumer behavior and expectations, where consumers are no longer directly beholden to service providers, while at the same time, have increased expectations for the quality and effective delivery of services. The second disruption summarizes the disruption to the competitive landscape. The digital world is now full of complementarities, integration and easier accessibility to enter the market. Digital infrastructures can help facilitate these intertwinements, which has changed traditional competition into one that is more decentralized. The last disruption of new digital technologies is the "increasing availability of data". The byproduct of digital technology usage is the capture, analysis, and exchange of data, making data more voluminous and increasingly valuable to organizations.

These disruptions ultimately "trigger" some type of organizational strategic response from a business and digital transformation perspective. These responses can be formulated as opportunities or threats given the organization's viewpoint. Consequently, an organizational digital business strategy and the digital transformation of requires careful planning and execution. This is not a standalone process, but one that has continuous attributes. The "use of digital technologies" enable different "changes in value creation paths" where new value propositions, networks, digital channels and organizational agility and ambidexterity may be fostered by new digital technologies.

Two different building blocks, organizational barriers such as resistance to change or having no response to the use of digital technologies affect the changes in value creation paths, and "structural changes" to organizational culture, leadership, and the roles and competencies of individual employees also affect "changes in value creation paths". Ultimately the "changes in value creation paths" generate both negative and positive impacts. Vial cites security and privacy as negative impacts and increased organizational operational efficiency and performance, along with more general improvements to industry and society as positive impacts. In sum, Vial presents a holistic digital transformation framework for application to the case of the World Health Organization.

4 Research Methodology

This thesis compilation is composed of five original peer-reviewed research articles. Publications [I] [III] [IV] and [V] were published in conference proceedings, and [II] was published in a journal. The primary methodology deployed for a majority of publications is a qualitative case study approach: [I] [III] and [IV]. Each single case is considered as a single unit of analysis. Publication [II] combines two methodologies, problem-structuring methodology (PSM) [43] and multiple criteria decision-making/aid (MCDM/A)[44], and implements two methods: cognitive mapping[45] paired with decision-making trial and evaluation laboratory (DEMATEL)[46] for explaining causality between relationships related to the challenges and barriers to cross-border e-service provision and for identifying potential e-services between Estonia and Finland. Both PSM and MCDM/A as well as cognitive mapping and DEMATEL will be thoroughly described in the proceeding subsections. Lastly, [V] conducts a policy analysis using the Data Governance Act as the central policy instrument of focus. Figure 2 shows a high-level summary of the publication methodologies and their corresponding data collection methods and research outputs.

The research presented uses mixed methods based on implementing multiple qualitative and quantitative methodologies and data collection methods. This thesis compilation is interdisciplinary due to a couple of factors. First, the characteristics of cross-border interoperability are inherently technical, legal, semantic, and organizational. Thus, this research draws primarily from the e-governance domain, which incorporates socio-technical areas that straddle the boundary between technology, society, and law. The second factor is that the essence of the Silver Economy has high intersectionality between technology and innovation, business, healthcare, and more. A concrete example of this intersectionality is the “Smart Living Environments” concept presented in publication [II].

The proceeding subsections will cover the particularities of the mixed-methods approach used in each publication to answer the research questions. Subsection 4.1 describes case study methodology and the primary qualitative data methods deployed in publications [I] [III] and [IV]: semi-structured interviews, thematic analysis, stakeholder workshops, and document analysis. The remaining subsections introduce multi-criteria decision-making and problem-structuring methodology with cognitive mapping and DEMATEL for [II], finishing with policy analysis from a methodological perspective for publication [V].

4.1 Case Study

Case study research seeks to empirically explain real-life contemporary phenomena by collecting and analyzing multiple qualitative and quantitative sources of evidence, such as interviews, documents, artifacts, surveys, and more [47]. The key to this data collection process is the triangulation of these sources, which involves systematic cross-verification and the inclusion of different stakeholder perspectives[47]. Furthermore, the premise of explanatory case study research, which asks “how” and “why” questions, is reflected in RQ1 and RQ2.

A case should also have spacial-temporal bounding, which results in a “system” to be investigated in-depth[48]. In publication [I], the geographical bounding was in Estonia, looking into how the X-Road data exchange platform developed interoperability in the past and its plan for next-generation microservices in the future. Six semi-structured interviews were conducted to achieve this objective, with relevant experts involved in creating, designing, and maintaining the X-Road data exchange platform in the past and present. The interviewees included the current CTO of NIIS, as well as the original architects of the X-Road. A pre-interview with the first expert validated the semi-structured interview

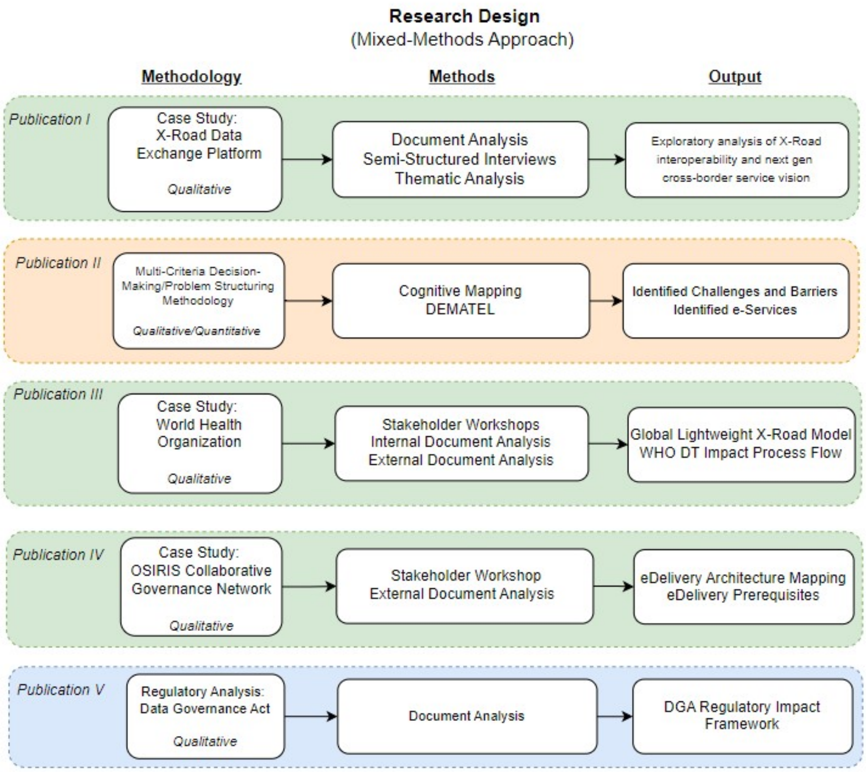

Figure 2: Research Design, Mixed Methods Approach

questions, and all interviews were recorded and transcribed for further analysis.

A semi-structured interview is an interactive qualitative method in which an interviewer asks a respondent predetermined questions. Still, there is flexibility in following up on answers to gather richer insights into the question. It eschews binary answers for agility, allowing for a more open interviewer-interviewee relationship, which adds robustness to collecting respondent data [49]. After collecting the interview data, the author used thematic analysis to synthesize the semi-structured interviews into presentable results. Thematic analysis is a qualitative method that enables researchers to understand interview and structure patterns from interview transcripts. For this publication, a concept-driven coding approach was adopted using the four interoperability layers from the EIF as a structural mechanism for the interviewee responses. The author analyzed documents from relevant sources about X-Road's development, and the Estonian government's next-generation digital government policy documents were examined to achieve triangulation.

For publication [III], the data collection was geographical to Estonia and Finland, as the country is a member-state of the WHO and NIIS organizationally governs the X-Road. At the time, COVID-19 was in full swing, requiring expedient responses pertaining to the global recognition of vaccine passports. Estonia was advocating for the adoption of X-Road along with NIIS. Thus, there was a global context considering the World Health Organization's multilateral priority for responding to global health-related issues. Two separate intensive stakeholder workshops were recorded and transcribed with a senior project stakeholder from Estonia, and the other with a senior technical stakeholder from NIIS.

Stakeholder workshops provide an avenue for reflection on key points of research interest during group discussion. The workshops also helped to validate a lightweight global vaccine passport recognition model using X-Road interoperability architecture. Additionally, the author had access to internal, non-confidential memos and other pertinent organizational documents. Furthermore, the author used external publications for corroboration. In this case, triangulation occurred by applying Vial's internal organizational digital transformation theory utilizing the information from the data collected.

[IV] focuses on the QH stakeholders participating in the OSIRIS Interreg BSR collaborative governance network from five countries: Estonia, Finland, Latvia, Lithuania, and Denmark. A stakeholder workshop was conducted to understand the prerequisites required to use eDelivery as a data intermediary provider for cross-border exchange data among stakeholders in the network. One project output was the Digital Silver Hub, a collective intelligence platform that facilitates open innovation. The workshop also validated the architectural eDelivery model that would most effectively integrate SilverHub.eu. Triangulation occurred through analyzing SilverHub technical documentation used for its development, analyzing eDelivery interoperability and governance documentation, and validating an architectural model that would be most optimal for QH network participants.

4.2 PSM and MCDM/A

Problems are complex and often contain a diversity of actors, perspectives, and conflicting interests for solving these problems. Problem structuring methods (PSM) are flexible mechanisms used for identifying improvements, solutions, or partial resolutions to the issue at hand. PSMs are characterized by iteration, cognitive accessibility, and their ability to synthesize diverging perspectives for identifying improvements or solutions to problems that have high complexity [50]. Typically, PSMs are combined with other methodologies to increase robustness [51].

In the case of publication [II], PSM was combined with multiple criteria decision-making/aid methodology and centered on Finland (Hameenlinna, Hame region) and Estonia (Tallinn) within the OSIRIS Interreg BSR project. MCDM/A is premised on giving systematic decision-support to decision-makers through identifying and evaluating the most optimal alternatives for solving a problem when given a set of factors [52]. In the context of this publication, the problem focused on the impediments to cross-border e-services between Estonia and Finland for older adults and identifying solutions to these challenges.

From this combined methodological perspective, the publication utilized cognitive mapping and DEMATEL. Cognitive mapping is a tool for visualizing problem interconnections and allowing participants to understand problems from their perspective, and it enables the merging of these perspectives into a networked structure [53]. Cognitive mapping was used as basis for implementing DEMATEL, a quantitative method focusing on identifying cause-and-effect relationships between multiple criteria through mathematical formulas [54]. DEMATEL is noted for its ability to resolve complex problems by providing decision-makers with systematic decision support. The output of DEMATEL, in this instance, were visual relationship graphs that reflected interdependencies and prioritization between factors assessing the problem. In the Estonian case, 267 factors were identified and grouped into five clusters, while in Finland, 331 factors were identified and grouped into six clusters. This was based on expert panel sessions with QH stakeholders in Estonia and Finland.

4.3 Regulatory Analysis

Regulatory analysis was deployed in [V]. This methodology seeks to systematically evaluate the regulation's effectiveness and implications on relevant stakeholders. The regulatory focus of this paper was the EU's Data Governance Act, which regulates cross-border interoperability and data exchange. It focuses on small and medium enterprises and data intermediaries as primary stakeholders. The analysis was conducted by reviewing relevant legal texts, regulatory documents, and compliance reports generated by the European Commission. Based on the document analysis, an impact framework showed the relationship between the regulation, SMEs, and data intermediaries.

5 Results

This thesis employs five publications to answer the research questions effectively and achieve its aims. The first publication, "A Historical Analysis on Interoperability in Estonian Data Exchange Architecture: Perspectives From the Past and for the Future", investigates the historical factors influencing the development of the Estonian X-Road interoperability platform and explores potential next-generation cross-border e-services through microservice architecture. The second, " Building Smart Living Environments for Ageing Societies: Decision Support for Cross-Border E-Services between Estonia and Finland," identifies the challenges and barriers to delivering cross-border e-services between Estonia and Finland, as well as a set of cross-border e-service domains and interoperability prerequisites in the context of the OSIRIS CGN for the Silver Economy.

The third, "Exploring EU e-Delivery Integration for Enabling Interregional Innovation through the SilverHub Platform," maps the optimal data intermediary architecture, eDelivery, to the OSIRIS collaborative governance ecosystem between QH stakeholders while providing interoperability requirements relevant to eDelivery for enabling cross-border data-exchange to occur. In addition, the publication explores integrating the digital collaborative "SilverHub" into the eDelivery data exchange network. Fourth is "Challenges and Implications of the WHO's Digital Cross-Border COVID-19 Vaccine Passport Recognition Pilot," which investigates a lightweight global data exchange instantiation of X-Road for recognizing vaccine passports under the World Health Organization initiative. The fifth publication, "The Role of Data Intermediaries for Small—and Medium-sized Enterprises in the Innovation Ecosystems of the Nordic-Baltic Silver Economy," analyzes the role of data intermediaries for SMEs in the Nordic-Baltic Silver Economy by exploring the provisions of the EU's regulatory Data Governance Act.

Publication [I] sets a foundational comprehension of the X-Road data intermediary through a historical analysis of its interoperability principles during its development, and also looking into the future of next generation cross-border e-services. The importance of establishing this baseline understanding is the X-Road platform has scaled to encompass additional national members like Finland, making the possibility of cross-border e-service provision and date exchange possible. Articles [II], and [IV] investigate the interoperability dynamics of different data intermediary architectures like the X-Road and eDelivery and their application to a Nordic-Baltic collaborative ecosystem (the case of OSIRIS) for the Silver Economy. In addition to interoperability requirements, Article II explicitly identifies a set of viable cross-border e-service domains, corresponding descriptions, and the challenges and barriers to their implementation.

[III] uses the case of the World Health Organization to understand the impact of digital transformation on an organization that was the centerpiece of a global interoperability project. The relevancy of this case is at the time, the X-Road data exchange platform was in contention for implementing the WHO's global vaccine passport, which required cross-border data exchange among its 194 state members. Article [V] focuses on data intermediaries for SMEs in innovation ecosystems in the Nordic-Baltic region, navigating the Data Governance Act, which is a regulatory instrument for data intermediary service providers in the EU. The paper focuses on how innovation ecosystem QH stakeholders may navigate this top-down bottom-up regulation for cross-border data exchange and a set of recommendations are given. The following sections will further explain the relationship of the publication results with the corresponding research questions.

5.1 Data Intermediary Architectures

The first research question states "How do different data intermediary architectures impact interoperability for cross-border data exchange and e-service orchestration in the Nordic-Baltic Region?" The impetus of this question is that the current heterogeneous environment of data interemediary architectures will have different impacts on cross-border data exchange and the delivery of e-services. For instance, the X-Road and eDelivery have differing structures and governing principles, which affects how collaborative ecosystems would deploy such data intermediation for their shared purposes in a regional cross-border context. To answer this research question, [I] looks explicitly into the historical development of the Estonian X-Road data exchange platform, understanding the context, thought processes, and decisions incorporated into X-Road's architecture, which impacts its usage in collaborative settings and cross-border e-service provision. Subsequently, semi-structured interviews were conducted with the original developers, architects, and policy-makers of the X-Road, including the current CTO of NIIS. The EIF layers—technical, organizational, semantic, and legal—structured the results, along with an additional component focused on understanding X-Road's future evolution and implementing asynchronous digital technologies, like microservices and AI, for providing next-generation digital government cross-border e-services. The legacy architecture of the X-Road does not support asynchronicity, a primary component of microservices and AI architecture used to deliver cross-border e-services, prompting the inclusion of this future outlook.

From a technical perspective, in 2001, the development of the X-Road centered around two architectural choices: a centralized system using Service Bus Architecture or a decentralized system where organizations use the public internet to exchange data synchronously. The architectural choice was the latter. The reason for deciding to implement decentralization was the possibility of a single point of failure in the centralized Service Bus model. Resource and infrastructure constraints also limit the potential of expensive networking protocols. There was a specific focus on encrypting data itself, not the transportation route, aptly summarized by an interviewee as the "data is king" principle.

The X-Road is technologically composed of an ecosystem of third-party trust providers, a central registry server of verified X-Road members, organizational security servers, and national authorities who are deemed operators of national X-Road instances. The X-Road supports Simple Object Access Protocol (SOAP) or Representational State Transfer (REST) for a wide variety of data types (JSON, XML, text, RDF, etc.) between registered organizations.From a legal perspective, two pieces of Estonian legislation were critical to adopting the X-Road—the first mandated e-identification for Estonian citizens and equivocated digital signatures with handwritten ones. Thus, organizations, which can be consumers, producers, or both in the X-Road ecosystem, digitally sign data to be exchanged with other organizations. The second piece of legislation was the Estonian Database Act, which gave X-Road legal validity as the primary data exchange infrastructure for the Estonian public sector.

Semantically, in the early 2000s, the Estonian State Information System Department (RISO) developed a repository to facilitate a shared understanding of data meanings. This repository has grown to encompass X-Road's scaling to other countries and is available on GitHub[6]. In the X-Road ecosystem, organizational interoperability centers around service-level agreements and security server installation. X-Road operators manage organizational identity to ensure that organizations exchange data only with other verified organizations in the network. The results also found no immediate plans for X-Road to transition to microservice architecture for implementing cross-border e-services due to limited resource capacity. One notable aspect was identifying technology as not a primary barrier to interoperability in the X-Road but rather misaligned internal organizational practices and policies as a key inhibitor.

[II] answers RQ1 by explaining the X-Road's federative properties to implement potential cross-border e-services between Estonia and Finland in the context of Smart Living Environments. Politically, in 2016, Estonia and Finland signed a joint resolution for establishing an "initial roadmap for cross-border data exchange and digital services." The resolution specifies bilateral data exchange for certain aspects of the silver economy: e-prescriptions, health records, social insurance, and more. As Estonia and Finland already exchange cross-border data between population registries, tax authorities, and business registries nationally, an established architectural and political foundation exists for scaling to cross-border e-services focused on the Silver Economy. This aspect is investigated in-depth in sub-questions 1.1 and 1.2.

[IV] addresses RQ1 by explicitly investigating eDelivery architectural components, interoperability requirements, and mapping the most optimal architecture for integrating an OSIRIS project output, the digital collaborative and collective intelligence platform, SilverHub[7], to become cross-border data exchange and e-service enabled, thereby increasing its digital maturity. According to Butt et. al[55] the SilverHub can be defined as "an environment where different stakeholders can collaborate in innovation processes using a methodology based on knowledge exchange, co-creation/cocreation/co-production techniques, and participatory methods." A key premise of the SilverHub is supporting innovation actors' smart specializations and their ability to collaborate. As Nordic-Baltic countries have greater or lesser social-financial capital as well as technical capacities in different domains of the Silver Economy, the SilverHub leverages network effects for communication, collaboration and coordination for regional innovation interventions based on country complementarities. Architecturally, SilverHub implements a classical three-tier architecture of presentation, logic, and data.

Structurally, the OSIRIS project has two layers of governance. The first level is "The Smart Silver Lab" (SSL) which serves as the foundation of the open innovation ecosystem. The SSL uses the SilverHub to communicate with other QH stakeholders who are involved in innovation activities, like providing services and developing products for the Silver Economy. In its current iteration, the SilverHub has one-way information directionality and aggregates information and ideas to The SSL collected from each OSIRIS participant country's regional Smart Silver Labs (RSSLs)[8], which QH stakeholders represent. In aggregate, The RSSLs form the second governance layer, the Transnational Cluster which provides an innovation development toolkit, a financing mechanism portfolio, and a knowledge diffusion toolkit containing regional Silver Economy assessment reports and QH stakeholder business descriptions and contact information specific to each participant country. This is all achieved through SilverHub functionalities. Still, the SilverHub has no supportive capabilities for cross-border data exchange and e-service provision. Thus, eDelivery was chosen as a potential data intermediary solution to improve the digital maturity of the SilverHub and, subsequently, the OSIRIS CGN. The publication frames the results through the four EIF layers, detailing the eDelivery interoperability requirements for SilverHub integration from technical, organizational, semantic, and legal perspectives.

eDelivery has different governance and technical dynamics than the X-Road; thus, it has different requirements for implementing the OSIRIS Interreg Baltic Sea case. eDelivery is an interoperability building block maintained by the Digital Europe Programme. It consists of reusable open specifications, standards, and software ideal for implementing pan-European projects in different policy domains, including those affecting society

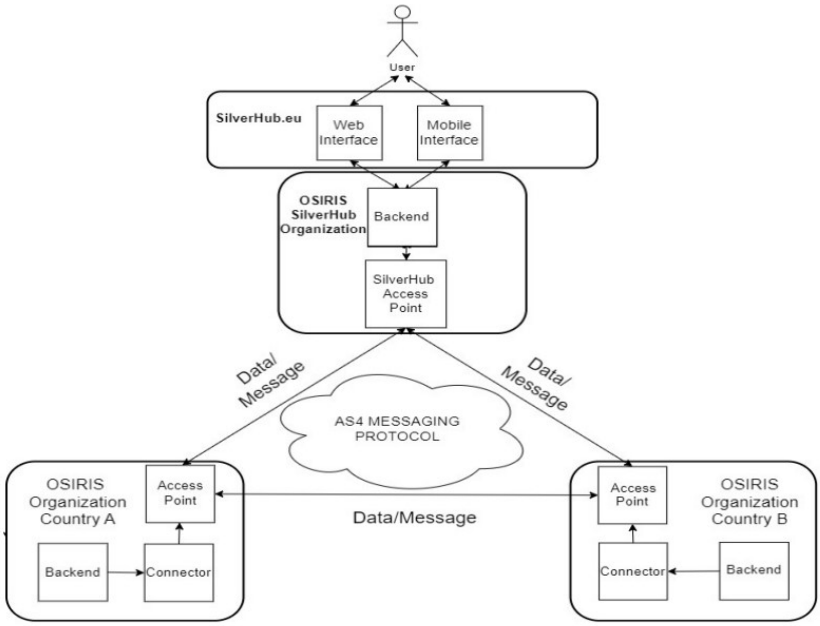

Figure 3: Organizational-specific Model (OSIRIS + SilverHub)

and the population. The author identified six technical and semantic interoperability requirements and their solution providers for integrating SilverHub with eDelivery. The author also ascertained two organizational interoperability permission processes: eDelivery on-boarding for SilverHub stakeholders and public/private SilverHub organizational registration. Additionally, the author pinpointed seven legal instruments to foster legal interoperability between SilverHub organizations, eDelivery governing organizations, and commercial-solution providers.

[6]https://github.com/nordic-institute/X-Road
[7]https://silverhub.eu/
[8]https://silverhub.eu/#ssl

Based on the workshop data and technical documents, the author considered a four-corner topological model, or mesh network, optimal for SilverHub scalability. The author determined from the workshop data that direct access point integration between SilverHub was infeasible, preferring internal or commercially installed connectors for access points to SilverHub organizational backends instead. Since eDelivery has different models that fit various collaborative objectives, the workshop participants selected an organizational-specific model (See Figure 3) as the most optimal. This particular model includes a dynamic discovery architecture (See Figure 4) that supports a centralized Service Metadata Locator provided by the SilverHub domain owner and Service Metadata Publishers for individual SilverHub member organizations.

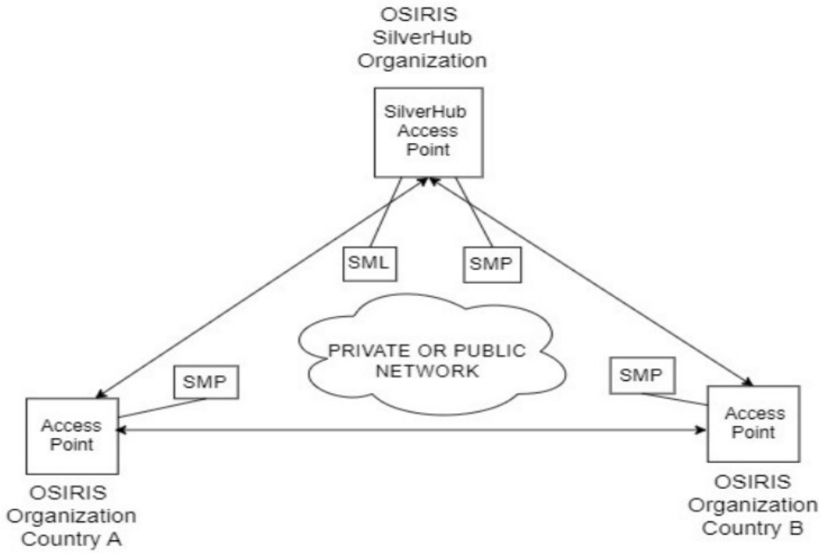

Figure 4: Dynamic Discovery Architecture (OSIRIS + SilverHub)

5.2 Cross-Border E-Services (Estonia + Finland)

Subquestion 1.1 asks, "What are the main challenges and barriers to cross-border e-services provision in the Nordic-Baltic Region?" The author proposes this sub-question to identify the challenges and barriers to cross-border Silver Economy e-services between Estonia and Finland. The framing of this question mainly looks at the supply side of service provision in Estonia and Finland from the involved QH stakeholders. During the cognitive mapping workshops, five common clusters were determined between Estonia and Finland: Actors Involved, Motivations and Benefits, Barriers and Limitations, and Knowledge-Based Resources, Skills, and Competencies related to service providers for the Silver Economy.

Using a methodological combination of cognitive mapping and DEMATEL, this research question executes a cross-comparison of five Barriers and Limitation clusters, each garnered between Estonia and Finland regarding inhibitors for Silver Economy cross-border e-services, as well as understanding the prioritization of the identified Barriers and Limitation factors. From a Finnish perspective, the five clusters were c21 (fifty percent of older people do not use or know how to use digital systems), c22 (inability to question current system structures), c23 (political struggles and funding challenges), c24 (fear of mistakes, prejudices, and dismissive attitudes), and lastly, c25 (lack of communication across organizations). On the Estonian side, the five clusters were: c21 (Biases/distrust of digital technology), c22 (infrastructural issues), c23 (lack of organizational knowledge), c24 (limited digital skills for end-users, service providers, and other crucial stakeholders), and lastly, c25 (no interest or awareness of services).

Subquestion 1.2 proposes "Which cross-border e-services are viable in the Nordic-Baltic Region? (Estonia + Finland), (investigated in the case of the Silver Economy)". The motivation behind this sub-question is to identify cross-border e-service intervention areas that are the most viable between Estonia and Finland. This subquestion led to seven

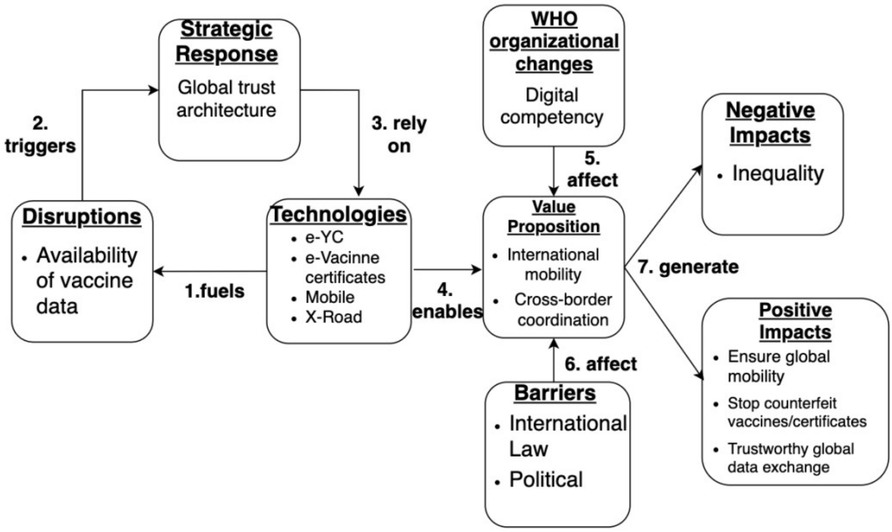

Figure 5: WHO Internal Digital Transformation

intervention areas and corresponding cross-border e-service descriptions based on the collected and analyzed data. The seven intervention areas include A1 (Social Welfare and Healthcare, Medicine, and Caregiving), A2 (Food and Nutrition), A3 (Leisure and Well-being), A4 (Finance), A5 (Mobility and Transportation), A6 (Housing), and lastly, A7 (Educational, Professional, and Other Activities). Subsequently, the publication results provide specific cross-border e-service descriptions in the identified intervention areas.

5.3 Organizational Digital Transformation (Case of the WHO)

The second research question is, "How does organizational digital transformation impact cross-border data exchange? (Case of the World Health Organization)" explicitly looks at organizational digital transformation theory and how that process would play out internally for a global vaccine passport initiative where cross-border interoperability between WHO member-states was the primary objective. This research question led to mapping a lightweight global X-Road data exchange instantiation and investigating the WHO's internal digital transformation processes required to undertake a critical global interoperability initiative during COVID-19.

Contextually, amid the COVID-19 pandemic, the WHO sought data intermediary candidates, of which X-Road was one, for implementing a global vaccine passport recognition. From the intensive stakeholder workshop with the Estonian representative, the results consist of two lightweight global X-Road architectural overviews and diagramming packet exchange between border officials, the WHO, and a private web app in which the vaccine passports were to be stored as well as a packet exchange between border officials, the WHO, and the home country responsible entity for validating vaccination organizations and an individual's identity.

Regarding organizational digital transformation, the WHO's implementation of the X-Road using Vial's theoretical framework (See Figure 5 starts with four technologies: e-vaccine certificates, e-yellow cards, mobile devices, and the X-Road. These technologies fuel the disruptive availability of vaccine data, which triggers the strategic response of

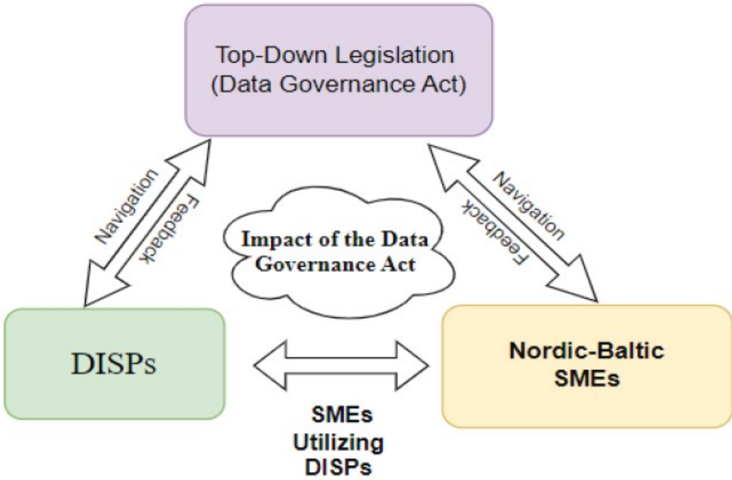

Figure 6: Impact and Navigation Framework

implementing global trust architecture. Closing this loop means that the worldwide trust architecture relies on these specific technologies, enabling the value propositions of facilitating international mobility and cross-border coordination.

The WHO's digital competency affects these value propositions, necessitating organizational change. Barriers regarding international law and political environments deal with the high-friction and controversial nature of pandemic response dynamics shaping the X-Road's political adoption. Ultimately, these value propositions have positive and negative impacts. On the positive side, such digital transformation in this context ensures global mobility, stops counterfeit vaccines and certificates and implements trustworthy data exchange on a global level. In contrast, a negative implication was the possibility of increasing inequality due to the unequal distribution of the COVID-19 vaccine in the Global South.

5.4 The Role of Data Intermediaries

The third research question asks: "What is the role of data intermediaries for interoperability in innovation networks for SMEs in the Nordic-Baltic region?" This research question seeks to understand the role of data intermediaries in fostering interoperability networks in the Nordic-Baltic region. As data intermediaries have different classifications and objectives, understanding their interplay with innovation ecosystems is pertinent for facilitating cross-border data exchange for innovation activities. The corresponding subquestion 3.1 states, "What are the implications for Nordic-Baltic SMEs regarding the Data Governance Act on cross-border data exchange for the Silver Economy?" This sub-question focuses on SMEs navigating top-down, bottom-up implementation of the regulation and the ramifications of the Act for SMEs who may be data intermediary themselves or require their services.

Figure 6 shows the Impact and Navigation Framework from publication [V]'s regulatory analysis. Starting at the top of the triangle is the DGA. The Data Governance Act, which takes a top-down approach, mandates that Data Intermediary Service Providers (DISPs) and Small and Medium-sized Enterprises (SMEs) adhere to this legislation within different regional settings, institutional policy coordination, and compliance frameworks. SMEs may also be DISPs themselves. The outflow from the top of the triangle is navigation for DISPs and SMEs. This bottom-up navigation will inherently be subject to tensions related to the institutions, policies, infrastructures, and resource environment in a local innovation ecosystem. The European Innovation Data Board is a crucial policy coordination actor that can help facilitate SME DGA navigation. Still, membership has yet to scale to encompass other European regions. The outflows from SMEs and DISPs are feedback mechanisms to the European Commission.

The impact of these relationships lies in the middle, where the DGA's motivation is to spur cross-border interoperable data sharing in a regulated environment. However, SMEs face numerous inherent disadvantages regarding compliance and leveraging the DGA to boost data value extraction. Relevant DISPs in the Nordic-Baltic region include the X-Road and the upcoming European Data Spaces. SMEs in the Nordic-Baltic region are recommended to engage with the forthcoming European Health Data Space, as the X-Road has a roadmap to be Data Space-enabled.

6 Conclusion

6.1 Limitations

This thesis research compilation contains multiple limitations. One identified limitation is the primary use of case study methodology. Although case study research is a valid methodology with a robust history of usage in academia, this approach has criticisms. Case studies have been criticized for lacking external validity, as the contextual nature of each case may limit the generalizability of conclusions [56]. In this case, the Nordic-Baltic region has specific dynamics that are more mobile, integrated, and have good political relations compared to other cross-border areas of the EU. Expanding the scope to other cross-border regions and their internal dynamics would be pertinent for a holistic understanding of EU-wide cross-border interoperability and data exchange dynamics.

A secondary limitation is a need for more scope on the organizational business processes inside QH stakeholders who participate in collaborative governance networks. The EIF outlines the alignment of organizational business processes as a critical factor for fostering interoperability between public and private organizations. In this research, there is an assumption that organizations already have incentives to collaborate based on their participation in the OSIRIS CGN. The granularities of QH stakeholder internal business processes fell outside this research's scope. Instead, the research objective was to understand how existing data intermediary architectures and requirements can be mapped to a CGN and elucidated to enhance interoperability between Nordic-Baltic QH stakeholders. Architectural mapping and interoperability requirements provide the foundation for secure data exchange for cross-border e-services in the Silver Economy. Ultimately, this led to the identification of cross-border e-service domains and lightweight descriptions therein.

A third identified limitation is the single regulatory focus on the DGA. The assortment of very recent regulations passed in the EU, like the AI Act, Interoperability Act, and Data Act, along with the DGA, are impacting cross-border interoperability. For the purposes of this research, the timing of the regulatory passing of the acts was quite late in the research process. As the investigator, the author decided to focus on the DGA because of its explicit focus on data intermediation and the governing requirements contained therein. More research and time are needed to assess whether these regulations will have the intended top-down effect as envisioned.

6.2 Implications for Future Research

Future research activities should focus more directly on the utility and implementation of the novel cross-border and cross-sectoral Data Spaces concept. Essential questions regarding data ownership and governance mechanisms still need to be sufficiently answered at this stage of its development. Concerning the Silver Economy, applying Data Spaces to QH stakeholders working in this space is a natural progression for research focusing on data intermediation for cross-border interoperability. Considering X-Road will be compatible with Data Spaces in the near future through some form of federative architecture, research investigating how X-Road could serve as a frictionless entry point for Nordic-Baltic organizations for increasing cross-border data exchange and uptake.

Another future research implication is using data intermediaries or other data exchange environments to foster interoperability between multilateral organizations like the World Health Organization. These organizations must often collaborate to rapidly address global disasters, pandemics, war, internal displacement, and other highly complex challenges. The appearance of data silos can have a debilitating effect on the efficacy of their disaster and conflict responses. If organizations were able to use data exchanged between one another securely, they could increase their efficiency and collaborative capacities to address some of the most significant global challenges.

Our current world is riddled with conflict, diseases, disagreement, and what appears to be intractable socio-political problems. Although interoperability is traditionally considered as a technical challenge, it is ultimately about achieving human cooperation and collaboration to improve and empower society and speaking on a human level. We need more cooperation and progress in the digital age. New digital technologies like AI have also brought new uncertainties about data movement, sovereignty, and unchecked asymmetries. Interoperability will continue to be vital for collaboration, innovation, and delivering e-services across borders and worldwide.

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Abstract

Cross-Border Data Exchange In the Nordic-Baltic Region: Data Intermediaries, Interoperability, and e-Services Orchestration

The interoperable data exchange across borders can enable innovation, e-service delivery, and collaboration between various quadruple-helix (QH) stakeholders (private, public, academia, and society) for addressing complex social problems. In the European Union, there is a growing impetus for fostering cross-border interoperability through an assortment of recently passed regulations for achieving a digital single market for data. This development coincides with the rise of data intermediaries, such as the X-Road and eDelivery, which are third-party organizations that leverage open-source software to help enable government and private organizations to securely exchange data to achieve a common objective.

However, despite this growing momentum and already existing data intermediaries, cross-border data exchange is still low due to fragmentation, heterogeneous architectures, and difficulty for organizations navigating the EU's top-down regulatory environment. Subsequently, this research seeks to investigate these cross-border interoperability dynamics through five publications. A majority of the publications are geographically bounded to the Nordic-Baltic region through the OSIRIS Interreg Baltic Sea collaborative governance network, consisting of QH stakeholders from Denmark, Estonia, Finland, Latvia, and Lithuania, with an emphasis on the Silver Economy, a cross-sectoral market focused on the delivery of products, and services for those over the age of 50. This research primarily investigated cross-border interoperability requirements, dynamics, and challenges from the perspective of this collaborative governance network (CGN) and a global data exchange case from the World Health Organization.

The theoretical grounding informing work was applying internal organizational digital transformation theory and the European Interoperability Framework, which provides four distinct but interconnected interoperability layers for structuring cross-border interoperability: legal, technical, semantic, and organizational. This research adopts a mixed-methods approach, primarily using qualitative case study methodology and quantitative problem-solving methods, including multi-criteria decision-making/aid and regulatory analysis, to achieve the research aims and answer the research questions.

Results from the publications are wide-ranging. Publication [I] is a historical analysis of X-Road interoperability principles and support for next-generation cross-border e-services. [II] delves into the challenges and barriers to cross-border e-service implementation between Estonia and Finland and identifies a set of cross-border e-service domains and descriptions. Publication [III] takes the World Health Organization's global vaccine passport case, modeling a lightweight X-Road architectural model and applying an organizational digital transformation theoretical model to the case. Publication [IV] maps eDelivery architecture and elicits requirements for fostering cross-border interoperability between QH stakeholders participating in the OSIRIS CGN. Publication [V] looks into the regulatory impact of the Data Governance Act, specifically from the perspective of small and medium enterprises.

Limitations of this thesis compilation relate to the lack of generalizability for case study methodology, lack of scope regarding business process alignment between QH stakeholders, and singular focus on the Data Governance Act. Future research implications entail further investigation into the utility and implementation of the novel cross-border and cross-sectoral Data Spaces concept planned for enabling cross-border interoperability on

a continental scale. Cross-border interoperability will continue to be an important issuefacing the European Union and the world in responding to complex social problems such as population aging and pandemics.

Kokkuvõte

Piiriülene andmevahetus Põhja-Balti regioonis: andmevahendajad, koostalitlusvõime ja e-teenuste orkestreerimine

Piiriülene andmevahetus võib võimaldada innovatsiooni, e-teenuste osutamist ja koostööd erinevate nelikheeliksi (QH) sidusrühmade (era-, avalik, akadeemia ja ühiskond) vahel keeruliste sotsiaalsete probleemide lahendamiseks. Euroopa Liidus on kasvav hoog piiriülese koostalitlusvõime edendamiseks läbi hiljuti vastu võetud määruste, mille eesmärk on saavutada ühtne digitaalturg andmete jaoks. See areng langeb kokku andmete vahendajate, nagu X-Road ja eDelivery, tõusuga – need on kolmandad osapooled, kes kasutavad avatud lähtekoodiga tarkvara, et aidata valitsusel ja eraorganisatsioonidel turvaliselt andmeid vahetada ühise eesmärgi saavutamiseks.

Kuid vaatamata sellele kasvavale hoole ja juba olemasolevatele andmevahendajatele on piiriülene andmevahetus endiselt madal killustatuse, heterogeensete arhitektuuride ja organisatsioonide ELi ülevalt-alla regulatiivses keskkonnas navigeerimise raskuste tõttu. Sellel põhjusel uurib käesolev uuring neid piiriülese koostalitlusvõime dünaamikaid viie publikatsiooni kaudu. Enamik publikatsioone on geograafiliselt seotud Põhjala-Balti piirkonnaga läbi OSIRIS Interreg Läänemere koostöövõrgustiku, mis koosneb QH sidusrühmadest Taanist, Eestist, Soomest, Lätist ja Leedust, keskendudes eakate majandusele, mis on sektoriülene turg, mille eesmärk on pakkuda tooteid ja teenuseid üle 50-aastastele. See uurimus keskendus peamiselt piiriülese koostalitluse nõuetele, dünaamikale ja väljakutsetele selle koostöövõrgustiku (CGN) ja Maailma Terviseorganisatsiooni ülemaailmse andmevahetuse juhtumi vaatenurgast.

Teoreetiline raamistik tugines organisatsioonide sisemise digitaalse transformatsiooni teooriale ja Euroopa koostalitluse raamistikule, mis pakub nelja eristuvat, kuid omavahel seotud koostalitluse kihti piiriülese koostalitluse struktureerimiseks: õiguslik, tehniline, semantiline ja organisatsiooniline. See uurimus kasutab kombineeritud meetodit, mis koosneb peamiselt kvalitatiivsest juhtumiuuringu metoodikast ja kvantitatiivsetest probleemide lahendamise meetoditest, sealhulgas mitmekriteeriumiline otsustamisabi ja regulatiivanalüüs, et saavutada uurimistöö eesmärgid ja vastata uurimisküsimustele.

Publikatsioonide tulemused on mitmekesised. Publikatsioon [I] on ajalooline analüüs X-Road'i koostalitluse põhimõtetest ja järgmise põlvkonna piiriüleste e-teenuste toetamisest. [II] süveneb piiriüleste e-teenuste rakendamise väljakutsetesse ja takistustesse Eesti ja Soome vahel ning tuvastab piiriüleste e-teenuste valdkondi ja kirjeldusi. Publikatsioon [III] käsitleb Maailma Terviseorganisatsiooni ülemaailmse vaktsiinipassi juhtumit, modelleerib kergekujulise X-Road arhitektuurimudeli ja rakendab juhtumile organisatsiooni digitaalse transformatsiooni teoreetilise mudeli. Publikatsioon [IV] kaardistab eDelivery arhitektuuri ja toob välja nõuded, et edendada piiriülest koostalitlust QH sidusrühmade vahel, kes osalevad OSIRIS CGN-is. Publikatsioon [V] uurib Andmevalitsemise määrus regulatiivset mõju, eriti väikeste ja keskmise suurusega ettevõtete vaatenurgast.

Käesoleva uurimistöö koostamise piirangud on seotud juhtumiuuringu metoodika üldistamise puudujäägiga, ulatuse puudujäägiga äriprotsesside joondamisel QH sidusrühmade vahel ja ühepoolse fookusega Andmevalitsemise määrus. Tulevased uurimissuundumused hõlmavad uute piiriüleste ja sektoriüleste andmeruumide kontseptsiooni kasulikkuse ja rakendamise edasist uurimist, mille eesmärk on võimaldada piiriülest koostalitlust ülemandrilisel tasandil. Piiriülene koostalitlus jääb oluliseks teemaks nii Euroopa Liidule kui ka ülejäänud maailmale, seoses keeruliste sotsiaalsete probleemide lahendamisega, nagu rahvastiku vananemine ja pandeemiad.

Appendix 1

[I]

E. B. Jackson, R. Dreyling, and I. Pappel, "A historical analysis on interoperability in estonian data exchange architecture: Perspectives from the past and for the future," in *Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance*. Association for Computing Machinery, 2022, p. 111–116

A Historical Analysis on Interoperability in Estonian Data Exchange Architecture: Perspectives from the Past and for the Future

Eric B. Jackson
TalTech University
eric.jackson@taltech.ee

Richard M. Dreyling
TalTech University
Richard.iii@tattech.ee

Ingrid Pappel
Taltech University
Ingrid.pappel@taltech.ee

ABSTRACT

The importance of interoperability for enabling e-governance and e-service provision cannot be overstated. In Estonia, the interoperability data exchange platform, X-Road, has been implemented since 2001 and was integrated with the Finnish public sector in 2018. In the context of the EU, it is an exceptional case of a cross-border interoperability platform. However, the Estonian government has proposed next generation government e-services using virtual assistants. This may necessitate potential changes to X-Road if the members from its collectively governed body, Nordic Institute for Interoperable Services (NIIS) decide to do so. Thus, this paper seeks to understand how X-Road developed historically related to European Interoperability Framework principles while also providing an outlook for the future based upon this next generation e-service concept. An exploratory case-study approach was adopted, and six semi-structured interviews were conducted with the architects, developers and public sector officials of the original and current version of X-Road. A thematic analysis was then applied. Based on this analysis, the decision to decentralize the initial X-Road helped create sustainable interoperability supported by legislation written at the time and since then. Future work is presented involving the integration of microservices on an abstract level.

CCS CONCEPTS

• **information systems**; • **applied computing** → enterprise computing; enterprise interoperability; information integration and interoperability;

KEYWORDS

e-governance, interoperability, data exchange, x-road

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1 INTRODUCTION

Interoperability is more than just technical specifications — it is a cornerstone of e-government, encompassing legal frameworks, semantics, ontologies, organizations and trust, among other variables [1]. Subsequently, the ability of governmental organizations to exchange data internally and externally unlocks the potential for creating digital services that are open, efficient, efficacious and citizen-centric [2]. When interoperability is not ensured, there may be serious consequences. In nationalized healthcare infrastructure, a lack of standardization and interoperable Electronic Health Records has led to medical errors, diminishing the well-being of patients [3].

In the EU nation of Estonia, the X-Road has been an established interoperable data exchange framework since 2001. It is a distributed, unified data exchange layer connecting over 600 Estonian private and public sector organizations over the public internet. X-Road handles nearly one billion queries annually [4] and operates under an MIT open-source license. For comparison, the EU's interoperable document exchange platform, eDelivery, which has exchanged almost half a billion documents since 2015 [5].

Although X-Road was originally coordinated by the state information system department (RISO) of the Ministry of Economic Affairs and later by the Estonian State Information System Authority (RIA), since 2017 the non-profit Nordic Institute for Interoperable Solutions (NIIS) is the governing entity of the X-Road core software (the national instances are governed by the authorities of each country).As a built-in feature, X-Road since version 6 supports cross-border data exchange through federative agreements. In 2018, this was actualized when the Estonian and Finnish X-Road ecosystems were connected to one another [6]. While the exact scope of value creation from this exchange is limited, valid interoperable cross-border exchanges in the EU and consequently, the connected X-Road ecosystems provide a real-life example of data interoperability between nation-states. X-Road instances have also been deployed globally in Iceland, Columbia, Argentina, Japan, the Faroe Islands and in other countries respectively [4].

Thus, it is fair to describe X-Road as a successful enabler of data exchange use-cases in Estonia and abroad.

However, although most services in Estonia are paperless, the Government Chief Information Office (GCIO) recognizes the provision of next generation e-services necessitates structural upgrades to X-Road. In 2020 the GCIO of Estonia published a white paper entitled "Next Generation Digital Government Architecture" outlining a strategic vision for implementing proactive, artificially intelligent e-services, termed the KrattAI initiative [7]. The cornerstone of this vision is developing virtual agents for automation of domestic and cross-border public services [7]. For example, a virtual assistant would proactively inform a citizen that their passport is expiring and automatically place an order for a new one. Incorporating AI into decision-making like in the scenario above is challenging [8], but to empower scalable, proactive virtual-agent-driven cross-border e-services as KrattAI intends, certain architectural changes to X-Road warrant investigation.

While X-Road has been explored in academic literature, it has primarily been conducted through comparative analysis [9] or specific aspects of the exchange layer have been investigated like private-public partnerships [10] and digital signature schema [11]. In contrast, the novelty of this research is presenting an analysis of X-Road from a historical perspective, while also investigating X-Road's compatibility with next generation digital architectures like KrattAI and microservices.

This paper has two objectives. First is analyzing the context at the end of the 1990s and the beginning of the early 2000s which enabled initial X-Road implementation and adoption based on interoperability principles. Through analyzing the premises of X-Road's initial development from interviewing Estonian policymakers, private sector actors and requirements architects who were there in the beginning, we better understand X-Road's evolution and potential scalability for future digital technologies. Second, this research seeks to understand X-Road's current interoperable capacity for the proposed Estonian next generation digital government architecture through interviewing the current CTO of NIIS. Based on these objectives, two research questions are proposed:

RQ1: How did the historical conditions related to interoperability principles affect X-Road implementation and adoption in Estonia?

RQ2: How is the current X-Road ecosystem equipped for the future of next generation government services?

In order to analyze this phenomenon, this research first presents the European Interoperability Framework (EIF) in the theoretical overview. Next, semi-structured interview methods and thematic coding based on the EIF is justified. Then the proceeding section presents the results of the interviews and discusses implications. Lastly, future work is provided to conclude the paper.

2 THEORETICAL OVERVIEW

The definition of interoperability has been proposed by many researchers and institutions in the fields of IT, public administration and healthcare, etc. The IEEE provides a simplistic definition of interoperability: "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [12]. Interoperability is also well summarized by the European Interoperability Framework: "the ability of organizations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their ICT systems". The EIF has further deconstructed interoperability into four levels: technical, semantic, organizational and legal [13].

Technical interoperability is a primary driver for providing e-services and from a general perspective "covers the applications and infrastructures linking systems and services" [14]. More specifically, it dictates the ability for subsystems to interface with one another through standardized practices, shared technical standards and frameworks [15]. The total aggregate of subsystem interconnectivity is what provides tremendous business value for the public sector. Data is also a critical component to technical interoperability. It's transformation from one standard to another, the security of its transport between different entities through Hypertext Transfer Protocol Secure (HTTPS) and various data integration services fuel decision-making in the public and private sector [16].

Further related to data is semantic interoperability. This level pertains to both the "semantic and syntactic aspects of data" [14]. On a basic level, semantics relate to everyone in a data exchange ecosystem speaking the same language; where data definitions and the corpus of words used to describe processes and information are all understandable [14]. Data has to be precise and error-free when exchanged, abiding by the correct syntax demanded by a compiler. Consequently, the deployment of different types of syntactical analyzers mitigates the potential for errors to occur [17]. While syntax has a specific and important function, semantic standardization was chosen for interoperability analysis in this paper.

The concept of organizational interoperability is closely connected to the semantic domain of data. Cooperative relationships between organizations are influenced by common business goals and agreeing to semantic standardization [14]. Internally, regulations and policies guide organizational adoption of interoperability with other organizations. Users also have representation in the organizational interoperability paradigm. The ability for organizations to provide effective and efficient services that meet the needs of users is also an important component to interoperability [14].

In society with the rule of law, organizations operate under legislation established by the public sector or sometimes in the case of the EU, supranational level. This impacts interoperability in a variety of ways. Data protection acts, legislation on digital signature requirements and its acceptability, e-identity and other legal frameworks shape the way interoperability occurs. In sum, the four levels of the EIF are the foundation for "integrated public service governance" [13]. In Estonia, X-Road ensures integrated public e-services like e-invoicing [18] occur at the local [19] and national level. As the IEF definition embodies a holistic approach to interoperability, it is the primary thematic coding framework applied in this research.

3 METHODOLOGY

In this paper, the authors deploy qualitative methods via an exploratory case-study approach. Case studies can embody qualitative methods by exploring specific phenomena through the triangulation of different data sources: interviews, focus groups, external articles, etc. [20]. A critical component to this research was the deployment of qualitative, semi-structured interviews with relevant stakeholders. Semi-structured interviews provide researchers a framework to talk with people in a 'self-conscious, orderly and partially structured" way [21] The open-ended format of this interviewing technique allows for flexibility and the ability for interviewees to reflect and express themselves to the fullest intent possible. In this research, we conducted six semi-structured remote interviews averaging roughly an hour each. Figure 1 describes the interviewee affiliations and roles related to X- Road's development in greater detail.

Interviewee Number	X-Road Role	Stakeholder Sector
Interviewee 1	e-Government expert and consulted on X-Road version one in the public sector	Former CIO of Estonia
Interviewee 2	Primary Architect of the X-Road version one	Private Sector
Interviewee 3	Head Co-Manager of X-Road version one	Private Sector
Interviewee 4	Interoperability expert who works on current and previous versions of X-Road	Private Sector
Interviewee 5	Technical advisor for X-Road version one	Private Sector
Interviewee 6	Currently the CTO of NIIS	NIIS

To validate our interview questions, we approached Interviewee 1 who an Estonian expert on e-governance is and was an influential proponent of X-Road in the Estonian public sector. After we identified the founders of X-Road from technical, legal, and organizational perspectives through research and networking, we contacted the interviewees and asked fifteen different questions about the historical conditions at the time related to the EIF interoperability principles. Additionally, we asked about X-Road's current and future outlook with next generation government e-services.

In order to gain greater qualitative insight into the X-Road phenomena, analytical thematic analysis was manually applied to the semi-structured interview transcripts through Otter.ai transcription service. There are two overarching approaches for conducting thematic analysis: concept-driven and data-driven. Concept driven takes ideas from previous theoretical literature and contextual information to form a framework for analysis [22]. Therefore, a list of keywords should be constructed beforehand and described before coding is conducted. On the other hand, data-driven coding doesn't start with a framework and instead starts with zero codes, letting the interviews organically form applicable topics [23].

In this paper, a concept-driven coding approach was adopted for answering the first research question. The authors use the four interoperability principles established by the EIF and described in the theoretical overview. For answering the second research question, a data-driven approach was taken. Analytical coding was applied to the transcripts. Gibbs [23] Describes analytical coding as containing more complex labeling of because it is based on the interpretation of the interviewer [23]. In sum, this research uses an exploratory case study approach by triangulating six interview transcripts, external articles and thematic analysis.

4 RESULTS

Historically, the Estonian public sector in the late 90s and early 2000s was transitioning from Sovietization to a newly re-independent country. As Interviewee 1 described, Estonia's public sector digital capacity during this period amounted to a few IBM components and a lack of IT human capital. Interviewee 4 further expanded on the public sector situation at the time: "real time, dynamic cooperation between agencies, was a real bottleneck. And one reason definitely was that some of the registries, most notably our population registry was building some kind of business model around. I would say selling or providing paid access to this data."

Hence, it was recognized this was an unsustainable practice for the development of e-governance in Estonia. According to Interviewee 3, in 1998-99 there were various public-private sector consultations trying to improve the situation: "many ministries found that they need to integrate their IT systems, and each of these ministries asked from the government to finance this. So, if we have ten different ministries, then we need to do ten integrations and fund all of them". However, the state did not have the funds at the time, and pragmatically there were "ideas to do something centrally and interconnect these ministries with one middleware."

4.1 Technical Interoperability

This led to two competing perspectives related to the architecture of X-Road's technical interoperability. On the one hand, the Estonian government's procurement for such a system called for a highly centralized system using Service Bus architecture which makes data format conversions easier. Yet there was a consortium of private sector companies who considered this unfeasible because of the chance for a single point of failure. Interviewee 3 summarized it as so: "For me it was obvious that it should be decentralized, because to have such a centralized system not working means that the whole country shuts down, like a virus you know."

Subsequently, they proposed a decentralized version of X-Road and designed organizational data exchange to be synchronous, which the Estonian government ultimately decided upon. In this first iteration, technical interoperability and availability of X-Road was ensured by the implementation of a closed Domain Name Security Extensions (DNSSEC) and an emphasis on "data being king". The lead developer of X-Road, Interviewee 4, clarified why X-Road protects the data itself through encryption and not the transportation route: "We decided that we need to protect data not channels. We don't need special channels; we can use some public channels (public internet). We say that data is king, and we protect this data by signing our data."

Therefore, X-Road's initial vision was based upon the design of the public internet, which is inherently decentralized and encrypted, along with some centralized organizational elements. However, the primary reason was due to lack of resources and infrastructure for private networks, not because of the internet's primacy. At the time, the Estonian Information Systems Authority was considered the central "operator" of the X-Road ecosystem, onboarding other organizations and establishing governance. In its current technical form, X-Road uses an ecosystem of third-party trust services (timestamping, certificate authorities and Online Certificate Status Protocol services,) a central registry server of X- Road members

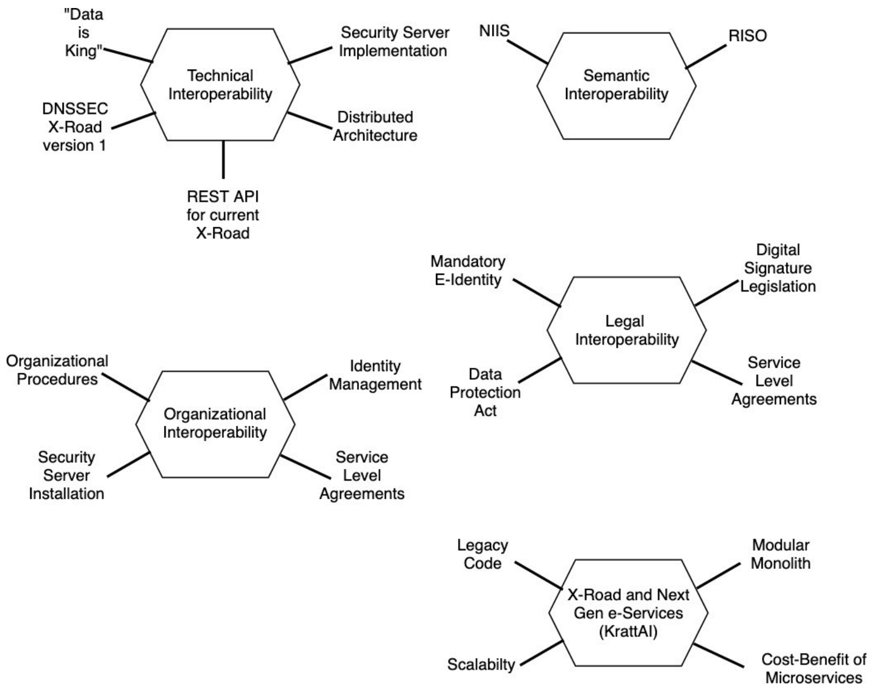

Figure 2: Thematic Analysis

and security servers that are configured to national, regional or local information systems [24]. Subsequently, each member can act as a service producer, consumer, or both [24]. Architecturally, X-Road supports both Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) for exchanging synchronous requests of JavaScript Object Notation data (JSON), XML, text, RDF and other forms of data between X-Road entities based on service-level agreements between them.

4.2 Semantic and Organizational Interoperability

Semantically for X-Road, responsibility for creating a common corpus of understanding was put to the state information system department (RISO) of the Ministry of Economic Affairs. RISO produced a common repository which Interviewee 2 was leading at the beginning of the 2000s. This repository was an important knowledge base for all developers and architects, leading to synchronicity and semantic interoperability. Nowadays, NIIS provides this repository via GitHub [25] and online training sessions for Security Server installation and administration.

Historically and presently, the X-Road ecosystem relies upon organizational interoperability. All organizations in the X-Road ecosystem follow established procedures for Security Server installation. In the opinion of Interviewee 4, “legal contracts (service level agreements) are like maybe 1/5 of the whole organizational complexity” in the X-Road ecosystem. The other components are related to organizational identity management: “X-Road is specifically a Secure Exchange Network, where you can be sure that the identity of an organization that is claimed is what this organization claims to be. This information system claims to be this information system. This is the identity you are managing in the center, so you must build yourself an understanding of what is the operator functionality: you are the Identity Manager of the systems. And if you are not fulfilling that position, your X-Road will never fly, you will just get another technical solution that means nothing because there is no organizational responsibility.”

Interestingly as Interviewee 4 points out, the number of interoperable organizations who use X-Road has actually been inflated. Before X-Road version 6 migration, the number of registered organizations in the ecosystem was at 1200 and using memory. Currently, there are now 600 registered organizations and thus almost half of the organizational membership “didn’t use or didn’t need X-Road”. Consequently, “the ecosystem was full of that kind of bloke and fat that wasn’t very useful.” Nonetheless, the migration to X-Road version 6 improved interoperability because it ensured that organizations who want to be an active part of the ecosystem are still participating.

4.3 Interoperability

Legal interoperability has been a cornerstone empowering X-Road's utility. Legislatively, the first version of X-Road was consulted in lockstep with Estonia's data protection authority. In parallel at the time, crucial legislation in the early 2000s made e-Identification obligatory for Estonian citizens and established digital signatures as equivalent to hand-written ones. These two legislative developments enabled X-Road's signing and logging scheme. Additionally, the Estonian Database Act was incorporated into the Public Information Act, enshrining X-Road as the main infrastructure of data exchange in the public sector through the State Register of Databases [26].

4.4 X-Road and Next Generation E-Services

The second objective of this paper is to answer the research question: How is the current X-Road ecosystem equipped for the future of next generation government services? As the CTO of NIIS, Interviewee 6 was asked specifically about potential microservice integration into X-Road. Asynchronous messaging between service producers and consumers is at the core of the KrattAI vision proposed by the Estonian government. Therefore, understanding the perspective of NIIS on this issue is important for developing future novel e-services in Estonia and abroad.

When asked if X-Road intends to use microservices in the future, Interviewee 6 pointed out that after X-Road's governance was officially transferred over to NIIS in June of 2018 they inherited its code base and responsibilities for maintenance and development. Interviewee 6 described this code as being a "modular monolith", because "when you build X-Road, you have to build the whole monolith. But then when we think about the Security Server, it consists of different modules that run as independent processes." The Security Server's modules mostly communicate through Akka based TCP protocol. Whereas in microservices, according to Interviewee 6, generally use HTTPS for interfacing. For X-Road, the vital question is how to support asynchronous messaging between service consumers and service producers in its current synchronous form. Microservices provide an architectural framework for achieving this aim, however there are other architectural patterns that can support asynchronous messaging that are not microservice driven.

Ultimately, the required changes to X-Road's architecture for implementing microservices requires too many resources and the cost-benefit of such a transition doesn't make business sense. As Interviewee 6 aptly describes, "It would be nice to say that we use microservices, we use blockchain and whatever is hot right now, but unfortunately we are a little bit boring. And that's why, at least not yet, we haven't gone into microservices."

Still, Interviewee 6 noted that microservices implementation would make a positive impact on X-Road's scalability. Bottlenecks can occur when there is a higher load pertaining to signing messages and logging. In order to scale, server capacity has to be increased, which means adding more resources to a single Security Server (scale up) or adding more Security Server instances (scale out). When scaling up, there is a limit where increased resource capacity to Security Servers doesn't meet scaling needs. As Interviewee 6 explains: "With microservices-based approach, especially when you run the whole system in containers, it might be enough to scale out the container that is responsible for signing the messages instead of scaling out the whole Security Server and all the components. So, it would make it a lot more efficient."

5 DISCUSSION

From the interview data, it is apparent that the historical foundations of X-Road considered a decentralized interoperability model, where instead of expensive VPNs and high infrastructure costs, the public internet was used as the primary communication channel. This was due primarily to pragmatism and a lack of IT capital at the time. Starting with ten public sector databases and then interconnecting them through the public internet with specific logging and electronic signing functionality used for auditing and accountability. Vital to the e-signature format integrated into the X-Road was e-Identification and digital signature legislation.

Without these two pieces of legislation, the ability for X-Road to have legitimacy would be inhibited, at least in Estonia. This is because when Estonia made e-Identification mandatory it created an incentive mechanism to use the X-Road organizationally. It should be noted that the Estonian law on digital signatures has now been replaced by the EU's EIDAS legislation, which X-Road already abided by domestically. Semantically, X-Road's development has been quite straightforward. The establishment of RISO provided clear guidelines, standards and frameworks for developers to use in the early 2000s. This has now been updated through NIIS who provides the guidelines through their GitHub and governance practices.

An interesting facet of the interview data was the premise that technology is not the primary inhibitor of interoperability in the X-Road. Rather, it is organizational practices and internal policies that become major barriers. A good example of this was the organizational glut that occurred when migration from X-Road version 5 to version 6 (it's current iteration) was initiated. If over half of the existing ecosystem was a member by name only, then interoperability was reduced based upon organizations not "buying-in" to the concept of X-Road. A transition to where X-Road is streamlined organizationally can only help strengthen the interoperability environment that is currently implemented.

Lastly, the introduction of microservices to the X-Road is not because of a lack of understanding of but purely based on organizational objectives, as it is currently not on the NIIS Roadmap. It is important to understand the division between X-Road's internal architecture and messaging protocols and the architecture used by service producers and consumers in the ecosystem. X-Road producers and consumers can have microservice capability as long as they comply with X-Road's messaging protocols. In the end, NIIS is exploring how asynchronous messaging patterns can be implemented, regardless if it is microservices or not.

As Interviewee 4 elaborated, microservices do not have to be integrated directly into the X-Road, which would only complicate things as they are currently. Instead, a top layer microservice component could be implemented that masks the synchronicity of X-Road into an asynchronous one. This would allow the simplicity of X-Road to continue, while still providing architectural requirements needed for the virtual assistant e-services proposed by the Estonian government.

6 CONCLUSION AND FUTURE WORK

This research has mapped out some of the historical interoperability conditions that led to X-Road's implementation in Estonia, while also addressing its potential for supporting next generation digital government services. It is clear X-Road empowers interoperability and thus Estonian integrated e-services through the EIF paradigm. Technical interoperability is ensured through Security Servers and REST/SOAP APIs. Semantically, RISO was established in the early 2000s and NIIS's GitHub provides current specifications, documentation and source code for organizations. Interoperability among organizations in the X-Road ecosystem relies on identity management, use of Security Servers and a multitude of service level agreements between the X-Road member organizations. Lastly, legal interoperability for the X-Road in Estonia was provided by Estonian legislation on data protection, e-signatures and e-identity in the early 2000s.

Future possible developments involve creating a microservice solution for a cross-border virtual assistant e-service between Estonia and Finland, as there is a close cross-border relationship between both societies. This microservice solution might not be integrated directly into X-Road, but rather work as a top layer component for enabling the next generation of cross-border e-services. As X-Road is jointly funded by the Estonian, Finnish and Icelandic governments through NIIS, the above-mentioned future opportunities support cross-border data exchange between NIIS member countries and Latin America. A preliminary survey to cross-border e-service providers in the Finnish and Estonian public sectors could further solidify what use-case is appropriate for the above microservice layer.

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Appendix 2

[II]

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Building smart living environments for ageing societies: Decision support for cross-border e-services between Estonia and Finland

Marina Weck [a,*], Eric Blake Jackson [b], Markus Sihvonen [a], Ingrid Pappel [b]

[a] HAMK Smart Research Unit, Häme University of Applied Sciences, Visamäentie 35, 13101, Hämeenlinna, Finland
[b] Department of Software Science, Tallinn University of Technology, Ehitajate Tee 5, 12616, Tallinn, Estonia

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ABSTRACT

Rapidly aging societies are exerting pressure on the public and private sectors to provide e-services as integral parts of age-friendly smart living environments (SLEs). It is also recognized that interoperable cross-border e-services can reduce this societal challenge, particularly in more 'individualistic' countries in Northern and Western Europe such as Estonia and Finland. This study primarily provides decision support for multiple stakeholders involved in the development and provision of interoperable cross-border e-services and related cross-border data exchange between Estonia and Finland. Given the high complexity of the research questions, this study adopted a constructivist, sociotechnical approach that combined cognitive mapping and the decision-making trial and evaluation laboratory (DEMATEL) technique. Based on two real-world cases, data were collected from two panels of experts who represented regional stakeholders involved in building e-services and age-friendly SLEs in Estonia and Finland. The study results include a multicriteria analysis framework of the context factors and recommendations for determining effective intervention strategies.

1. Introduction

Throughout the world, the older population is growing at a faster pace than ever before. Moreover, in the more 'individualistic' societies in Northern and Western Europe, people tend to live independently, with greater privacy and control over household decisions [1,2]. The highest proportions of people aged 65 years or older who are living alone are in Estonia and Finland, at 37% and 36% of the total population of the country, respectively [3]. The governments of these two countries are under enormous pressure to maintain this living arrangement preferred by their older people. The major challenge of these governments is to support the healthy, active, and independent lifestyle preferred by these older people outside an institutional care setting and to provide them with key public services that keep pace with their needs.

The European Commission (EC) has recognized that products and electronic services (e-services) based on information and communication technology (ICT) have the potential to address the aforementioned challenge and the corresponding needs that drive a great demand for public services [4]. It is also acknowledged that integrating e-services for older persons into smart living environments (SLEs) holds great promise in enabling older people to live extended lives while staying active and independent members of society. Therefore, SLEs are a common target of governments and businesses worldwide. Thus, in this article, age-friendly SLEs represent physical spaces where services requested by older people can be enabled through the Internet of Things (IoT) and ICT solutions [5]. It is also noteworthy that age-friendly SLEs are the focus of the *Decade of Healthy Ageing* (2021–2030) proclaimed by the UN, an advocacy that emphasizes the need for imperative international collaboration among governments, civil society, international agencies, academia, the media, the private sector, and other stakeholders to achieve healthy aging [6].

This international collaboration in building age-friendly SLEs also encourages cross-border e-services between countries across Europe, where common regional goals necessitate the seamless data exchange needed to support the services [7]. One such regional goal is the EC's Digital Single Market Strategy (DSMS), which seeks to remove barriers to EU cross-border e-commerce, access to public and private e-services, and the free movement of people and capital across borders [8]. According to the EC, by 2023, 21 online cross-border e-services will be provided through the *Your Europe* portal [9]. Inherently, EU cross-border e-services in the public and private sector are citizen-centric, where the needs and demands of citizens shape service

* Corresponding author.
E-mail addresses: marina.weck@hamk.fi (M. Weck), eric.jackson@taltech.ee (E.B. Jackson), markus.sihvonen@hamk.fi (M. Sihvonen), ingrid.pappel@taltech.ee (I. Pappel).

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provision [10]. This means that the citizen is placed at the center of service delivery, where the needs of citizens are addressed in an efficient, effective, and open manner [11]. Subsequently, the public sector is now viewed as a facilitator of e-services powered by agile organizational networks. However, in order to provide effective cross-border e-services that are citizen-centric, interoperability between different national information systems is a preconditional requirement. Interoperability is the "ability of organizations to interact towards beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their ICT systems" ([12]: 5).

Although there are studies devoted to the issue of e-service design and uptake in ageing societies in the EU [13,14] specific focus on the older population segment from a cross-border perspective, is lacking in the literature. Furthermore, the underlying cross-border data exchange and interoperability components necessary for cross-border e-service implementation are not addressed. Thus, to pave the way for the development and provision of interoperable cross-border e-services between Estonia and Finland that will especially benefit the multitudes of older persons living alone in such countries, it is important to provide relevant decision support to multiple stakeholders therein to enable them to understand better the context factors and determine effective intervention strategies. Accordingly, the following questions have to be answered:

- What factors are inhibiting the provision of cross-border e-services between Estonia and Finland?
- What types of cross-border e-services between Estonia and Finland have been identified as needed most?
- How can interoperable cross-border e-services and age-friendly SLEs be established in Estonia and Finland?

Due to technology development and the emergence of innovative alternatives to supporting aging societies, decision-making has become far more complex and multifaceted than ever before, pushing decision-makers to search for and adopt new approaches and methodologies for collaborative decision-making [15] based on both qualitative and quantitative criteria [16]. This article reports on the results of multiple case study of collaborative decision-making using problem structuring methods (PSMs) and multiple criteria decision making/aid (MCDM/A). The applied methodology combined cognitive mapping and the decision-making trial and evaluation laboratory (DEMATEL) technique.

Cognitive mapping assists decision-makers in structuring ideas and aggregating different points of view [17,18] and brings new insights into analyses that could not be revealed by using only statistical methods [19,20]. DEMATEL facilitates analyses of cause-and-effect relationships among identified criteria based on the knowledge and experience of experts [21]. Both techniques have been extensively used in different decision-making contexts, and their potential as tools for collaborative decision-making has been demonstrated in studies that used each technique individually [22]. However, while studies have affirmed the value of combining methods to address complex and multidimensional research questions and contexts, the use of such combined methods does not seem very common in literature, and no report on the use of combined methods in the context of this study has been found.

The combination of cognitive mapping and DEMATEL, two well-established techniques, in this study enabled us to develop the following: (a) a multicriteria analysis framework that helps multiple stakeholders to understand the factors identified as relevant to the provision of interoperable cross-border e-services between Estonia and Finland; and (b) recommendations for determining the effective intervention strategies. Thus, drawing on the study conducted in Estonia and Finland, this article also expands the existing scarce body of literature on cross-border e-services and presents research results that make an important practical contribution to the development of interoperable cross-border e-services and related cross-border data exchange between the two countries.

The structure of this article is as follows. The second section provides a brief overview of related literature, with special attention given to cross-border e-services and data exchange as well as to the European Interoperability Framework as a key enabler of the implementation of the EC's DSMS. The third section presents the decision-making tools used in the two case studies, cognitive mapping and the DEMATEL technique. The fourth section describes the implementation of the case studies and the procedures involved. The fifth section discusses the results and answers the research questions. The final section discusses the research limitations, the theoretical and managerial implications, and the grounds for further research.

2. Related literature

2.1. EU cross-border e-services in public and private sectors

Lindregen and Jansson [23] developed a generalized conceptual model of public-sector e-services as supporting value creation between service providers and end-users (e.g., older people) through a specified service process. This process is inherently 'mediated' electronically via the internet and integrates information technology (IT) components, like backend public-sector registries, and responsive interfaces for both the service providers and the end-users under a public regulatory framework. Thus, high-maturity e-services should anticipate the needs of older people and intelligently automate service processes to meet such needs using existing data [24].

In the EU, multiple regulations, directives, and initiatives support and shape cross-border interoperability, data exchange, and e-service environments. The EC's DSMS was adopted in 2015 and proposed measures which are based on three main pillars: (1) better access for consumers and businesses to digital goods and services across Europe, (2) the creation of the right conditions for digital networks and services to flourish, and (3) maximization of the growth potential of the European digital economy [8]. The European Regulation on Electronic Identification and Trust Services (eIDAS) critically shapes the DSMS as it sets the legal foundation for the use by EU citizens and businesses of their national electronic identifications (eIDs) to securely access digital public services from other EU countries [25].

This necessitates trust infrastructure and mutual recognition of EU eIDs by all 28 EU member countries, although in practice, only a few EU member countries have set up a sufficient eID [26]. From a technical perspective, the EU's Single Digital Gateway is an online mechanism for EU citizens and the private sector to easily access reliable and quality information about national and EU administrative procedures, rules, regulations, and cross-border services via integration with the Your Europe portal [9].

2.2. European Interoperability Framework

A key enabler of the implementation of the DSMS is the European Interoperability Framework (EIF). For cross-border e-services to be implemented, the interoperability of national public administration systems must be ensured. The EIF defines interoperability as "the ability of organizations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their ICT systems" ([12]: 5). The EIF covers three types of interactions ([12]: 7): A2A (administration to administration), which refers to "interactions between public administrations (e.g., Member State or EU Institutions)"; A2B (administration to business), which refers to "interactions between public administrations (in a Member State or an EU Institution) and businesses"; and A2C (administration to citizen), which refers to "interactions between public administrations (in a Member State or an EU institution) and citizens."

Furthermore, the EIF provides a theoretical basis for cross-border interoperability through four component levels: technical, semantic, organizational, and legal [12]. Technical interoperability pertains to "the applications and infrastructures linking systems and services" [27]. Thus, the combination of different subsystems integrated with one another through standardized technical frameworks, practices, and standards is the primary focus of technical interoperability. A major challenge towards achieving cross-border technical interoperability is the usage of legacy technologies, which results in siloed and fragmented information systems, inhibiting the ability to securely exchange information and data. Data plays an important role in technical interoperability, as its availability, secure transportation, and transformability are key drivers of public-sector decision-making and the provision of e-services [28].

Semantic interoperability is also a data-centric concept. The "semantic and syntactic aspects of data" relate to shared definitions, schematic vocabularies, and ontologies that facilitate the exchange and usage of data [28: 5]. In other words, data structures and definitions must be understandable to all parties involved, whether through XML, JSON, metadata, or other data forms. Consequently, a public sector information management strategy is necessary for enabling cross-border agreements on data references, including "taxonomies, controlled vocabularies, thesauri, code lists, and reusable data structures/models" ([12]: 28). These data referential components greatly foster semantic cross-border interoperability between public sector organizations. Data must not only be securely exchanged but must also be accurate and error-free when processed and utilized during e-service implementation and provision. This means data compiled or parsed by public-sector entities must have no syntax inconsistencies. In the EU, a semantic interoperability standard, ISA2 (Interlinear Scripture Analyzer 2), is being used.

In this cross-border e-government context, organizational interoperability refers to interorganizational collaboration and cooperation on shared business goals, policies, and services. Agreements on semantic standardization, exchange architectures, and processes are all essential elements of this layer [27]. Therefore, the internal regulations and policies of a public-sector organization dictate its integration with another cross-border organization to foster their interoperability through Memorandums of Understanding and Service Level Agreements. Organizations are also responsible for collecting, maintaining, preserving and securing base registries, metadata, master data and reference architectures [12]. Particularly when it pertains to base registries, organizations are responsible for providing authoritative data in different domains, like property registration, population registry, business registration, vehicles, and cadastres, for instance. These base registries must have quality assurance controls to ensure data is up-to-date, understandable and is electronically uncorrupted.

In the public sector and in societies that operate under the rule of law, national and supranational legislation, regulations, mandates, and other legal mechanisms shape the implementation of not only e-government but also cross-border interoperability. Weber ([29]: 5) described legal interoperability as "full harmonization of normative rules between jurisdictions and a complete fragmentation of legal systems". If the rules between transnational jurisdictions are too synchronized, the idiosyncratic nature of culture and social norms may be disregarded, which will lead to disputes [29]. If the legal systems of the jurisdictions are indeed completely fragmented, the harmonization of their rules is impeded [29]. In sum, legal interoperability cannot be viewed as an afterthought when it comes to cross-border interoperability because it sets the legal environment in which transnational e-services can occur.

2.3. Cross-border data exchange between Estonia and Finland

Finland and Estonia represent unique cases of cross-border data exchange and e-services integration in the European landscape. With nearly 50,000 Estonians living in Finland [30] and high rates of cross-border travel between the two countries' populations, the exchange of data and the integration of specific databases of the two countries have been identified as providing value to the Estonian and Finnish public sectors. In 2016, the Estonian and Finnish prime ministers signed a joint resolution for the establishment of an "initial roadmap for cross-border data exchange and digital services," which made the issue a political priority of the two nations [31]. The resolution outlines potential domains for automating bilateral data exchange, including SLE applications such as digital prescriptions, health records, and social insurance benefits. For instance, the population registers of Finland and Estonia have been exchanged automatically since 2020 using the interoperable X-Road data exchange layer [32].

The key technical backbone of the cross-border data exchange between Estonia and Finland is the X-Road data exchange layer. The overall governing entity of the X-Road core software is the non-profit Nordic Institute for Interoperability Solutions (NIIS), which is funded by both the Estonian and Finnish Ministries of Finance. Estonia, Finland, and Iceland are all members of NIIS. Although NIIS is the overarching governing authority of the core X-Road software, national X-Road instances are managed individually by the national authority of each country.

X-Road can be viewed as a facilitator of interoperable data exchange between service consumers and producers through an ecosystem of central trust services, legal contracts between organizations, and organizational security servers. Organizations are onboarded on the X-Road environment, provided digital certificates from trusted certificate authorities, and registered in a central registry server. Data payloads are encrypted and exchanged via security servers using the REST (Representational State Transfer) or SOAP (Simple Object Access Protocol) messaging protocols, with the security servers mediating calls and responses. Data exchanges are timestamped, and legal agreements between organizations specify which kinds of data will be exchanged and the legal responsibilities of each organization.

Ultimately, X-Road is a distributed architecture with centralized elements that enable data exchange between trusted information systems by ensuring the integrity, confidentiality, and availability of data in an interoperable ecosystem. X-Road is a proven technology for facilitating cross-border data exchange, and, at a national level, for providing digital services to all types of citizen groups, including older people.

3. Methodological background

As acknowledged in the MCDM/A literature [19] the methodological option depends on the decision context, participants involved, and/or decision problem at hand, and the PSMs are commonly combined with various methodologies in accordance with the problem characteristics [33]. Thus, with the highly complex research questions and context of this study, we combined two methodological approaches: PSMs and MCDM/A. In particular, we used cognitive mapping to appropriately structure the highly complex decision problems and to develop a multicriteria analysis framework; and we used the DEMATEL technique to analyze the cause-and-effect relationships among identified criteria in response to the need for more accurate and better-informed decisions.

This study has many characteristics that are similar to the study in which PSMs were developed. PSMs are flexible mechanisms that are particularly useful for addressing complex issues characterized by the presence of multiple decision-makers, who often preserve different perspectives and objectives and even conflicting interests [34,35]. Cognitive mapping has been increasingly used as a PSM and has been widely reported in literature (cf [17,36]). It is a method of problem structuring [19,37–39] and "was developed as a tool to help understand how different people involved in a situation made sense of it, or understood it, for themselves" ([40]: 6). The tool facilitates the identification of cause-and-effect relationships between multiple criteria in a decision-support system [41,42] and thus, can help individual decision-makers and groups to examine decision problems more systematically and thoroughly.

A cognitive map is the visual "representation of thinking about a problem that follows from the process of mapping" ([36]: 673). From a practical point of view, it represents a network of concepts or nodes and links or arrows where the direction of the arrows implies perceived causality between the nodes [36]. To summarize, cognitive mapping assists decision-makers with decision-making by enabling them to do the following: (1) structure complex decision-making situations; (2) deal simultaneously with quantitative and qualitative factors; (3) sustain teamwork; and (4) facilitate strategy development and implementation [43,44]. Given these advantages, we used cognitive mapping in this study combined with the DEMATEL technique.

The DEMATEL technique has been widely acknowledged as capable of resolving highly complex decision problems in various areas and with multiple decision criteria [45–48]. It was developed to reveal and analyze cause-and-effect associations between system components [49]. It is used to understand more fully the relationships and interdependencies between factors in complex decision problems based on experts' knowledge and experience [21,50,51]. DEMATEL is a mathematical technique that quantifies the interdependence between variables and helps decision-makers construct graphs that reflect such relationships [52,53]. Furthermore, DEMATEL can assist to prioritize defined factors based on the type of relationship as well as identify the severity of their effect on other factors by analyzing visual relationships among entities and their groups [54].

Lee et al. [56] divided the DEMATEL process into four main phases: (1) "find the average matrix A"; (2) "calculate the normalized initial direct-relation matrix D"; (3) "compute the total relation matrix"; and (4) "set a threshold value and obtain the impact-relation-map (IRM)" (cf [55].: 6747–6749).

4. Methodological application

This section focuses on the application of the combined methodology used in the multiple case study. The study was conducted in Finland (Hämeenlinna, Häme region) in 2019 and in Estonia (Tallinn) in 2020 under the OSIRIS Interreg BSR project, which focused on addressing the challenges of the governments of the Baltic Sea countries in meeting the needs of their older people. In the Finnish case study, the focus was on examining the experts' collaborative decision-making process related to age-friendly SLEs; and in the Estonian case study, the focus was on examination the provision of cross-border e-services as integral parts of age-friendly SLEs.

The primary aim of the study was to define the complex problems for which decisions had to be made by focusing on the cause-and-effect relationships between the multiple decision criteria identified and analyzed by the relevant decision-makers in the multistakeholder and multisectoral context. This encompassed a collaborative decision-making process for which knowledgeable and heterogeneous experts were engaged. The heterogeneity of their professional expertise and hands-on knowledge of the building of e-services as integral parts of age-friendly SLEs was ensured by applying the quadruple helix (QH) innovation approach, which, according to Arnkil et al. [56], emphasizes broad collaboration in innovation between government, academia, industry, and civil society. Thus, the experts recruited for both case studies represented public and private service providers in social welfare and healthcare, research and business organizations, regional and national policymakers, administrative and finance authorities for older persons, and associations of older people.

It is also important to point out that in both case studies, the experts were not selected to make the study results representative or generalizable [57,58]. Instead, they were selected based on their ability to collaborate effectively as members of a group, contribute to productive discussions of the problem at hand [19], and understand deeply the complex decision problem together. Their availability and commitment to collaborate by sharing their knowledge and experience were also carefully considered as essential to the entire decision-making process.

4.1. Finnish case study

In the Finnish case study, eight experts participated voluntarily in two expert panel meetings held in Finland, following the guidelines of Eden and Ackermann [17] and Ribeiro et al. [18] that the number of participants in this kind of meeting be between 6 and 10. The experts represented (1) the local policymaking organization (two experts); (2) a research institution (two experts); (3) the business sector (one expert for finance and another for urban architecture); (4) an association for older people (one expert); and (5) the municipal social and health services agency for older people (one expert). Both panel meetings were facilitated by an experienced facilitator or instructor and two assistants who were responsible for coordinating the panel meetings and recording the results, respectively.

The first panel meeting focused on the analysis of the issues related to the age-friendly SLEs and their multistakeholder and multisectoral context. The meeting lasted approximately 4 h. The collaborative decision-making process enabled the eight panel members to define and structure the problem using the "post-it technique" [37]. They generated 331 decision criteria or context factors and wrote down each criterion on its own post-it note. Next, they were asked to organize the identified criteria into areas of concern [59] and to add a negative sign (−) at the corner of the post-it note in the case of a negative relationship between a given criterion and the main topic [31]. All the identified decision criteria were grouped into six clusters (see Table 1).

The last part of the panel meeting was dedicated to ranking by importance all the criteria for each cluster and organizing the respective post-it notes on a whiteboard from the most important at the top to the least important at the bottom. In this part of the decision-making process, the panel members had a greater chance to reflect on each criterion, which enabled them to participate actively in the structuring of the cognitive map [60]. This procedure also included a discussion and characterization of age-friendly SLEs. The following were identified as the most essential characteristics of, or the strategic criteria for, age-friendly SLEs: (1) a comfortable life; (2) an active life; and (3) an independent life. After the panel members completed the problem structuring, the Decision Explorer software (www.banxia.com) was used to create a cognitive map.

The same group of experts participated in the second panel meeting, which was conducted to validate the cognitive map. Each panel member was provided a copy of the map and the opportunity to discuss it and suggest any changes and corrections. The developed cognitive map was a visual representation of the decision problem. It showed all the identified clusters related to the age-friendly SLEs with their criteria or context factors and their multistakeholder and multisectoral context, as well as the arrows that represented cause-and-effect relationships between clusters. The validated version of the cognitive map is available upon request (see also [61]).

4.2. Estonian case study

In the Estonian case study, the provision of interoperable cross-border e-service solutions as integral parts of age-friendly SLEs were

Table 1
Finnish case clusters.

Identification of Clusters	
C1	Involved Innovation Actors
C2	Motives and Benefits
C3	Barriers and Limitations
C4	Improvement Actions and Initiatives
C5	General Skills, Capabilities and Competences
C6	Resources and Knowledge-Based Activities

the primary focus of two expert panel meetings. The guidelines for recruiting panel meeting members in the Finnish case study were adopted. Thus, seven experts participated in the two panel meetings: (1) three from the business sector–a service provider and a consultancy; (2) one from a research institution; (3) one from a governmental organization; (4) one from a nongovernmental organization involved in social affairs; and (5) one representative of older people. However, due to the coronavirus disease 2019 (COVID-19) pandemic, both panel meetings were conducted online and lasted two and a half hours each. They were both moderated by one facilitator and two assistants who recorded the feedback and results.

The first panel meeting was conducted to analyze and structure the decision problems related to cross-border e-service solutions through a decision-makers' debate and sharing of knowledge and experience. A total of 267 criteria were generated with the help of the facilitator and assistants. These decision criteria were grouped into five clusters and seven subclusters (see Table 2).

To complete the analysis tasks of the panel in the first panel meeting, the nominal group technique and multi-voting were performed through email. Therefore, a brief explanation was given of the following steps that were to be taken at the end of the meeting. After the meeting, based on the collected results of experts' evaluation, a cognitive map was constructed. The map graphically represented all the identified decision criteria, clusters, and subclusters, as well as the cause-and-effect relationships between them.

As in the Finnish case study, one of the main tasks of the panel in the second panel meeting was to validate the developed cognitive map, following the procedure used in the Finnish case study. Each panel member was asked to analyze the cognitive map and to consider whether any additions to or changes in the links or terms were necessary. The validated version of this map is available upon request (see also [61]). Once the cognitive map was validated, it was analyzed using the DEMATEL technique, which allowed decision criteria to be hierarchically structured. The analysis will be discussed in the next section.

5. Results analysis

This section presents an integrative perspective on the results of the multiple case study, which enabled the development of the following: (a) a multicriteria analysis framework to help multiple stakeholders to understand the identified context factors relevant to the provision of cross-border e-services between Estonia and Finland; and (b) recommendations for determining effective intervention strategies. Accordingly, the section is organized in such a way as to present results of our analysis following the research questions. The first section explains the factors that are inhibiting the provision of cross-border e-services or barriers and limitations. The second section integrates and discusses the results related to the types of cross-border e-services that were identified as needed most between Estonia and Finland as well as stakeholders involved. The final section elaborates our recommendations for establishing interoperable cross-border e-services and age-friendly SLEs in Estonia and Finland.

Thus, the analysis results are integrated in this section to provide evidence of how the context factors (i.e., decision criteria are respective clusters and sub-clusters) identified in the two cases complement one another and helped to describe more thoroughly the multistakeholder and multisectoral context of interoperable cross-border e-services and age-friendly SLEs in both countries (see Tables 3, 6, 7, 12 and 15). That is to say, the cognitive maps developed in both country cases and resulting analyses are complementary, and we were able to enhance our understanding of the context using different methodological approaches. The cognitive map of the Finnish case study shows 331 criteria or factors of the age-friendly SLEs' context grouped into six clusters, whereas the Estonian map represents 267 criteria of the context of cross-border e-services grouped into five clusters.

Table 3 summarizes the identified common and complementary clusters and sub-clusters with their sizes (i.e., numbers of criteria grouped in each cluster and sub-cluster) of both cases and helps to see the level of similarity between them. Although the comparison was not the aim of the integration of the analysis results, four clusters were defined as similar, but their sizes were not well comparable [61]. The numbers of identified criteria show the significance and complexity of each cluster and sub-cluster. The five prioritized criteria or context factors with the highest centrality agreed upon by the Estonian and Finnish expert panelists for each cluster are presented in Tables 3, 8, 13 and 16.

The particular interest of the Estonian panel members in the cause-and-effect relationships between identified decision criteria, and the way the causal dynamics among the criteria were analyzed, allowed for the application of DEMATEL. This is a different scenario compared to Finland, where the initial problem was to structure the conceptualization of the age-friendly SLEs and their multistakeholder and multisectoral context.

5.1. Factors inhibiting the provision of cross-border e-services

In this section, we present the results of our DEMATEL analysis of the factors that are inhibiting the provision of Estonian-Finnish cross-border e-services, following the four-phase DEMATEL analysis process introduced by Lee et al. [55]. Table 4 shows the five prioritized decision criteria agreed upon by the Estonian and Finnish expert panelists for the Barriers and Limitations cluster. Although this cluster was similarly defined in the two cases, the number of factors in this cluster differed between the two cases (i.e., the division of factors per cluster was not uniform, having also noticeable differences in terms of the number of

Table 2
Estonian case clusters and sub-clusters.

Identification of Clusters and Sub-Clusters		
C1	Motives and Benefits	
C2	Barriers and Limitations	
C3	Actors Involved	
C4	Knowledge-Based Resources, Skills and Competencies	
C5	Broad Areas of Possible Intervention	
	A1	Social Welfare and Healthcare, Medicine and Caregiving
	A2	Food and Nutrition
	A3	Leisure and Well-being
	A4	Finance
	A5	Mobility and Transportation
	A6	Housing
	A7	Educational, Professional and Other Activities

Table 3
Identified common and complementary clusters and sub-clusters.

Identified Common Clusters	
Finnish case clusters	Estonian case clusters
C1 Involved Innovation Actors (31) C2 Motives and Benefits (59) C3 Barriers and Limitations (54) C5 General Skills, Capabilities and Competences (61)	C3 Actors Involved (27) C1 Motives and Benefits (36) C2 Barriers and Limitations (29) C4 Knowledge-Based Resources, Skills and Competencies (28)
Complementary Clusters and Sub-Clusters	
C4 Improvement Actions and Initiatives (93) C6 Resources and Knowledge-Based Activities (33)	C5 Broad Areas of Possible Intervention (in total 147) A1 Social Welfare and Healthcare, Medicine and Caregiving (25) A2 Food and Nutrition (24) A3 Leisure and Well-being (22) A4 Finance (14) A5 Mobility and Transportation (16) A6 Housing (28) A7 Educational, Professional, and Other Activities (18)

Table 4
Selected decision criteria or context factors of corresponding clusters from the Estonian and Finnish cases.

Cluster C2: Barriers and Limitations	Cluster C3: Barriers and Limitations
Estonian case (29 decision criteria/context factors)	Finnish case (54 decision criteria/context factors)
c21: Biases/distrust of digital technology	Fifty percent of older people do not use and do not know how to use any digital system at all.
c22: Infrastructural issues (high-speed broadband accessibility)	Inability to question current system structures
c23: Lack of knowledge	Political struggles and funding challenges
c24: Limited digital skills (for end-users, service providers, and other crucial stakeholders)	Fear of mistakes, prejudices, and dismissive attitudes
c25: No interest or awareness of services	Lack of communication across organizations etc.

Table 5
Matrix T calculations.

	c21	c22	c23	c24	c25	R
c21	2.1525	1.7026	2.2724	2.2718	2.3285	10.7277
c22	1.9932	1.3028	1.8554	1.8901	1.9554	8.9969
c23	2.3073	1.6805	1.9928	2.1841	2.2314	10.3960
c24	2.2117	1.5996	2.1392	1.9326	2.1919	10.0749
c25	2.1376	1.5233	2.0538	2.0448	1.9056	9.6650
C	10.8022	7.8087	10.3136	10.3233	10.6128	

Table 6
Criteria interaction scores.

	R	C	R + C	R–C
c21	10.7277	10.8022	21.5299	−0.0744
c22	8.9969	7.8087	16.8056	1.1882
c23	10.3960	10.3136	20.7096	0.0825
c24	10.0749	10.3233	20.3982	−0.2484
c25	9.6650	10.6128	20.2778	−0.9478

Table 7
Interoperability analysis of cluster C2 (Estonian case).

Cluster C2: Barriers and Limitations (decision criteria)	Related EIF Layer(s) (EIF, 2017)
c21: Biases/distrust of technology use	Technical, Organizational
c22: Infrastructural issues (high-speed broadband access not available everywhere)	Technical
c23: Lack of knowledge	Organizational
c24: Limited digital skills (for end-users, service providers and other crucial stakeholders)	Organizational
c25: No interest or awareness of services	Organizational

Table 8
Selected decision criteria of corresponding clusters in the Estonian and Finnish cases.

Cluster C3: Actors Involved	Cluster C1: Involved Innovation Actors
Estonian case (27 decision criteria)	Finnish case (31 decision criteria)
c31: Contact persons of older people	Public authorities
c32: Customers and users	Private and public service providers
c33: Public sector	Building constructors and end-users
c34: Service providers	Older people, researchers, designers, students, and families
c35: Third sector	Third sector etc.

Table 9
Matrix T calculations.

	c31	c32	c33	c34	c35	R
c31	2.3540	2.7623	2.6144	2.7168	2.5942	13.0418
c32	2.3415	2.3366	2.3780	2.5091	2.4049	11.9701
c33	2.3156	2.4494	2.1915	2.4808	2.3882	11.8256
c34	2.3504	2.5561	2.4259	2.3382	2.4531	12.1238
c35	2.5900	2.8106	2.6503	2.7247	2.4580	13.2335
C	11.9515	12.9150	12.2601	12.7696	12.2984	

Table 10
Criteria interaction scores.

	R	C	R + C	R–C
c31	13.0418	11.9515	24.9933	1.0902
c32	11.9701	12.9150	24.8851	−0.9450
c33	11.8256	12.2601	24.0857	−0.4346
c34	12.1238	12.7696	24.8934	−0.6458
c35	13.2335	12.2984	25.5319	0.9351

Table 11
Service areas and service descriptions.

Cluster C5: Broad Areas of Possible Intervention (subclusters and decision criteria)
A1: Social Welfare and Healthcare, Medicine and Caregiving S1: Access to e-service providers S2: Assistive technology (to provide independence) S3: Monitoring older people's health S4: Online training (keeping active with online training) S5 Status monitoring (home-based solutions, wearables, etc.)
A2: Food and Nutrition S6: Delivery services from shop to home (self-driving cars, outside cupboards, etc.) S7: Health monitoring data (sending information through smart devices) S8: Mealtime reminders (older people living at home forgetting to eat) S9: Simple solutions for ordering food from grocery stores S10: Smart assistance tools for food preparation; etc.
A3: Leisure and Well-being S11: Bank services S12: Common events for the local community S13: Encouraging an active and healthy lifestyle (physical activity, mental activity, social activity, and diet) S14: Involvement of older people S15: Online communication tools to keep in touch with family and friends etc.
A4: Finance S16: Developing financial literacy: knowledge and skills on personal budgeting S17: Free or AI-based legal support for older people S18: Raising financial awareness (online training sessions on financial terms, legal topics, and work- and pension-related topics) S19: Safe payment solutions S20: Simple banking solutions; etc.
A5: Mobility and Transportation S21: 'Bolt' service for older people (transportation through a 'simple order') S22: Self-driving vehicle solutions S23: Sharing economy in the community S24: Supporting home delivery of basic necessities (food, medicine, etc.) S25: Supporting MaaS (mobility-as-a-service) etc.
A6: Housing S26: Community housing services (laundry, sauna, etc.) S27: Data from wearables and health- and location-tracking devices for dementia S28: Distance-controlled housing S29: Robots that help with house maintenance and cleaning S30: Smart home solutions that help to control and analyze data regarding electricity, water, and heating; etc.
A7: Educational, Professional, and Other Activities S31: Different events and trainings in the community S32: Easy platforms to keep the mind and brain active and in shape S33: Involvement of older people in sharing their knowledge S34: Promoting lifelong learning S35: Raising digital skills of older people etc.

Table 12
Cross-border e-service descriptions.

Cross-border e-services (decision criteria)	Service areas (subclusters)	Cluster C3: Actors Involved (decision criteria)
S1: Access to e-service providers	A1: Social Welfare and Healthcare, Medicine and Caregiving	c33: Public sector c34: Service providers c35: Third sector
S21: 'Bolt' service for older people (transportation through a 'simple order')	A5: Mobility and Transportation	c34: Service providers
S34: Promoting lifelong learning	A7: Educational, Professional, and Other Activities	c33: Public sector c34: Service providers c35: Third sector
S35: Improving digital skills of older people etc.	A7: Educational, Professional, and Other Activities	c33: Public sector c34: Service providers c35: Third sector

Table 13
Selected decision criteria of corresponding clusters from the Estonian and Finnish cases.

Cluster C1: Motives and Benefits	Cluster C2: Motives and Benefits
Estonian case (36 decision criteria)	Finnish case (59 decision criteria)
c31: Access to information (using ICT tools)	Good and open communication between actors and easy access to information
c32: Encouraging cooperation between service users, service providers, and service developers	Controlling the growing costs of care of older people
c33: Keeping older minds active	New era of living and an easy life
c34: Promoting lifelong learning	Accessibility for everybody
c35: Providing flexible working conditions etc.	Social care, shared spaces, etc.

Table 14
Matrix T calculations.

	c11	c12	c13	c14	c15	R
c11	0.9111	1.0638	1.3088	1.3151	1.0759	5.6747
c12	0.8843	0.6780	1.0616	1.0429	0.8288	4.4956
c13	0.8692	0.7948	0.8865	1.1075	0.8510	4.5091
c14	0.9636	0.8698	1.2003	0.9693	0.9358	4.9387
c15	0.9266	0.8810	1.0943	1.1099	0.7434	4.7552
C	4.5548	4.2874	5.5516	5.5446	4.4349	

Table 15
Criteria interaction scores.

	R	C	R + C	R–C
c11	5.6747	4.5548	10.2295	1.1199
c12	4.4956	4.2874	8.7830	0.2083
c13	4.5091	5.5516	10.0607	−1.0426
c14	4.9387	5.5446	10.4834	−0.6059
c15	4.7552	4.4349	9.1901	0.3203

context factors), which indicates the significance and complexity of the cluster. Additionally, the EIF was used as a tool for understanding these barriers and limitations more deeply in the context of the interoperability of the e-service systems.

It is worth noting that the DEMATEL technique was applied only in the Estonian case following the four phases of the DEMATEL analysis process and related calculations [55,62]. This technique allowed for cause-and-effect analyses of the context factor relationships that enable the provision of e-services as integral parts of age-friendly SLEs.

At the start of the DEMATEL analysis, an initial direct-relation matrix was created by asking the panelists to rate the influence of each criterion

Table 16
Selected decision criteria of corresponding clusters from the Estonian and Finnish cases.

Cluster C4: Knowledge-based Resources, Skills, and Competencies	Cluster C5: General Skills, Capabilities, and Competencies
Estonian case (28 decision criteria)	Finnish case (61 decision criteria)
c41: Customer/end-user skills and awareness (using ICT tools)	Understanding users' needs
c42: Integration of various stand-alone systems between governments and citizens	Appreciative attitude toward others and willingness to listen
c43: Knowledge of user centers for service design	Willingness to question current practices
c44: Market knowledge (what customers actually need)	Capability to address meaningful issues
c45: Product owner	Ability to filter information, reliability of actors, etc.

on the others on a scale of 0–4 (i.e., 0 = no influence; 1 = little influence; 2 = medium influence; 3 = strong influence; and 4 = very strong influence) to understand the cause-and-effect relationships of each criterion with the other decision criteria [63].

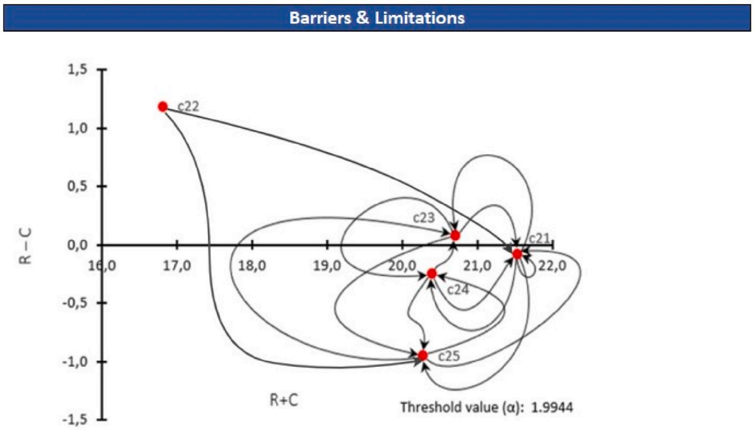
After the initial direct-relation matrix was normalized using the related equations, matrix T introduced the R and C values, with R measuring the degree of the influence on a given criterion by other criteria and C measuring the degree of the influence of a given criterion on the remaining criteria [64]. Table 5 shows matrix T with the R and C values, which indicate that criterion (c) 21 (Biases/distrust of technology use) had the highest influence on the four other criteria, with a score of 10.7277, and c23 (Lack of knowledge) had the second highest influence, with a score of 10.3960. For row C, c21 (Biases/distrust of technology use) was also the most influenced by the remaining criteria at 10.8022, and c25 was the second most influenced at 10.6128.

All the scores presented in matrix T were averaged to arrive at the threshold value of 1.944, which was essential for developing the impact-relation map (IRM) as it strained out inconsequential influences and determined the degree of importance of a given criterion [65]. Using this threshold value, the cells in Table 5 which scored higher than 1.944 and are considered more important in this analysis of the DEMATEL results. Contrarily, the cells which scored lower than the threshold value are thus not considered very important in this analysis.

Table 6 expands Table 5 by adding R and C to produce an absolute value that shows the degree of influence of a particular criterion on the remaining criteria and by subtracting C from R to produce an absolute value that shows whether a given criterion has a higher influence on the remaining criteria. As a result of these values in Table 6, the interrelationship complexities of the criteria are visualized in the IRM in Fig. 1. From the criteria distribution and the cause-and-effect mapping, is apparent that c22 (Infrastructural issues) and c23 (Lack of knowledge) are causes of the other criteria because they are above the R–C y axis. On the other hand, c21 (Biases/distrust of digital technology, c24 (Limited digital skills), and c25 (No interest or awareness of services) are effects/consequences in this cluster because of their placement below the R–C y axis. Criterion c21 (Biases/distrust of digital technology use) is the most important criterion in this cluster by scoring on the far-right side of the R + C axis, while c22 is the least important due its position on the far-left side of the R + C x axis.

Table 7 presents an interoperability analysis of the criteria for Cluster (C) 2 (Barriers and Limitations) for the Estonian case. This cluster is analyzed because the provision of interoperable e-service solutions is a primary focus of the Estonian case study.

On c21, in the Estonian case study, the panelists reached the consensus that the older people are biased towards technology and do not trust it, which inhibits their potential cross-border e-service usage. A plethora of literature has been devoted to generally understanding older persons' distrust of technology [66]. Yet not all older people are alike; in fact, they have many heterogenous characteristics. However, the distrust narrative has general applicability in Estonia and Finland.



c21	Biases/distrust toward digital technology use
c22	Infrastructural issues (high-speed broadband access not available everywhere)
c23	Lack of knowledge
c24	Limited digital skills (for end-users, service providers and other crucial stakeholders)
c25	No interest, no awareness of services

Fig. 1. Impact-relation map (IRM) for cluster 2.

Statistically, there is a significant age gap in internet use between older people and other population segments in Estonia. While 99.5% of those between the ages of 16 and 24 use the internet, only 59.9% of 65- to 74-year-olds do [67]. In relation to interoperability, the goal of organizations is to hide backend complexities while creating a trust environment for cross-border e-service usage and data exchange. Technologically, this can be accomplished through ‘privacy by design’ interoperability principles, where data minimization techniques and the processing of data is proportional to the specific service provided are ways to garner trust from older adult users [12].

On c22, the lack of high-speed broadband facilities and service that will allow older people to access cross-border e-services is a major hindrance to their potential uptake of such e-services. It should be noted that Estonia ranks very high on internet accessibility and digital infrastructure. As of 2020, fixed broadband penetration in Estonia was at 83%, with no obstacles to internet access [67]. However, there is a significant gap in internet use between older people and other population segments, and broadband accessibility is one variable recognized by the panel as influencing this gap. Digital infrastructure is a core issue that affects cross-border e-service provision. From an EIF perspective, interoperability is hindered by the lack of technological infrastructure devoted to providing older people high-speed internet access, as well as its affordability, which obstructs the accessibility and inclusivity of cross-border e-services [12]. For instance, in Estonia the price of state-sponsored, rural high-speed broadband internet for older persons is currently very expensive, where high user access and installation fees have prevented a larger number of new high-speed internet subscriptions [68]. High-speed internet provision is unaffordable for older rural-located citizens in Finland as well. As this criterion was considered a cause of the remaining criteria, policymakers should prioritize its resolution to pave the way for the implementation of cross-border e-services.

On c23, the experts agreed that organizations lack specific knowledge about older people in terms of their needs, which kinds of e-services should be provided to them, and what kind of data types and associated reference architectures are needed to provide such cross-border e-services. Without this information, cross-border e-services for older people would be difficult to design and implement. This would derail the availability of potential cross-border e-services and inherently impacts the organizational layer of interoperability [12]. Organizations need to create knowledge flows for understanding the problems of older people in order to implement interoperable cross-border e-service solutions. One aspect is both countries’ public sector organizations and private sector companies need to establish a standardized data glossary and reference architecture in the e-service domains described in Section 5.2. As the X-Road provides cross-border federative data exchange opportunities, Finnish and Estonian private and public sector organizations have a technical ecosystem to securely exchange data interoperably. Yet, data availability, quality, security and integration components must be agreed upon through contracts or specific Service Level Agreements (SLAs).

On c24, the limited digital skills of older people are recognized as an inhibitor of cross-border e-service uptake. Without adequate digital literacy, older people would have difficulty accessing e-services because they would find it more difficult to use interface functionalities (even if their interface has good usability features); and without contextual knowledge of technology or e-service objectives, user trust will also be diminished. Fifty percent of older people do not use or do not know how to use any digital system at all. Literature has shown that this barrier and limitation is part of the digital divide, where motivations and digital skills directly impact internet participation [69]. To maximize the value of cross-border e-services implementation, the digital skills of older people in both Estonia and Finland have to be improved.

On c25, the experts noted that a key impediment to cross-border e-service provision is the lack of interest of organizations in creating such services. Organizations need incentive mechanisms for creating cross-border e-services because in Finland, there are insufficient funding streams from the public sector.

5.2. *Stakeholders and cross-border e-services*

In this section, we present our identified e-service areas and stakeholders involved as well as prospective Estonian-Finnish cross-border e-services based on our DEMATEL analysis of two clusters: Actors involved and Broad areas of possible intervention. First, to set the stage for identifying the types of cross-border e-services, an analysis of which stakeholders need to be involved was conducted using the same DEMATEL technique and calculations.

Table 8 presents the five stakeholder criteria agreed upon by the experts for C3 (Actors involved). Criterion c31 concerns helpers of older people, social workers, and relatives who are contact persons of older people; c32, customers and end-users, whom the panelists noted might not always be the same; c33, national and local public-sector entities, including sub-institutions; c34, providers of different services for older people in the private sector; and c35, community service providers, interest and support groups, volunteer organizations, and the like.

The same procedure used in Section 5.1 was used to generate matrix T in Table 9. Criterion c35 (third sector) had the highest R score of 13.2335, meaning it was the most influenced by the other criteria. Column C shows that c32 influenced the other criteria the most, with a score of 12.9150. To ameliorate inconsequential effects, a threshold value of 2.4878 was calculated for the criteria interaction scores matrix. Table 10 presents the R + C and R–C columns, from which values an IRM was produced (see Fig. 2). Fig. 2 shows that c31 (Contact persons of older people) and c35 (Third sector) are causes in this cluster. Criterion c32 (Customers and end-users), c33 (Public sector), and c34 (Service providers) are the effects in this cluster. Based on the R + C and R–C values, c35 (Third sector) is deemed the most important in this cluster, and c33, the least important.

From the analysis results, it is clear that contact persons of older people play an integral role in cross-border e-service provision. From an e-service perspective, they facilitate the emergence of potential e-service end-users among older people and can also be considered potential customers. Interestingly, the results analysis showed that the panelists regarded the public sector as playing an insignificant role as a cross-border e-service stakeholder. However, the public sector is instrumental in providing different types of social services and should not be regarded as inconsequential to cross-border e-service provision.

To understand the intervention areas in which cross-border e-services would be useful, the panel experts organized C5 (Broad Areas of Intervention) into seven subcluster areas (see Table 11). For each subcluster area, five of the highest-priority services were identified, for a total of 35 services. To apply our cross-border perspective, we analyzed each of these services and identified the four services with cross-border e-service viability in Table 12.

S1 concerns general access to cross-border e-service providers in the A1 subcluster (Social Welfare and Healthcare, Medicine and Caregiving). The actors involved in implementing such cross-border e-services are c33 (Public sector), c34 (Service providers), and c35 (Third sectors), all of whom can be considered potential e-service providers based on each actor's organizational objectives. An important aspect of S1 is the provision of a single service point to c31 (Contact persons of

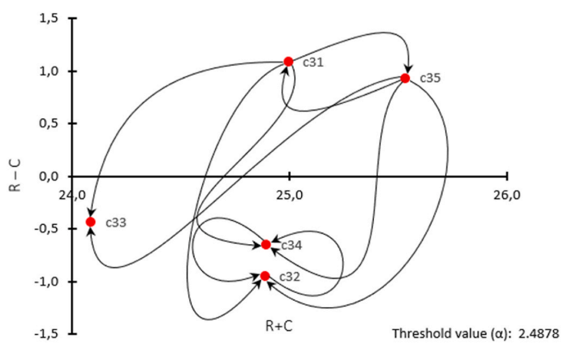


Fig. 2. IRM for cluster 3.

older people) and c32 (Customers and end-users) for accessing potential cross-border e-services. A one-stop-shop concept with Estonian and Finnish language capability would centralize service provision in this subcluster. For example, different Finnish caregivers in the private sector could provide their services through this platform, which would create a secure e-service channel for booking, by Estonian contact persons of older people, of different caregiving services in Finland, even if the person booking the services resides in Estonia. The mutual recognition of Estonian and Finnish electronic identification cards (eIDs) would also create a secure environment for a centralized cross-border e-service hub.

Due to the large migration flows between Estonia and Finland, A5 (Mobility and Transportation) was identified as an intervention area. The S2 cross-border e-service concept provides older people an easy-to-use e-service to help them to get where they need to go through a 'simple order' in Estonia or Finland. For instance, for older people who want to go to Finland by ferry and then to the mainland, the e-service would coordinate all their travel needs, thereby lowering their potential pains in ordering different mobility services. The actors involved in this cross-border service could be c34 (Service providers) who specialize in transportation and mobility services.

S3 and S4 focus on the A7 (Educational) intervention area for improving the digital skills of older people and promoting their lifelong learning. The actors involved are c33 (Public sector), c34 (Service providers), and c35 (Third sector). In this context, educational institutions, such as the Open University at the Tallinn University of Technology, would provide online educational resources and training for older people who reside in either Estonia or Finland. Existing cross-border recognition of Estonian and Finnish eIDs would enable secure verification of identity and can be connected to a cross-border database, storing digitally signed course or degree completion certificates. X-Road could be potentially leveraged in this area, as it already provides the interoperability architecture needed to implement cross-border data exchange and authentication of identity. Although the above services have been described from a general perspective, they leave room for further development.

According to the EC, the highest maturity level of e-service provision is "Personalized Government," where electronic proactive communication is utilized to meet the needs of citizens without requiring an individual to initiate interaction with the public sector [70]. In this sense, services are made "invisible," which is the most efficient and cost-effective means of delivering services due to its low usability and accessibility barriers for citizens. Proactive e-services are triggered by life events, such as marriage, unemployment, divorce, and even death. Technologically, these types of e-services rely on event-driven architecture through a microservices framework and automation of data exchange. This is premised on the different public administrations already having the necessary data from citizens to proactively respond to their life events when those occur.

The Estonian Information Society Development Plan 2020 has outlined developmental steps for designing and implementing proactive e-services, and the implementation of the plan is currently in the early stages of requirements analysis and procurement [71]. For SLEs, proactive e-services are optimal for older people, as they put the impetus of service e-delivery on the public sector instead of citizens having to expend time and energy searching and applying for different types of services and benefits.

5.3. Recommendations

We used the outcomes of our analysis of the DEMATEL results for C1 and C4 as the bases of our recommendations. Table 13 summarizes the five criteria identified by the panel experts using the same procedures and calculations as before. They explain the motives and benefits of organizations for creating and implementing cross-border e-services. The total influence scores were then calculated, producing R and C outcomes for Matrix T in Table 14. The results showed that c11 (Access to information) influenced the other criteria the most at 5.6747, while c13 (Keeping elderly minds active) was the most influenced by the remaining criteria. From the criteria interaction scores in Table 15, an IRM was produced in Fig. 3 for C1 (Motives and Benefits).

Fig. 3 indicates that c11 (Access to information), criterion c12 (Encourage cooperation between service users, providers and developers) and c15 (Provide flexible working conditions) are causes in this cluster. Criterion c13 (Keeping elderly minds active) and criterion c14 (Promote lifelong learning) are the effects/consequences of the above causes. Criterion c14 (Promoting lifelong learning) is the most important factor in the results analysis, and criterion c12 (Encouraging cooperation between service users, providers and developers) is the least important.

The five decision criteria identified by the panelists for C4 (Knowledge-based Resources, Skills, and Competencies) are presented in Table 16. Similar to the DEMATEL results analysis, the matrix T calculations were performed and produced the data in Table 17, which show that c43 (Knowledge of user centers for service design) had the highest influence on the other criteria at 9.5305, and c41 was influenced the most by the remaining criteria by 9.6120. Using the criteria interaction scores in Table 18, Fig. 4 shows that c42 (Integration of various standalone systems between governments and citizens), c43 (Knowledge of user centers for service design), and c44 [Market knowledge (What customers actually need)] are causes of the Knowledge-based Resources, Skills, and Competencies of organizations. Criterion c41 (Customer/end-user skills and awareness) and c45 (Product owner) are effects/consequences in this cluster. The most important factor in this cluster is c43 (Knowledge of user centers for service design), and the least important is c45 (Product owner).

Our recommendations are based on our analyses of the decision criteria in the following clusters that were identified in both the Estonian and Finnish cases: C1 and C2 (Motives and Benefits) in Table 13, and C4 (Knowledge-based Resources, Skills, and Competences) and C5 (General Skills, Capabilities, and Competences) in Table 16.

The following recommendations are specific to the interrelated criteria c31/c32/c43/c44. Based on c31, access to information (using ICT tools) is a primary motivator of organizations in building cross-border e-services. Enabling this access requires not only a strong understanding of what information is valuable to the Estonian-Finnish older population segments but also interpreting the (c43) market knowledge (what customers actually need) and (c44) obtaining knowledge from user centers for service design. As mentioned in Section 5.2, the customer/end-user population segments are not always the same. Sometimes, the end-users of a cross-border e-service are not older people but their contact persons. Furthermore, older people are not a homogenous population; they have heterogeneous characteristics that distinguish them based on age group. For instance, the needs of people aged between 50 and 60 are different from those of people aged between 70 and 80.

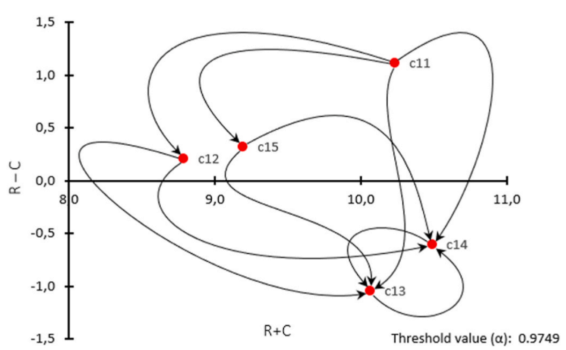


Fig. 3. IRM for cluster 1.

Table 17
Matrix T calculations.

	c41	c42	c43	c44	c45	R
c41	1.7036	1.7688	1.7443	1.6816	1.6230	8.5212
c42	2.0197	1.7148	1.8875	1.7555	1.7228	9.1003
c43	2.1056	2.0137	1.7585	1.8479	1.8048	9.5305
c44	2.0177	1.9229	1.8963	1.5903	1.7101	9.1373
c45	1.7654	1.6350	1.5767	1.4772	1.3255	7.7798
C	9.6120	9.0552	8.8633	8.3525	8.1862	

Table 18
Criteria interaction scores.

	R	C	R + C	R–C
c41	8.5212	9.6120	18.1332	−1.0907
c42	9.1003	9.0552	18.1554	0.0451
c43	9.5305	8.8633	18.3939	0.6672
c44	9.1373	8.3525	17.4898	0.7848
c45	7.7798	8.1862	15.9660	−0.4063

To capture valuable information including on the needs of older people, we recommend that Estonian and Finnish cross-border e-service actors conduct workshops related to each intervention area described in Table 11. These workshops should include older people of different age ranges to capture the heterogeneous needs for each age range. The contact persons of older people should also be included. This recommendation also pertains to c32 (Encourage cooperation between service users, service providers, and service developers), as it would bring all stakeholders together in one place either physically or virtually. Selecting QH stakeholders (the public and private sectors, academia, and older people and their contact persons) to participate in the workshop would bring a rigorous participant dynamic for understanding cross-border needs in different contexts.

The workshop objectives should identify what information has value and should map out the needs of older people for the development of software requirements using different elicitation techniques. With such requirements as a foundation, interfaces should be made as easy to use as possible for accessing identified valuable information. This requires user testing with older people and understanding design principles geared towards this population segment. For instance, the use of flashing lights and pop-up windows is often distracting, and service processes that are complex and require many steps dissuade older people from using such e-services. The integration of support tools such as user-friendly chatbots to guide customers/users throughout a service process should also be considered.

Through these workshop sessions, a list of functional and non-functional requirements can be constructed for building interoperable cross-border e-services, where different types of data are identified as having utility, referenced, and standardized in a cross-border data glossary between relevant organizations responsible for the welfare of older people. Using the Estonian-Finnish federated X-Road instance that already enables the exchange of cross-border e-prescription data, business registry information and population registry data, there can be established as well technical, semantic, organizational and legal interoperability through organizational contracts, and SLAs. This provides a robust cross-border data exchange environment for the implementation of cross-border e-services described in Section 5.2.

The interrelated c33 (Keeping older minds active), c34 (Promoting lifelong learning), and c35 (Providing flexible working conditions) are the motives of public and private service providers for building e-services not only for older Estonians, but at a cross-border level as well. We recommend that organizations prioritize allocating resources for pursuing these motives.

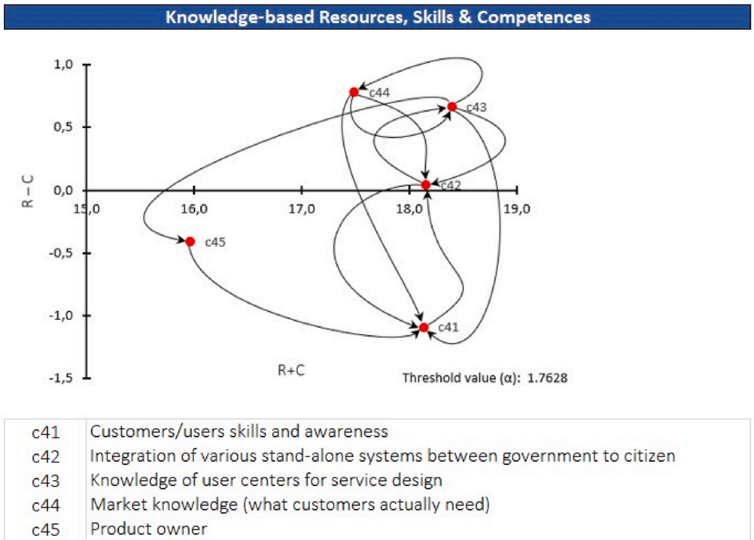


Fig. 4. IRM for cluster 4.

For c41, understanding customer/user skills in using e-services and customer/user awareness of different types of e-services was recognized by the panelists as instrumental in the adoption of potential cross-border services. To build such awareness, we recommend the use of traditional advertising channels such as local newspapers, television, and direct mail, which are most suitable for the older population in Estonia and Finland. A further recommendation is to provide digital skills training for older persons in Estonia and Finland and for their family members and contact persons, who can act as a medium for imparting and demonstrating different digital skills. Service providers could also take part in these training sessions to provide them with a resource to gauge the digital skills of their potential target users.

For c42, the integration of various stand-alone cross-border systems between governments for citizens will facilitate secure and interoperable cross-border public e-services. As Estonia and Finland are already exchanging data interoperably between population registers through the X-Road, the foundations are already in place for expanding cross-border e-services to other domains. In addition to the X-Road, both countries have their own citizen portals (eesti.ee and suomi. fi) that could be leveraged as one-stop shops for older people to access cross-border e-services. A successful cross-border example that is already being implemented between Estonia and Finland is the recognition of cross-border e-prescriptions. This could potentially be emulated in other intervention areas. We recommend greater Estonian-Finnish collaboration between public-sector authorities, which have social responsibilities to serve older people, for promoting and creating awareness of cross-border public e-services.

For c45, although product ownership was viewed as the least important factor in Fig. 4, it is essential for e-service provision, as product owners have the primary role of communicating with developer teams in agile software development. Additionally, every cross-border service must have an owner who is responsible for implementation and maintenance. It is recommended that information flows between product owners and customer/end-user segments be built by including them in the previously described workshops.

6. Conclusion

This article reports on the results of multiple case study conducted in two countries, Estonia, and Finland that focused on e-services and age-friendly SLEs, respectively. By adopting a constructivist, sociotechnical approach and combining well-established methodological techniques (i.e., cognitive mapping and DEMATEL), the following main results were obtained: first, a multicriteria analysis framework, which provides decision support to multiple stakeholders for better understanding of the context factors relevant to the development and provision of interoperable cross-border e-services between Estonia and Finland; and second, recommendations for determining suitable intervention strategies. The developed multicriteria analysis framework holistically incorporates two cognitive maps, with a wide range of contextual factors (i.e., clusters and criteria) and cause-and-effect relationships between them, and thus, can also support decision-makers in selecting and implementing the most appropriate intervention strategies.

This study expanded the existing scarce body of literature and empirical studies dealing with cross-border e-services specifically focused on older persons. First, factors inhibiting the provision of cross-border e-services between Estonia and Finland have been identified as the lack of knowledge of organizations about the older persons user group; the distrust and bias of older persons towards the use of cross-border e-services; and the lack of broadband infrastructure, or the ability to connect to the internet efficiently. Second, four types of cross-border e-service concepts between Estonia and Finland were identified as basis for future development. Finally, recommendations for establishing interoperable cross-border e-services and building age-friendly SLEs in Estonia and Finland were given, such as bringing together service developers and providers as well as older persons and their contact persons in a workshop to draw forth the technical requirements for cross-border e-services. As the necessary data exchange infrastructure is already in place through the X-Road interoperability ecosystem, we recommend the further collaboration of public authorities in Estonia and Finland.

The DEMATEL technique combined with cognitive mapping was particularly useful in analyzing and structuring the highly complex decision problems related to our research questions. Cognitive mapping implied transparent and collaborative decision-making, which demonstrated great potential for developing a holistic view of the multi-stakeholder and multisectoral research context. The main reason for the choice of the mapping technique in this study was the added value of eliciting and structuring decision criteria from various perspectives using the experience and knowledge of experts, which allowed the integrated results to enhance recommendations [72]. DEMATEL, in turn, effectively facilitated analyses and modeling of the cause-and-effect relationships between the decision criteria, which fostered better-informed decision-making in this study.

However, the application of this combined methodology also had the following limitations. First, the decision-making process that was followed was non-linear and intrinsically subjective in nature. Therefore, the results are context-dependent, which means the idiosyncratic features of the proposed multicriteria analysis framework may not be generalizable to different contexts and diverse stakeholder needs, and expertise may be needed to customize the framework's hierarchical structure and content. Although during the expert panel meetings, the decision-making process was very collaborative and thoroughly interactive in terms of knowledge and experience sharing, the created framework should not be seen as final. From a constructivist perspective, the process allows for an interactive exploration of potential changes in the framework and offers opportunities for further discussions [14].

Indeed, these limitations open avenues for further investigation. Subsequently, to reinforce the results of this study on the subject under analysis, similar analyses could be conducted in future studies, adopting principles of other MCDA techniques. Another suggestion is to repeat the procedures implemented in this study with different expert panels in the field or with experts from different countries to arrive at more robust conclusions and hence, achieve greater confidence in our recommendations for effective intervention strategies. Future research could also seek to understand the sociotechnical requirements for proactively engineering different types of cross-border e-services for older people in Estonia and Finland.

Credit author statement

Marina Weck: Conceptualization, Methodology, Investigation, Results Analysis, Writing. Eric Jackson: Conceptualization, Results Analysis, Investigation, Writing, **Markus Sihvonen**: Results Analysis, Writing, Editing, **Ingrid Pappel**: Results Analysis, Editing.

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Appendix 3

[III]

E. B. Jackson, R. Dreyling, and I. Pappel, “Challenges and implications of the who’s digital cross-border covid-19 vaccine passport recognition pilot,” in *2021 Eighth International Conference on eDemocracy & eGovernment (ICEDEG)*. IEEE, 2021, pp. 88–94

Challenges and Implications of the WHO's Digital Cross-Border COVID-19 Vaccine Passport Recognition Pilot

Eric B. Jackson
Dept. of Software Sciences
TalTech University
Tallinn, Estonia
eric.jackson@taltech.ee

Richard Dreyling
Dept. of Software Sciences
TalTech University
Tallinn, Estonia
richard.iii@taltech.ee

Ingrid Pappel
Dept. of Software Sciences
TalTech University
Tallinn, Estonia
ingrid.pappel@taltech.ee

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***Abstract*—As the development and distribution of COVID-19 vaccinations continues, the concept of a digital Yellow Card or smart vaccine passport has been discussed. Verifying an individual's COVID-19 vaccination would improve cross-border mobility and limit the potential spread of the virus. Recently, the WHO signed a Memorandum of Understanding with the Government of Estonia for providing expertise and technical solutions like the interoperable cross-border data exchange ecosystem, X-Road, for piloting a smart vaccine passport trust architecture. Subsequently, the WHO is in the beginning stages of undergoing a process of digital transformation to accommodate the pilot (DT). In this paper, the authors present an exploratory case study using qualitative workshop methods and data triangulation to investigate the technical, political and organizational DT processes occurring in the pilot project. The results suggest the proposed cross-border data exchange trust architecture would exchange non-sensitive personal health information. Some WHO countries are willing to participate and engage in the pilot, but political and legal barriers remain for large-scale implementation. Ultimately, the potential establishment of a trusted global architecture health framework, where not only COVID-19 vaccine data can be exchanged, but new cross-border health services can be created, warrants further investigation.**

***Index Terms*—digital transformation, interoperability, data exchange, cross-border, COVID-19 vaccine**

I. Introduction

More than a year on from the onset of the COVID-19 global pandemic, the world continues to grapple with its negative impact on cross-border mobility. Despite the presence of logistical hurdles, the recent creation and distribution of the AstraZeneca/Oxford, Pfizer and other COVID-19 vaccines bring positive developments to the situation. Vaccination is an important strategy for mitigating transmission and facilitating the reintroduction of mass global travel. It is also common practice for people to be vaccinated for specific diseases when traveling to certain nations. For instance, many countries require a Yellow Fever vaccination before entering [1]. A global document for proving an individual has been vaccinated for viruses like Yellow Fever is the International Certificate of Vaccination or Prophylaxis (ICVP), commonly referred to as a Yellow Card (YC) [2].

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As a public health multilateral, the World Health Organization (WHO) is responsible for managing the "...central repository of all required disease surveillance information" [3]. Member-states of the WHO abide by the 2005 International Health Regulations (IHR) treaty, which provides global governance and standardization for the YC (who link). Recognition of a digital YC (e-YC) would require a secure, interoperable architecture for verifying the validity of the eYC. Under this framework, the WHO is in the beginning phases of creating a COVID-19 Smart Vaccine Passport pilot for WHO member-states, digitally confirming individuals have received an approved COVID-19 vaccine via a digital certificate, which is then connected to the e-YC. For the purposes of this paper, the term Smart Vaccine Passport and e-YC are used interchangeably.

The nation of Estonia and the WHO signed a Memorandum of Understanding that outlines Estonia as a project leader due to its expertise in digital transformation [4]. Estonia's e-governance ecosystem is widely considered to be on the forefront of innovation and development locally [5] and internationally [6]. The primary reasons behind this reputation are a robust electronic identification (eID) regime and the high organizational adoption of X-Road [7]. Using an ecosystem of security servers, trusted certificate authorities and contractual agreements, X-Road securely delivers data payload over the public internet. Since 2002, the X-Road has enabled secure, interoperable data exchange between over 1,000 Estonian public and private sector entities [8]. In addition to internal use, X-Road is the data exchange layer between certain Estonian and Finnish governmental entities [8].

The non-profit organization, Nordic Institute for Interoperable Solutions (NIIS) administers, implements and maintains the X-Road, which is considered a public good and published under an MIT open source license [9]. At the highest organizational level, the Ministry of Finance in Finland and the Ministry of Economic Affairs and Communication in Estonia are governmental body members of NIIS. In addition to Estonia and Finland, variations of X-Road have been implemented in Germany, Iceland, Faroe Island and Japan among other countries [10]. NIIS is uniquely positioned to provide expertise in cross-border data exchange necessary for recognizing vaccine certificate data, as it has a reputable track record facilitating trust architecture across multiple borders.

In order for such a schema to work in practice between the 194 WHO member-states, interoperable, cross-border data exchange infrastructure must be implemented on a technical, organizational and legislative level. This inherently brings a host of different questions worth investigating from the field of digital transformation (DT). DT as a research paradigm seeks to explain "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [11]. To make better sense of the early phases of this pilot project, the authors apply the DT paradigm of [11] to the case. Thus, this research uses an exploratory single case study approach for investigating the following research question:

How is the current technical, organizational and political environment shaping the digital transformation of the WHO's vaccine certificate recognition program?

In order to explore this meta research question, we conducted two primary stakeholder knowledge-sharing workshops with the National Digital Advisor from Estonia and the Chief Technical Officer of the X-Road, collected internal documentation from the WHO, and cross-referenced this data with external articles. First we present the pilot's technical architecture through two different models: one detailing data exchange and the other a simplified network architecture overview. Secondly, we present [11]'s DT framework to understand the DT processes the WHO as an organization is undergoing for the pilot. Lastly, the political and legal barriers are identified and explained.

The paper is structured as follows: Section II contains a theoretical overview of DT, Section III describes the exploratory case-study methods deployed, Section IV provides results of the workshops and associated data, Section V provides a synthesis of the results through discussion and presenting future work and Section VI concludes the paper.

II. Theoretical Overview

The primary theoretical underpinning of this research is DT. In Information Science, DT holds an important role in providing a framework for understanding the impact Information Communication Technologies (ICTs) have on society, culture, and different economic sectors [12]. DT can also apply organizationally, where market dynamics or public policies necessitate a company, multilateral, government entity, etc., to undergo transformation of analogue processes into digital ones, in order to compete or improve existing services to be more efficient and effective [11]. Although DT focuses primarily on organizations and their strategy for implementing novel digitization, it's application can be analyzed at an individual level as well. IT literacy and the digital skills of workers, managers, bureaucrats, CEOs and Presidents correspond with DT as a phenomena and should be adequately accounted for in analysis [13].

A. Vial DT Framework

Vial [11] comprehensively analyzed 282 DT scientific papers and constructed an inductive DT process model that summarizes existing DT literature through eight categories connected into different phases. Although VIAL notes their inductive DT process model does not "represent statistical relationship or a causality found in variance models" it does provide a rigorous, holistic framework directly applicable for sense-making of the WHO's vaccine passport digitization program.

[11]'s first category describes the essence of different digital technologies; mobile, Platforms as a Service, Internet of Things, e-identification, and many more. The use of these digital technologies "fuel" the second category: disruptions. ICTs have the ability to profoundly disrupt the way consumers and citizens behave, as it has driven an expectation of service and citizen empowerment by service providers in the public and private sector. Disruption also captures new digital infrastructures like blockchain and microservices that can shift digital architectures from monolithic to decentralized. A third component to disruption is the availability of data. The more data available, the greater likelihood technological disruption can occur.

These components of disruption necessitate some form of organizational action classified as either a "digital business strategy" (DBS) or "digital transformation strategy" (DTS). Inherently, DBS or DTS responses to disruption are powered by the use of digital technologies, which enables the next phase: "changes in value creation paths". DT has four types of effects in this stage: "value propositions, value networks, digital channels, and agility and ambidexterity". Value propositions relate to the transition of organizations providing traditional products with services. In the WHO case, the analogous product is the physical YC document and the service to be transitioned to is a global, interoperable infrastructure that enables immediate digital verification of COVID-19 vaccination, which allows the resumption of transnational mobility.

Value networks describe DT as a way to connect multiple stakeholders together to create greater value through collaboration. The stakeholders in this case are the 194 countries who form the WHO's governing body (network), and through collaboration can provide an interoperable way to identify those who have taken the COVID-19 vaccine. DT in relation to digital channels represents the direct impact digitization has on an organization's distribution and sales. Lastly, agility and ambidexterity describe an organization's ability to quickly adopt and adapt novel digital innovation into their processes and structure.

Next, there are two input stages that simultaneously affect the "changes in value creation paths". The first input, "structural changes", encompasses organizational structure, culture, leadership and individual digital skill sets. The second input is "organizational barriers", which can be summarized by organizational "inertia and resistance". Humans tend to resist change, especially change that may disrupt an individual's job or create friction transitioning to new processes and ICT systems [14].

Changes in value creation paths generate two byproducts: negative and positive impact. There are not only internal ramifications when an organization undergoes DT or transitions to new processes enabled by innovative ICTs, but there are societal consequences as well. The WHO's vaccine passport clearly demonstrates this. If fully adopted, the transformation would have global impact on the resumption of travel to pre-COVID levels. There are also immense ethical implications as there has been inequitable distribution of vaccines amongst nation-states.

In the public sector, there are different incentive mechanisms dictating DT compared to the private sector. Corporations and firms are motivated to undergo DT by outcompeting private competitors in innovation [15], As no such competition exists in the public sector, DT can be viewed as a way to improve governance for the well-being of citizens and the economy [16]. Political will is an important factor to DT in the public sector. The agendas and policies brought forth by political vision shape the very nature of bureaucratic organizations and how they implement current and future processes [17]. Based upon the literature, it is evident DT is an evolutionary process with many inputs and outputs along the way leading to a positive or negative outcome. In the results section, the authors apply [11]'s evolutionary DT framework as a guide for investigating the Smart Vaccine Passport phenomena in the results section of this paper.

III. Methodology

This paper is rooted in qualitative research principles. The authors implemented exploratory case study methodology through analyzing internal stakeholder data and conducting in-depth knowledge sharing workshops, along with external articles. Qualitative research has traditionally been viewed as less methodologically rigorous than quantitative methods, where assertions of hypotheses are backed by creatively constructed evidence [18]. However, qualitative methods can rigorously provide rich and fresh insights for capturing the human element of research questions and paradigms. It operates under the accurate assumption that individuals who construct organizations are "knowledge agents", meaning they inherently understand "what they are trying to do and can explain their thoughts, intentions, and action" [19]. The in-depth stakeholder workshops were conducted with this assumption in mind.

Encapsulated in qualitative methods is exploratory case study research design. Exploratory research enables the observation of phenomena that is of interest to a researcher and provides a foundation for future investigative inquiries into the subject at hand [19]. Case studies contain a wealth of insight to researchers by going beyond the quantitative and experimental, capturing human complexity and by triangulating multiple points of data researchers are able to explore specific, real-life phenomena by applying case study research methodology [20]. For the purpose of this paper, the contemporary phenomena investigated is DT and cross-border interoperability within the context of the WHO's digital COVID-19 smart vaccine passport recognition program.

Case studies are defined by the use of multiple sources of data for analysis. In our case, the data analyzed consists of two intensive semi-structured workshop transcripts: one with a senior project stakeholder from Estonia and the other with a senior technical stakeholder from NIIS. The authors were also provided access to internal, non-sensitive memoranda and other relevant organizational documentation. Additionally, external articles were used for cross-referencing. In synthesizing the captured data, a sense-making approach can be applied to the case of YC digitization and cross-border recognition of digital vaccine certificates. This is an important topic to understand as it represents a potential global response to the detrimental effects of COVID-19.

IV. Results

During both workshops, the technical implementation of the proposed program was presented verbally and transcribed to form a basic understanding. Based on these discussions, Figure 1 provides a simplified architectural overview of the proposed smart vaccine passport pilot. As the premise of the pilot is to ensure international travel, an entry official will check the traveler's e-YC through the global trust architecture. A firewall or security server is configured in order to handle authentication and cyber security risks. The entry official uses a client-side application to access the WHO's database of national health authorities from member-state pilot partners. The WHO data directs the official to the overall trusted health authority in each pilot member country. Subsequently, that national health trust authority has a database of trusted vaccine (certificate)providers. It is from this trusted list that the COVID-19 vaccine verification takes place. Additionally,

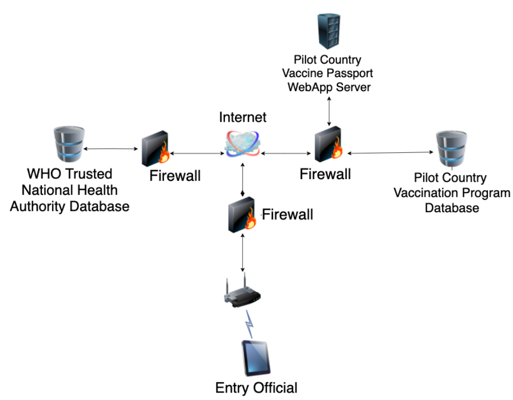

Fig. 1. Simplified Architectural Overview

the WHO can point the official to a trusted proprietary web app service for the verification procedure, in place of a national health authority database.

Overall, what was conveyed in the workshops was the architecture is meant to be as lightweight as possible to reduce the technological and organizational burden on not only the WHO, but pilot entities. With many countries establishing their own vaccine certificates, the interoperability in question is about how to verify digital COVID-19 vaccine certificates are from an approved source from the country of origin. Having access to this data in a secure and seamless way is an important objective of the WHO's DTS. Through utilizing a small amount of non-sensitive data points to be exchanged across borders, the pilot project's technical infrastructure is streamlined for simplicity from a technical perspective.

Figure 2 shows how the cross-border data packet exchange would be structured between the travel entry official, the WHO and the home country responsible for registering trusted vaccination providers. When a traveler presents their smart vaccine passport or e-YC to the border official or airline representative, he or she will scan an interoperable QR code presented on the traveler's mobile application. Once scanned, the trust architecture will first check the WHO's database registry list of trusted national health authorities. After the official verifies who the traveler's national health authority is, the process flow proceeds to interface with that national health authorities own database of valid vaccine providers. After checking if the traveler's vaccine certificate is from a trusted source in the country of origin, the official can grant the traveler entry. Figure 3 shows a similar configuration, but instead of accessing a national database registry list of valid vaccine providers, the border official or airline representative accesses a trusted and verified private sector web application.

In its current conception, the smart vaccine passport program operates under a global trust framework established by NIIS. In the future, the goal is for the WHO to serve as a trust anchor in this ecosystem with NIIS providing the technical underpinnings for exchanging cross-border data securely. The NIIS X-Road ecosystem provides an already tested trust framework between its members. As the current

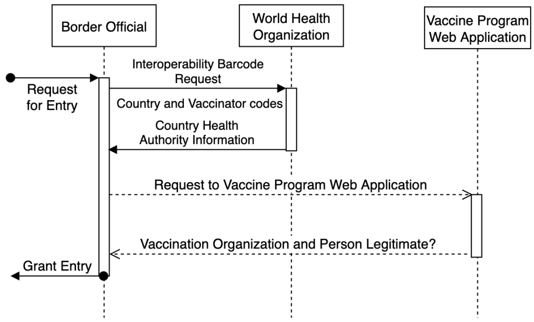

Fig. 3. Packet Exchange Between Travel Official, the WHO and Private WebApp

pilot participants are at a low number, scalability is not an issue at this time. However, In order to scale to hundreds or even thousands of different national information systems, this X-Road instantation would be modified and potentially scaled through microservice architecture and dumb message brokering rooms, termed X-Rooms[21].

A. *Applying Vial DT Framework*

Based upon the workshop proceedings, internal memorandum and external articles, Figure 4 is a modification of [11]'s DT process model to capture the WHO case study context. In Stage 1, there are multiple technologies fueling COVID-19 vaccine data availability, which the authors classify as a novel digital disruption. For example, the use of standardized, proprietary digital vaccine certificates like VaccineGuard [22] and public sector schemas are planned for digitally authenticating COVID-19 vaccination providers and individuals. The certificates can then be embedded into an e-YC proof of concept or exist as a separate passport entity until e-YC integration can occur. Accordingly, the availability of global vaccination data from certified healthcare providers in Stage 2 has triggered the DTS of implementing global trust architecture, which aims to include every member-state of the

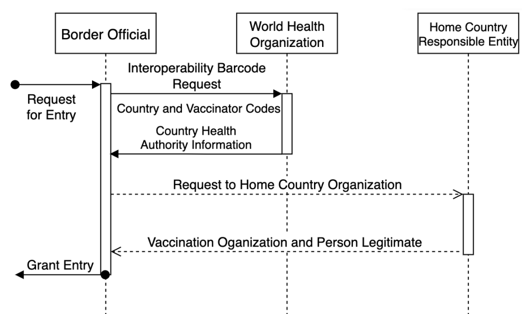

Fig. 2. Packet Exchange Between Travel Official, the WHO and Home Country of Origin

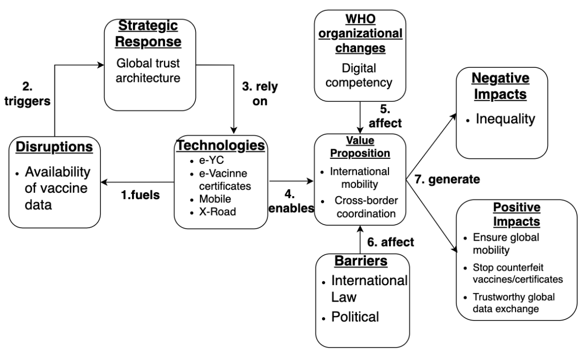

Fig. 4. Vial's DT Framework Applied to the WHO Case

WHO, but in its current conception is scaled to a few nations for a proof-of-concept pilot. The WHO's DTS relies on the trust architecture of the NIIS X-Road, which already has a mature interoperable data exchange ecosystem in-place. From a citizen point of view, the e-YC can be instantiated as a e-identification card or mobile phone application with the smart vaccine certificate embedded as a QR code.

Technologically, it is the combination of the X-Road's interoperable trust framework, smart vaccine certificates and the e-YC that is the basis for the primary value proposition of the DT: international mobility and cross-border coordination. Stage 5 describes specific organizational change inputs that affect the value proposition. Structurally, the WHO as an organization will undergo transformation related to its digital competency. The ability of the WHO to act as a trust anchor containing linked database information will require not only top-level organizational evolution, but the digital upskilling of individual WHO employees who partake in the pilot. The barriers outlined in Stage 6 are primarily related to the political dynamics of the WHO as a multilateral institution that lacks enforcement capability, along with the challenges of amending international law and agreeing to a standardized data language. More on these political and legal issues will be expressed in the following sub-section.

Stage 7 outlines the generated positive and negative impacts from the value proposition. There are multiple potential positive impacts of the proposed pilot initiative. The uptake of a globally recognized COVID-19 smart vaccine passport that uses a standardized framework will not only increase transnational mobility, but provide further opportunities for health-related data to be shared across borders. Added value and services can be integrated into the e-YC cross-border infrastructure, drastically reducing data friction when it comes to healthcare.

A primary reason for the WHO's DTS is facilitating global travel to pre-COVID-19 levels. If an individual receives an approved vaccine from a certified healthcare provider and this data is securely embedded into an e-YC, then transnational mobility to pre-COVID levels is possible. As of this paper, 227 million people globally have received one or two doses of a COVID-19 vaccine [23]. Although there is still a long way to go, the rapidity of vaccination roll-out will accelerate the need for such a global trust infrastructure.

In addition to facilitating international travel, the WHO's DTS focuses on mitigating counterfeit vaccinations by being responsible for creating and maintaining a list of trusted national health authorities who will verify trusted vaccine providers through a health response team. Of course, member-states will need to share their list of verified vaccine providers with the WHO to begin with. Having a verified list can drastically cut down the potentiality of forged vaccine certificates and limit the spread of counterfeit COVID-19 vaccines as well. Contrarily, there are also negative impacts to any DT process. In the case of the WHO, privacy advocates have criticized the concept of a vaccine or "immunity" passport considering the unequal distribution of vaccines in the West compared to the rest of the world, leading to a division of classes: those who are vaccinated or have recovered from COVID-19 and those who have not. International law dictates that nation-states have a responsibility to protect their constituents from discrimination [24]. Thus, does requiring citizens to provide a Smart Vaccine Passport when traveling internally or internationally constitute a violation of rights? Does facilitating global travel to pre-COVID levels with privacy and trust built into the system outweigh inequity concerns? These are larger societal questions to be analyzed presently and in the future.

B. *Political and Legal Barriers*

One primary idea conveyed in the workshops was the importance of confronting political and legal challenges inhibiting the potential success of the project. Accordingly, political trust was a prominent theme throughout the workshops, being the primary driver for 194 member-states to agree on a smart vaccine passport minimum viable data set. The WHO is currently working on these trust issues through a standardization working group. A second component the working group is analyzing vaccine certification solutions governments are using. Some of the certificates are created by the private sector, thus triggering the question if it is trusted by the national government where it is being distributed. And in the long run, does the certificate comply with WHO's global standards that will be created?

Legally, there are challenges to the pilot project because of international law. The World Health Assembly (WHA) is the legislative body of the WHO that gives the WHO its mandate. Currently, the X-Road ecosystem and Estonia are the primary guarantors of the pilot trust architecture. However, the WHA will convene in late Spring for potentially transfering the trust architecture mandate directly to the WHO. If this mandate does not pass, then Estonia will continue to run the pilot as the global trust architecture operator for the time being. Another barrier is legal enforcement authority. In the end, it is the enforcement authority of the WHO which will provide a mechanism for actual global-scale implementation. Much like the UN General Assembly, the WHO is classified as a soft law entity and lacks adequate legal power to enforce trust infrastructure adoption [25] . But this barrier can be overcome by the WHO by providing and proving the trust infrastructure has economical value for member-states.

V. Discussion and Future Work

It would be prudent to start the discussion with the limitations of the exploratory case study. First, the researchers only captured limited perspectives. Although Estonia cooperates intensively with high-level WHO stakeholders, it limits the applicability of generalized statements about the internal workings of participating pilot partner countries. Further stakeholder interviews are needed to holistically understand the implications of international digital vaccine certificate recognition on a broader geopolitical scale. Yet, the initial data collected at this early stage suffices for understanding interesting organizational insight into DT within the WHO and

Estonia's role as a primary driver for facilitating global data exchange architecture.

At its core, the envisioned technical trust architecture requires the WHO to indicate who the overall trusted national health authority is in each pilot member country. Meaning each pilot member country is responsible for developing and maintaining the list by verifying healthcare provider vaccinations processes and conducting a survey of the IT infrastructure of the healthcare provider. That respected authority has a list of trusted COVID-19 vaccine providers. It is from this list that the vaccine verification takes place. Legally, it is up to the WHO and member-states to agree to technical standards and amend the WHA regulations for adding COVID-19 standardization into the e-YC parameters and mandating the WHO as the global trust architecture anchor. During the workshops, it was highly emphasized that although the global data exchange infrastructure is reliant on a technological ecosystem of the X-Road, the pilot would be built through the lens of fostering community among participants.

As mentioned previously, this case study is not without controversy. What happens if some countries recognize vaccine certificates and providers as valid but others do not? For instance, the nations of Greece and Cyprus have agreed to recognize the Israeli "green passport" confirming an individual is COVID-19 negative [25]. This begs the question of will there be multiple, separate blocs of smart vaccine certificate ecosystems? In the EU, there is opposition to smart vaccine passports from Germany and France based upon the premise that it is too early to tell if vaccines enable complete immunity, especially with new, more transmissible COVID-19 variants being discovered [26].

Opponents have also been critical of the COVID-19 immunity passport concept because of potential entrenchment of inequity. Privacy advocates are also sensitive to the issue of data protection, especially when it comes to personal health information. It should be noted that in the workshops it was emphasized no personal data is going to be exchanged and the system should be as light as possible. As understood by the authors, the data exchanged is minimal; a number representing the traveler, a code for the trusted health provider and whether the trusted health authority finds them legitimate. Ultimately, the implementation of an X-Road-based eYC is a political decision, and it is up to the WHO's leadership to decide whether the described data exchange architecture will be adopted on a global scale or not.

Future work involves assessing the actual deployment and implementation of the WHO pilot project from technical, organizational, legal, political and end-user perspectives. For instance, applying DT frameworks for understanding the level of digital upskilling necessary within the WHO to be a sustainable trust anchor for the digital yellow card. Additionally, for privacy advocates, future work could involve a neutral third-party verifying the data collected and exchanged among member-states is only limited to COVID-19 data points. In sum, there is a plethora of future work to conduct as the WHO is at the beginning phases of implementing the pilot and its DTS to accommodate the necessary infrastructure needed for exchanging cross-border vaccine certificates.

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Appendix 4

[IV]

E. B. Jackson, P. Kivimäki, I. Pappel, and S. B. Yahia, “Exploring eu e-delivery integration for enabling interregional innovation through the silverhub platform,” in *Proceedings of the 24th Annual International Conference on Digital Government Research*. Association for Computing Machinery, 2023, p. 172–179

Exploring EU e-Delivery Integration for Enabling Interregional Innovation through the SilverHub Platform

Eric B. Jackson
eric.jackson@taltech.ee
Tallinn University of Technology
Tallinn, Estonia

Petteri Kivimäki
petteri.kivimaki@niis.org
Nordic Institute for Interoperable Solutions
Tallinn, Estonia

Ingrid Pappel
ingrid.pappel@taltech.ee
Tallinn University of Technology
Tallinn, Estonia

Sadok Ben Yahia
sadok.ben@taltech.ee
Tallinn University of Technology
Tallinn, Estonia

ABSTRACT

Populations are aging rapidly in the EU, creating significant challenges and opportunities in the Silver Economy. The OSIRIS Interreg Baltic Sea initiative is a response to this aging challenge and is composed of quadruple helix stakeholders in Denmark, Finland, and the Baltic states. An ICT-based outcome of the project was SilverHub.eu, a collective intelligence digital platform that provides users with Silver Economy market reports, partner contact search, and innovation-supporting digital tools. However, it does not contain cross-border data exchange or e-service provision capability, which requires digital interoperability architecture and transitioning to becoming a more digitally mature platform. The Digital Europe Programme's cross-border data exchange building block, eDelivery, was identified as a potential integration solution to improve SilverHub's platform maturity level. This study is an initial qualitative investigation of the interoperability dynamics and requirements for the SilverHub ecosystem to integrate with eDelivery. Document analysis and several workshops with SilverHub stakeholders were conducted. Based on these results, an eDelivery organizational-specific model was deemed most appropriate for the SilverHub ecosystem, along with a dynamic discovery model for cross-border data exchange. Future work includes a feasibility analysis of eDelivery integration and simulating eDelivery data exchange between SilverHub and its organizational members.

CCS CONCEPTS

• **Software and its engineering** → **Interoperability**; • **Computer systems organization** → **Peer-to-peer architectures**; • **Applied computing** → *E-government*.

KEYWORDS

interoperability, data exchange, silver economy, cross-border

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1 INTRODUCTION

In the European Union and around the world, aging populations are quickly growing. By 2050, one in four people will be over the age of 65 in the European Union [1]. This trend has pressured the public and private sectors to respond with visions, policies, and services tailored to older age segments. The "Silver Economy" is a broad concept defining this development as "the economic opportunities arising from the public and consumer expenditure related to population aging and the specific needs of the population over 50" [2]. In more generalized terms, the Silver Economy is the provision of many kinds of products and services to older adults who are still active in the workforce, are nearing retirement, or are retired.

The leveraging of ICTs by both the public and private sectors to provide digital services and foster innovation in the Silver Economy has been documented as an important objective by the EU [3]. As life expectancy increases and a higher proportion of the population ages, it is necessary for government and businesses to innovate and adapt to the heterogeneous needs of older citizens, especially in the public sector, where there is a political mandate to look after their welfare.

In the EU Digital Single Market (DSM) context, population aging is not only an internal issue but extends across borders. Subsequently, interoperability, or the ability of public and private sector organizations to exchange and use data, is a fundamental aspect of transnational innovation and e-service delivery. In the EU, multiple cross-border interoperability solutions enable the exchange of data securely and seamlessly across borders. One such solution is eDelivery, a Connecting Europe Facility building block containing a vendor-neutral solution for establishing interoperable and trusted networks of unified nodes [4]. Private and public sector organizations can implement eDelivery's standardized messaging protocol and architectural specifications to exchange data for the provision of e-services internally, regionally, or across borders [4]. In practice, eDelivery is used for geographically pan-European projects focusing on a specific domain, such as justice, procurement, invoicing, healthcare, social security, and more [5].

Similarly, a pan-regional approach is required to maximize cross-border e-service delivery in Silver Economy domains like caregiving, healthcare, education, wellness, mobility, and welfare. This cross-border aspect requires transitioning to higher maturity levels for public and private sector e-service providers [6]. The OSIRIS Interreg Baltic Sea project is a recent cross-border regional initiative to co-create innovation in the Silver Economy using ICTs. The project is a regional open innovation network consisting of five countries: Denmark, Estonia, Latvia, Lithuania, and Finland [7]. Each partner country is represented by Quadruple Helix (QH) stakeholders from academia, business, the public sector, and older citizen group who form Smart Silver Labs (SSLs) in each country. Organizationally, SSLs provide data, expertise, consultation, and co-creation in the Silver Economy domain and serve as governing stakeholders in the OSIRIS Baltic Sea project.

One primary output of the project is SilverHub (SilverHub.eu), a transnational collaborative e-platform that consolidates and aggregates information from the SSLs into one place [7]. The platform is multilingual and provides regional Silver Economy assessment reports as well as “innovation supporting tools” to enable regional cooperation on funding and facilitating the uptake of new Silver Economy products and services in each country [7]. It is a one-way information flow without service ordering capability and secure cross-border data exchange. As the ability to exchange data securely and interoperably across borders increases the collaborative capacity of organizations to innovate and provide services, the authors were motivated to investigate e-Delivery’s potential in the context of a transnational multi-stakeholder network focused on population aging. The authors have previous research and working experience regarding another European cross-border data exchange platform, the X-Road [8], and thus wanted to explore an alternative data exchange platform. Furthermore, in the literature pertaining to the Silver Economy, the "supply" side has traditionally not been the primary focus of research in this domain. Instead, the "demand" side has taken precedence [9]. Subsequently, this paper represents an exploration of the "supply" side of the Silver Economy, particularly from the public sector, which is politically responsible for the welfare of older citizens and the economic impact of demographic aging on societies. This paper represents an initial research contribution to leveraging eDelivery cross-border integration for boosting transnational data exchange in the Silver Economy.

In order to raise SilverHub’s capacity to support cross-border data exchange, e-services, and innovation, exploration is necessary for understanding the interoperability components and requirements necessary for eDelivery integration. A document analysis was conducted to understand and contextualize eDelivery architecture and instantiation processes in combination with several workshops conducted with SilverHub QH stakeholders from partner countries. The workshops attempted to understand which high-level eDelivery models are most appropriate for SilverHub integration. To achieve the research objective, the following research question and sub-questions are presented:

RQ1: How can SilverHub be integrated with the EU e-Delivery interoperability platform for providing cross-border Silver Economy e-services and innovation? SQ1: What are the cross-border interoperability dynamics of EU e-Delivery? SQ2: What is required for SilverHub to integrate with e-Delivery, and which topology is optimal?

This paper is structured as follows: the first section presents the methodological approach; the second describes cross-border interoperability literature, the eDelivery context, and the SilverHub background. The third section offers the interoperability dynamics of eDelivery and the requirements necessary for SilverHub integration. Lastly, a conclusion and future work is given.

2 CASE BACKGROUND

2.1 eDelivery

The current version of eDelivery is maintained by the Digital Europe Programme and serves as an interoperability building block through the provision of open specifications, standards, and software that is reusable in a diverse amount of policy domains, such as justice, healthcare, social security, invoicing, population, and society, etc [5]. Generally, eDelivery is for individual pan-European projects in a specific domain and can be considered an interoperable digital communication infrastructure. It supports the exchange of documents and data internally, regionally, and across borders between independent and diverse backend IT systems from public sector administrations, private sector organizations, and citizens [10].

Interoperability in eDelivery is achieved through a distributed network of nodes for a given project or policy domain. Each node is conformed to eDelivery’s technical requirements, messaging protocol, and standardization procedures that are by design, vendor, and data payload agnostic [10]. Thereby, any supported document or digital data structure (XML, JSON, etc.) can be exchanged across borders once an organization is connected to a node [11].

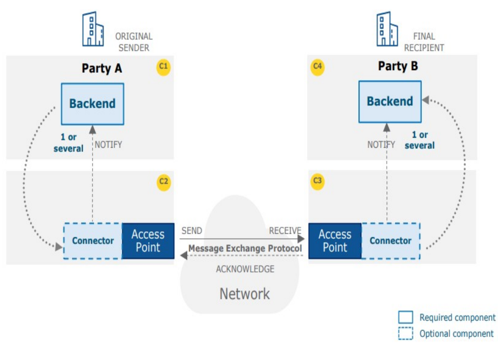

Figure 1: eDelivery Four Corner Model [12]

Architecturally, eDelivery is commonly based on a four-corner topology (see Figures 1 [12] and 2 [12]), but it can also support two and three-corner topologies as well [13]. There are four core components to establishing an eDelivery network: Connectors, Access Point (AP), Service Metadata Locator (SML), and Service Metadata Publisher (SMP). In Figure 1, IT backends (C1 and C4) represent organizational IT systems that are permitted on the eDelivery network and are able to exchange data or provide services across borders without having to integrate themselves directly. Subsequently, the backend systems can either be integrated with an AP internally (C2 and C3) or through Connectors, which may be "built, bought or reused" [12] from service providers. As the name implies, the Connectors enable backend communication with the APs, they are an optional component considering the use case.

The AP is of central importance to eDelivery. It executes an open messaging protocol, Applicability Statement 4 profile (AS4-profile), to interoperably exchange documents and data asynchronously between independent backend systems. AS4-profile was an eSENS project outcome based on ebMS3.0 and OASIS standards [14]. It is a SOAP-based web protocol for message payload and packaging [14]. The European Commission has provided an open-source AS4-profile compliant software solution, Domibus [15], for organizations to use for implementing their AP. Additionally, various third-party AS4-profile compliant vendors are available for setting up an AP [16].

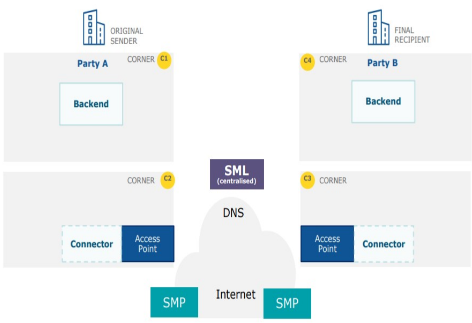

Figure 2: eDelivery data exchange architecture [12]

In order to understand which network participants do what, two metadata management components are incorporated in the eDelivery building block: Service Metadata Locator (SLM) and Service Metadata Locator (SML). In Figure 2, the SML is centralized and manages resource records of network actors (host name and IP) in the Domain Name System (DNS). The SMP is an accessible catalog of partner metadata containing the location of APs and the technical, semantic organizational, and even legal capacities of partners in the eDelivery Messaging Infrastructure. SML and SMPs may be managed by the same organization, but it's also possible different organizations manage them. In an eDelivery policy domain using dynamic discovery, one or more SMPs may be managed by one party or by different parties.

The eDelivery network ensures integrity and confidentiality by supporting digital certificates and encryption, where network participants are required to sign a confirmation that they have received a message digitally. For instance, in Figure 1, if C1 wants to send a message to C4 through the eDelivery network, C1's message is first sent to C2, digitally signed, encrypted, and sent to the public internet using the AS4 messaging protocol. After receiving it, C3 decrypts the message and verifies the message's digital signature. Then the message is decompressed, and once verified, an acknowledgment is sent from C3 to C2 and the message is stored at C4 for C1 to download and receive.

2.2 SilverHub

SilverHub can be considered a "digital collaborative platform" because it satisfies specific requirements defined by Staub et al. [17]: it is a modular software system; that facilitates coordination between external stakeholders in government, academia, and business and for citizens to foster innovation in the Baltic Sea region; and serves as a centralized hub to a transnational Silver Economy ecosystem that is connected through boundary resources. The ecosystem consists of different member profiles: SMEs, entrepreneurs, researchers, older citizens, policymakers, and national representatives in Denmark, Estonia, Latvia, Lithuania, and Finland [7]. Each partner country is also represented by Quadruple Helix (QH) stakeholders in academia, policymakers, and senior citizens. These QH stakeholders form Smart Silver Labs in each country. SilverHub is also described as a "collective intelligence" platform, where the centralization of different Silver Economy service providers, consumers, and market data creates an information and collaboration network for producing innovation in this domain [18].

For instance, in the current SilverHub architecture, an SME who provides services or products can access Silver Economy Baltic and Nordic market reports, find contact information of relevant government and social organizations who may provide funding, or serve as a delivery mechanism for the SME's services or products to older populations. From the software side, SilverHub was implemented using agile development methods and supports a mobile and web-based multilingual interface and content [19].

SilverHub has a classical three-tier architecture: presentation, logic, and data. The presentation tier or user interface combines HTML, CSS bootstrap framework, add-ons, JavaScript, and BlaB! AX chat [19]. The logic tier is built with PHP and the data tier is a MySQL database [19]. Currently, it is incapable of cross-border service provision to consumers (thus, requiring interoperable data exchange). It is classified as a web page supporting different Platform as a Service (PaaS) functionalities.

Therefore, to transition SilverHub to cross-border data exchange capability, it needs an integration process that implements eDelivery nodes to raise its maturity level. Consequently, the existing architecture and SilverHub ecosystem will need to be reconfigured and made compatible, necessitating an analysis presented in the results section.

3 RELATED WORK

3.1 Cross-border Interoperability

The interoperable exchange of data is a primary driver of cross-border e-services implementation. It is shown that cross-border data availability and accessibility between public and private sector organizations save time and human and financial resources and help standardize cross-border administrative processes while improving data optimization [20]. According to the New European Interoperability Framework (EIF) [21], interoperability is defined as the "ability of organizations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their ICT systems".

The New EIF specifies four layers (technical, semantic, organizational, and legal) that shape internal and cross-border interoperability, forming integrated public service governance: technical, semantic, organizational, and legal [21]. Technical interoperability focuses on compatible specifications, components, infrastructures, and the integrations or linking systems between two or more information systems [21]. Semantic interoperability is data-centric. This layer concerns the data structure, format, and integrity being preserved and comprehensible for all data exchange network participants [21].

Organizational interoperability is about ensuring network participants understand each other's business processes while also delegating responsibilities and roles in data exchange and service implementation by using official documents like service level agreements and memorandums of understanding to coordinate objectives and services between all parties [21] Lastly, legal interoperability is about understanding the impact different legal frameworks, regulations, and national legislation have on a data exchange network [21]. Subsequently, these layers must be coordinated between organizations when implementing cross-border interoperability architectures and data exchange protocols.

In addition to the EIF, the EU has a host of projects, strategies, regulations, and initiatives for enabling cross-border interoperability between government-to-government (G2G), government-to-business (G2B), and citizen-to-government (C2G). The Digital Single Market (DSM) is a high-level strategy that seeks to remove digital barriers inhibiting the free movement of people, services, and goods across EU borders [22]. As Krimmer et al. [2022] point out, cross-border interoperability plays an integral role in the DSM, where EU businesses and governments are seen as key facilitators of this strategy [5].

From a regulatory perspective, the European Regulation on Electronic Identification and Trust Services (eIDAS) [23] is one of the most impactful regulations influencing the DSM. EIDAS established the legal environment for cross-border e-identification and recognition of e-signatures and their quality from citizens, businesses, and the public sector. In principle, this allows the DSM to securely access and receive cross-border services irrespective of their location in Europe.

Although great political priority and financial resources have been devoted to implementing cross-border data exchange and e-service provision in the EU, many challenges still persist [21]. For instance, the diverse amount of legacy systems used by the public and private sectors is seen as a primary cross-border interoperability inhibitor [21]. Data Exchange Layers (DEL) seek to ameliorate some of these challenges by deploying standardized technical architecture and shared semantic and organizational protocols for facilitating data exchange regardless of location or information system used.

4 METHODOLOGY

To investigate SilverHub integration with e-Delivery, this paper takes a qualitative methodological approach to satisfy the research objective. Qualitative research is a process that uses non-quantified data to explore specific phenomena through "finding sources, becoming deeply familiar with a topic, and then distilling and communicating some of its essential features" [24]. Although information technology studies are traditionally quantitative or design-based, qualitative methods can also be applied to describe in-depth information systems development through field studies, interviews, document analysis, workshops, ethnographies, and grounded theories [25]. Triangulation is an important criterion of qualitative methods. There is an expectation to answer research questions by collating at least two independent sources of evidence to increase the robustness and confidence of findings [26].

This study adopts two qualitative data-capturing methods for triangulation: document analysis and workshop discussion with relevant stakeholders. First, document analysis is used to contextualize, analyze and interpret the text from digital and non-digital sources [26]. In this case, electronic documents related to e-Delivery technical architecture, organizational, legal, and security requirements, and integration procedures were analyzed. Documents comprised academic articles, technical manuals, policy papers, and website information. Thereby, the authors were able to contextualize and interpret how e-Delivery works, its objectives as a cross-border interoperability facilitator, and integration requirements and procedures.

Several workshops were conducted in the Spring of 2022 involving relevant QH SilverHub stakeholders, primarily from academia and the private and public sectors, who have expertise in policy-making, and the Silver Economy and have been developing services and research for the past two decades on population aging. The workshops explored how SilverHub could mature into a transactional platform that enables cross-border data exchange and e-services through facilitated discussion. The eDelivery network was identified as a pan-EU cross-border interoperability enabler and was thus chosen as a focal point for workshop discussions. The workshops' outcome elicited certain technical, semantic, organizational, and legal requirements for such an integration. Three visual diagrams of the integration architecture were developed, including an overall summary of the exchange model, discovery model, and trust architecture decided as an outcome of the workshop sessions. Thus, this study's combination of qualitative research methods ensures triangulation is satisfied and the garnered results have validity. Based on document analysis and discussions, a starting vision was developed regarding SilverHub and e-Delivery integration.

5 RESULTS

5.1 Technical, Semantic and Organizational eDelivery Interoperability Dynamics and Requirements

Based on the document analysis, eDelivery has specific technical, semantic, organizational, and legal interoperability requirements that SilverHub and its relevant members must conform to. Technical requirements (see Table 1) center around the eDelivery software ecosystem and establishing a trusted digital communication network. To begin eDelivery integration for the SilverHub, a four-corner topological model or mesh network (see Section 2.1) was deemed most conducive to scalability for the SilverHub and its organizational members. Since the backend systems in the mesh network are not directly exchanging information, SilverHub, and its organizational members will need to integrate their backends to an AP individually. One avenue is a direct integration, which was deemed beyond the technical capacity of organizational participants. The other is implementing a connector between the backend system and the AP. Connectors can be installed by a commercial service provider or done internally. After successfully implementing either method, connectivity between the backend and the AP can be established. backend Connectors must be developed, tested, and deployed in order for SilverHub and its relevant organizational members to exchange information between each AP and the corresponding backend system. As many AP solutions are available on the market, reusing existing APs is the most feasible and cost-efficient. The APs enable secure and seamless data exchange to occur on the network by conforming to the AS4 communication protocol described in Section 2.1.

The open-source Domibus software provided by the European Commission or an AS4-compliant service provider can be used to build and host the APs independently for each SilverHub organization and the SilverHub platform itself. If a SilverHub organization has the technical capacity, they can decide to host the AP themselves if suitable. However, this was viewed as cumbersome for the current SilverHub organizational ecosystem. Based on the available AP solutions as a hosted service [14], all partner countries have potential local hosting partners available.

Organizationally (See Table 2), two processes will need to occur to establish digital trust in the network. The first is related to the SilverHub itself. Organizations that want to become members of the platform would need to apply, be verified, and have particular Silver Economy relevance as service providers or consumers. The second is an eDelivery trust–based onboarding process where SilverHub and its member organizations would undergo a verification procedure involving allocating digital certificates and signing keys provided by a Central Authority. There are three different pathways for establishing trust [13]. The first is establishing a dedicated Public Key Infrastructure (PKI) for the APs, SMPs, and SML in the eDelivery network for the SilverHub. This entails sharing a common root digital certificate from a Certificate Authority (CA) between these components. The dedicated PKI is based on the eIDAS framework and managed by the Directorate-General for Informatics (DGIT), which can be viewed as CA trust solution provider for this pathway specifically [14].

The second pathway is more distributed, mitigating a single point of failure by relying on the mutual exchange of digital certificates through a local trust store model. Each eDelivery component (AP, SML, SMP, etc.) maintains an SML trust store of PKI certificates that are trusted and valid. This reduces the complexity of cross-certifying PKIs that issue different digital certificates while eliminating the need for processing cumbersome certification paths since the CAs are part of the local trust store. The downside of this pathway is it requires high maintenance, as any change to an AP/SMP requires all local trust stores to be updated. The distributive nature of exchanging digital certificates through local trust stores also means network participants do not have complete control over determining certificate policies [14]. Lastly, the third pathway relies on sharing a domain-specific trusted list of certificates from the CA of an organization's choice, as long as the CA follows the domain's certificate terms and policies. This creates a lot of flexibility for organizations regarding which CA they use. However, the maintenance output of the trusted domain list, including the certificate used to sign the list, is higher than the other two trust pathways [14].

5.2 Legal Interoperability Requirements

There are a variety of policies and regulations governing eDelivery (see Table 3). The SilverHub ecosystem will have to abide by the terms and conditions when using eDelivery's PKI or any valid CA, as well as the eDelivery Master's Service Arrangement. The Service Arrangement is non-binding, yet it is a good-faith agreement and must be followed to ensure smooth integration [27]. From the provider side, eDelivery's Privacy Statement describes the data protection policies implemented in eDelivery PKI and the SML when processing organizational data from the SilverHub ecosystem [27].

On a Pan-EU level, eIDAS influences eDelivery PKI and other CA's by regulating e-signature quality level standards and fostering an internal demand for trust services in the Digital Single Market. Besides eDelivery, there will also have to be legal agreements between the SilverHub platform and its member organizations. MoUs provide a starting legal instrument for promoting cooperation and collaboration and signifying an intention to connect to the SilverHub and, thus, eDelivery. A standard legal approach is the creation of Service Level Agreements between the SilverHub, specifying service KPIs, roles, responsibilities, etc. Differences in national laws of each SilverHub partner country will also have to be considered for understanding what can be harmonized and what nuances will affect eDelivery integration and SilverHub e-service provision.

5.3 eDelivery Integration Architecture for SilverHub

Technical reports show there are three different overarching models [28] for setting up an eDelivery network, all with various requirements. The organizational-specific model (see Figure 3) was regarded as the most appropriate during the workshops. The reason being there is more flexibility in this model because each organization is responsible for its own AP deployment. On the other hand, this model is also more resource and human-capital-intensive than the others [28]. Although open-source eDelivery software is available, and validated commercial service providers can develop and host APs for SilverHub organizations, the troubleshooting burden would mainly be on these organizations' shoulders [28]. Even so, there was a consensus that flexibility would be necessary given the many domains the Silver Economy covers and that certain partner countries do not have national eDelivery access point infrastructure [28]. Inside the organizational-specific eDelivery model are two possible routing and metadata lookup pathways for APs: static discovery vs dynamic discovery [29]. It was important to understand

Table 1: Technical and Semantic Interoperability

Core Components	Software and Specifications	Solution Provider
AP installation	ebXML Messaging 3.0 AS4 Conformance Profile	AS4 compliant commercial service provider
Connector	ETSI REM Standard	Internal or commercial service provider
PKI	eDelivery PKI	Directorate-General for Informatics (DIGIT) or CA
SMP	OASIS Service Metadata Publishing (BDX SMP)	Hosted by commercial service provider or internally
SML	OASIS eDelivery BDXL (DNS)	Digital Europe Program or commercial service provider
Backend	Organizational dependent	Internal

Table 2: Organizational Interoperability

Organizational Process	Description
Permitted on the eDelivery Network	eDelivery on-boarding for SilverHub network stakeholders
Permitted on the SilverHub	SilverHub registration for public/private sector organizations

Table 3: Legal Interoperability

Legal Instruments	Description
Memorandum of Understanding	Official document between OSIRIS stakeholders outlining cooperation intention
eDelivery Privacy Statement	Outlines how the European Commission processes user data for eDelivery PKI and SML
eDelivery PKI Service Terms and Conditions	Outlines the terms and conditions for using eDelivery PKI
eDelivery Master's Service Arrangement	Non-binding statement of good faith outlining the terms and conditions of eDelivery
eIDAS	EU regulation defining eID, trust services, and e-signature quality levels
Service Level Agreements	Agreements between OSIRIS network stakeholders regarding service provision
National Law	Specific differences between national laws

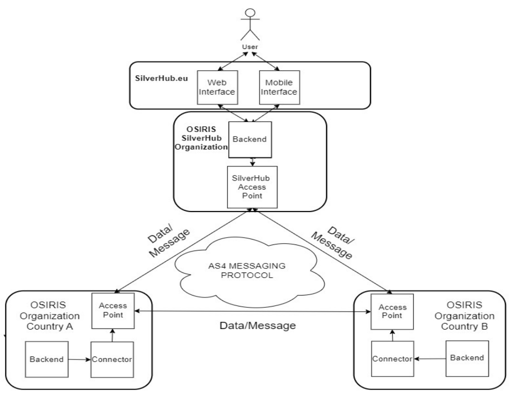

Figure 3: Organizational specific model

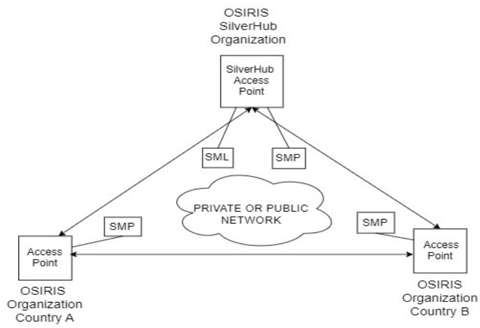

Figure 4: Dynamic Discovery Model

which pathway is most appropriate for the SilverHub ecosystem, as this will dictate the data flows between organizational APs. Static discovery relies on sender APs creating, managing, and storing a list of fixed information about receiver APs: communication capacity, IP address, location, etc. This list is statically consulted when an AP wants to exchange data or information with another receiving AP. The static discovery model requires no processing time for execution. Still, it requires manual processes from the sending AP administrator to compile the receiver's AP information and send it through external channels.

On the other hand, the dynamic discovery model provides comprehensive details about a receiver's business processes, capabilities, data types supported to a sender, etc. The discovery model utilizes the Service Metadata Locator (SML), which runs DNS global lookups for Service Metadata Publisher (SMPs) at runtime to achieve this. SML requires centralization and management by the domain owner in the SilverHub ecosystem. On the other hand, the SMPs will be deployed by all individual SilverHub organizations and is a component provided by the Digital Europe Program. These two components serve in a support role for APs and enable services to be delivered because the SMPs provide business process descriptions.

6 CONCLUSION AND FUTURE WORK

This work has presented the interoperability dynamics of eDelivery and the requirements necessary for the SilverHub ecosystem to integrate with eDelivery. Results data was captured through triangulating document analysis and workshop outcomes with SiverHub partner country organizations. The eDelivery interoperability dynamics comprise technical, semantic, organizational, and legal factors affecting integration. An organizational-specific model using dynamic discovery was the most likely eDelivery network architecture. With SilverHub exploring the potential of cross-border e-service provision in the future, a dynamic discovery model was chosen as the most feasible data exchange architecture due to its metadata-sharing capability and scaling capacity.

This paper initially explores eDelivery integration with SilverHub and its organizational members. Future research includes conducting a feasibility assessment of SilverHub eDelivery integration and simulating eDelivery data exchange within the SilverHub ecosystem. Another research avenue is comparing eDelivery interoperability requirements with other DEL solutions. While identifying specific cross-border Silver Economy e-services was not the main focus of this work, the concept of the SilverHub representing a common European data space is also of further research interest.

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Appendix 5

[V]

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The Role of Data Intermediaries for Small- and Medium-sized Enterprises in the Innovation Ecosystems of the Nordic-Baltic Silver Economy

Eric Blake Jackson[1], Marina Weck[2], Ingrid Pappel[3]

[1]Tallinn University of Technology, Tallinn, 19086, Estonia
[2]Häme University of Applied Sciences, Hämeenlinna, 13100, Finland
[3]Tallinn University of Technology, Tallinn 19086, Estonia

ABSTRACT

Data are a strategic asset for organizations in both the private and public sectors that spans multiple domains and sectoral boundaries. For innovation ecosystems, the ability to frictionlessly exchange data across borders between stakeholders for better decision-making, predictive capability, and automation represents a competitive advantage in the market. Data are also inputs for providing and receiving services online. Recent regulations such as the Data Governance Act (DGA) have placed the role of data intermediaries for cross-border data sharing at the forefront. However, the impact of the regulation on small- and medium-sized enterprises (SMEs) and the role of data intermediaries are still uncertain. This exploratory study investigated these dynamics by focusing on the perspective of SMEs in the Nordic-Baltic region through a sense-making policy and regulatory impact analysis. SMEs face significant legal uncertainties under the DGA, which impact cross-border uptake. The silver economy is a prime cross-sectoral market for cross-border data sharing, and established data intermediary solutions in the region could be leveraged to achieve innovation in this area.

Keywords: Innovation Ecosystems, Interoperability, Data Exchange, Data Governance, Silver Economy

INTRODUCTION

With the digital transformation in the 21st century, society is witnessing an explosion of big data, artificial intelligence, and the increased notion of data-driven decision-making and business models, ushering in Industry 4.0. Data are a strategic asset for organizations in both the private and public sectors that spans multiple domains, sectoral boundaries, and national borders. In the European Union (EU), the Data Governance Act (DGA) regulates the ability of organizations to share, exchange and reuse data seamlessly and frictionlessly to achieve a digital single market. (European Union, 2022).

This policy instrument shapes cross-border data governance by supporting and promoting greater reuse and sharing of trustworthy datasets and safeguarding personal or nonpersonal data exchange between the private sector, public sector, nongovernment organizations, and individuals (European Commission, 2022). Inherently, these top-down policymaking decisions require interoperability capacity between societal stakeholders to receive and exchange information across borders to facilitate e-service provision, catalyze innovation, and garner data-driven insights on regional and EU-wide levels. Therefore, organizations must integrate or connect information systems to share data in compliance with EU regulations and service-level agreements (European Commission, 2017). This also means that organizations must have shared meanings for data objects and human capital to handle data appropriately (European Commission, 2017).

In an increasingly complex and interconnected world, market competition has shifted to more networked collaborative approaches between quadruple helix (QH) stakeholders (government, academia, private sectors, and civil society) to solve the most pressing issues in society and respond to economic needs and deficiencies (Moore, 1993). The concept of markets or industries has been replaced by “innovation ecosystems,” which are characterized by multifaceted and dynamic artificial or self-regulating interactions and boundaries between various stakeholders, including small- and medium-sized enterprises (SMEs) (Colombo et al., 2019).

For SMEs, cross-border data flows play an integral role in spurring digital innovation for Industrial 4.0s, particularly in providing new e-services, implementing AI, and leveraging big data and Internet of Things (IoT), among other digital trends. Despite the benefits of frictionless cross-border data exchange, SMEs face immense challenges compared with larger enterprises. Capitalizing on data value is a higher expense for SMEs, as they frequently need more human and technical resource capacity to operationalize value extraction (Meierhofer et al., 2022).

Thus, to actualize cross-border interoperability in the EU, as required by the DGA, secure and privacy-compliant data exchange must be facilitated across borders between a network of QH organizations, including SMEs, which is the focus of the QH stakeholders in this study. Data intermediaries fill this role by mediating trust and securing data-sharing connections between organizations through various technical architectures and business objectives.

However, the role of data intermediaries still needs to be clarified in the literature concerning cross-border innovation from the perspective of SMEs. In the EU, the current data intermediary environment for cross-border applications is highly fragmented, with silos occurring because of the plethora and dynamic nature of digital architectures and solutions.

Furthermore, a greater understanding of how data intermediaries work *in practice* is needed. In particular, the QH perspective of SMEs regarding the role that data intermediaries can play in their business cases must be clarified, particularly under the legal framework of the DGA Thus, the aim of this study was to examine how Nordic-Baltic SMEs can navigate top-down regulations such as the DGA, the impact of the DGA on SME operations and identify different data intermediaries service providers in the Baltic-Nordic that may have utility. A brief set of recommendations are given.

This initial exploratory study focused on cross-border data intermediation for SMEs in a cross-sectoral domain, the Silver Economy, which is the product and service that targets the population aged 50 years and older. In the EU, projections show that this economic market will reach 5.7 trillion dollars by 2025 (Erlenheim, 2021). Aging affects societies of the Nordic-Baltic region acutely, which has a large proportion of older adults (United Nations Department of Economic and Social Affairs, Population Division, 2019). Additionally, the Nordic-Baltic region seeks to be the most integrated region in the EU by 2030, by promoting "cross-border by default" principle in the creation and deployment of digital services (Nordic Council of Ministers, 2023). One focus area of this initiative is "social sustainability" which encompasses silver economy attributes like health and well-being, social cohesion, lifelong learning, and strong social networks.

The structure of this article is as follows. The next section describes the concepts of data intermediaries, their types, and their relationships with the DGA and SMEs. The third section provides a methodological description of the data collection. The fourth section presents the results, along with an accompanying discussion of the implications of data intermediation for cross-border data flows from the perspective of SMEs in the Nordic-Baltic region. Finally, we present the conclusion and brief future work in the final section.

DATA INTERMEDIARIES

The literature and policy documents present various definitions of data intermediaries and their purposes. Janssen & Singh (2022) provide one of the most comprehensive definitions: "A data intermediary serves as a mediator between those who wish to make their data available, and those who seek to leverage that data. The intermediary works to govern the data in specific ways and provides some degree of confidence regarding how the data will be used" (Janssen & Singh, 2022, p. 2).

They further describe this interplay, in which data intermediary organizations are the trusted conduit between stakeholders who supply and consume data for a broad spectrum of public and private usage, analytics, and innovation purposes (Janssen & Singh, 2022). Although the very premise of the Internet is on coordinated, protocol-based networks, data intermediaries have unique characteristics that are intended to reduce the power asymmetries of big tech monopolies on data collection and use (Liu, 2022). One characteristic is fostering greater individual or collective data ownership through different technologies, architectures, and governance models and tools. Another essential attribute is the assurance of third-party neutrality, which means that the data intermediary organization has no business conflict of interest with the data it governs responsibly and contractually. Thus, data intermediaries should be distinct from data brokers, as the latter is concerned with extracting monetary value from data by selling it to other parties without public innovation or inclusive data governance principles (Micheli et al., 2023).

DISPs in the DGA Framework

The DGA is the guiding policy instrument in the EU that governs data exchange between various stakeholders. The implication of this regulation is the promoted use of DISPs. Article 2 of the DGA defines data intermediaries as "a service which aims to establish commercial relationships for the purposes of data sharing between an undetermined number of data subjects and data holders on the one hand and data users on the other, through technical, legal, or other means, including for the purpose of exercising the rights of data subjects in relation to personal data" (European Union, 2022, Art. 2[11]).

Under the DGA, DISPs must fulfill several obligations. One requirement is that potential DISPs must first notify a competent authority. This authority must ensure that the application process is fair, that the DISP supplies all necessary information, and that it can deliver all data intermediation services through a separate legal entity (European Commission, 2022). After approval, the DISP will be included in an EU central registry of verified data intermediaries and can operate with an official EU recognized data intermediary designation.

Classifications of Data Intermediaries

The vast heterogeneity of the digital landscape has given rise to various data intermediaries. Micheli et al. (2023) present six classifications, each with specific defining attributes, but intersectionality may exist between key players, objectives, and outcomes. In the context of Nordic-Baltic SMEs participating in innovation ecosystems for the Silver Economy, data marketplaces (DMs) and data sharing pools (DSPs) may be the most relevant, as they focus on something other than individual data rights and align with commercial purposes as a driving impetus. The following section describes DMs and DSPs in the context of data intermediary service providers (DISPs) under the DGA framework.

DMs and DSPs

Although not explicitly mentioned in the DGA, DMs and DSPs fall under broad regulatory parameters. DMs may differ in governance and structural arrangements according to various factors: accessibility, domain specificity, technical architecture, and business models related to pricing and revenue (Spiekermann, 2019).

However, in recent times, DMs have emerged to satisfy innovation purposes, connecting data sellers with buyers, and facilitating data exchanges and transactions. These innovation specificities tend to be more complex and data intensive, such as developing ML algorithms, IoT sensor-related data, and cross-border supply chain data. According to Azcoitia and Laoutaris (2022), DMs follow a four-tier architectural model. The first tier is a foundational infrastructure for general data security, storage, and processing services. The next layer is comprised of enablers for standardizing DM services by facilitating data exchange through API calls and responses. The third layer is comprised of a technical data processing pipeline from acquisition to end delivery to relevant consumers or customers. Lastly, the top management layer orients toward business processes and functionalities, including setting prices, contractual obligations, invoicing, payment, and the more frequently performed data monitoring actions. DMs may also implement third-party orchestration and matchmaking algorithms to boost precision and synergies between data suppliers and consumers.

By contrast, according to Micheli et al. (2023), DSPs involve establishing collaborative and collective partnerships to achieve mutually shared goals, objectives, and successes. By their nature, DSPs explicitly champion the equitable distribution of data value to all DSP stakeholders, alleviating concerns about unfair competitive advantages in the market and fostering cooperation.

The governance of DSPs is highly collaborative and incorporates wide-ranging stakeholder accessibility and usage. Subsequently, DSPs are well suited to health-care contexts because of the sensitivity of health-care data and strong embedded inclusive governance principles. In summary, both DM and DSPs have commercial interests in mind. However, DSPs are structured around collaboration, cooperation, and fair data usage. At the same time, DMs have specific matchmaking objectives to satisfy supply and demand, and the technical infrastructure to support data exchange between various organizations.

METHODOLOGY

The methodology used in this study involves a systematic review and analysis of previously conducted research to examine the dynamics of data sharing for SMEs within the legal framework of the DGA. This approach was used to systematically examine existing knowledge theories, models, and empirical findings related to data intermediation practices, challenges, and opportunities among SMEs in the Nordic-Baltic region operating in the silver economy. We synthesized insights from various scholarly articles, academic papers, reports, and case studies. The Discussion section will provide recommendations for how SMEs can leverage data intermediaries such as DMs and DSPs for solving their business cases and overcoming the cross-border challenges of their usage under the DGA legal framework.

RESULTS

Navigation of Top-Down Regulations for SMEs

Transformative top-down regulations such as the DGA will require bottom-up implementation. For SMEs, this means navigating inherent tensions between EU-level policy and on-the-ground regional contexts such as institutions, infrastructures, capacity, capabilities, and established innovation ecosystems (Boschma, 2017). This may result in a gap between EU regions with mature regional innovation capacity to capitalize and actualize data intermediation compared with those that need to catch up. Consequently, transitioning from top-down regulations such as the General Data Protection Regulation, which created friction in data exchange, to regulations that promote more open data sharing, such as the DGA, will potentially lead to enhanced regional innovation capabilities.

Thus, top-down policy coordination must be in tune with regional innovation ecosystem dynamics. This will include the emerging field of monitoring and evaluating the transformative implications of the DGA by establishing feedback loops that embed processes to facilitate continual improvements and the adaptation of regulations based on real-time insights (Ghosh et al., 2021).

One noted EU-level policy coordination actor for SMEs in this space is the European Innovation Data Board (EIDB). SMEs have representation in the EIDB through a designated EU envoy appointed by a network of SME envoys. Currently, seven members were involved in the writing of this paper, of whom five are European-level organizations, including the European DIGITAL SME Alliance. The other two organizations are from Germany (the National Academy of Science and Engineering and the French Health Data Hub). This organizational membership list must scale and include members from other European regions to improve robustness and scalability. In the end, the top-down and bottom-up implementation of the DGA will require multilevel policy coordination and top-down actors who can ease the transition from isolated data silos to scaled interoperability. The impacts of these actors' roles and institutional structures are yet to be clarified, as their connection with innovation ecosystems is just beginning owing to the newness of the DGA and its implications.

Impact of the DGA on SMEs

In contrast to the General Data Protection Regulation (GDPR), the impetus of the DGA is promoting interoperable data sharing for stimulating the European digital economy and innovation and promoting such a concept. The DGA undoubtedly impacts SMEs, which can be data holders, data users, or DISPs. Nevertheless, the legal contradictions and uncertainty in the DGA provide certain challenges to SMEs that face inherent disadvantages compared with resource-rich big tech companies and firms.

For SMEs that want to provide data intermediation services, the European Commission has a lightweight application process that requires DISPs to notify their declaration of intent to provide data intermediation. After notification is given, it is up to competent member-state authorities to check whether the DISP is compliant with articles 11 and 12 of the DGA. However, the process of the compliance check is still undetermined, as is its intensity. For instance, it may just require surface-level investigation of the applicant's materials related to technical infrastructure, organizational capacity, and structures for data security or direct auditing and inspection of the technical and data assets of DISPs. How this evaluator process plays out will have important compliance cost ramifications for SMEs.

SMEs that are data holders or users face numerous technical, business, organizational, and legal challenges in the use of DISPs. As the name implies, SMEs generally have a lower resource capacity for investing in the appropriate levels of data governance and protection, particularly if this requires technical infrastructures such as the installation of security servers or other mechanisms that also have a maintenance cost. From a business perspective, trust is a foundational component of for exchanging data. However, it is difficult for SMEs to build trust with larger partners or competitors, as it is unclear how the “neutrality” of DISPs will play out in practice. Under the DGA, DISPs are not allowed to combine the primary data-exchange function with additional services such as data storage, curation, conversion, anonymization, and pseudonymization. Therefore, DISPs must create a separate legal entity to provide these additional services so as not to cause conflicts of interest. However, this could lead to a legal loophole where “neutrality” is undermined by these separate legal entities. This could give competitors an advantage if they share sensitive data with one another, freezing SMEs to capture their market share.

Data protection from unauthorized access and distribution is fundamental to the viability of data exchange for innovation ecosystems. SMEs may lack the necessary cybersecurity professionals and infrastructure capacity to adequately comply with the DGA as a data holder or user. SMEs may face heightened data security risks, as they may not have the same cybersecurity measures and protocols as larger organizations. Ensuring the security and integrity of data, especially sensitive or personal information, is crucial for compliance with the DGA but can be challenging for SMEs with limited resources. From a legal aspect, navigating and interpreting a complex top-down regulatory environment, especially if they operate in multiple jurisdictions, are a major barrier toward adapting to a fast-changing cross-border data exchange environment.

Nordic-Baltic SMEs Utilizing DISPs for the Silver Economy

In terms of cross-border data flows, the Nordic-Baltic Council of Ministers declared that the region's objective in 2021 was to develop digital services through the "cross-border by default" principle, which, in practice, may necessitate the use of data intermediaries for various purposes (Nordic Council of Ministers, 2023). The Silver Economy is a ripe cross-sectoral market for data intermediation, as it encompasses a large spectrum of domains such as mobility, healthcare, and the labor market, education. Furthermore, these areas tend to have high intersectionality and public sector support, which lead to diverse stakeholder groups and complex data sharing for innovation. For instance, supporting smart living environments for the healthy and active aging of older adults entails the provision of e-services through IoT devices and ICT tools, and research on aging-related diseases and reskilling older adults requires multisectoral stakeholder collaboration. The Nordic-Baltic region already has DMs, DSP, and DISPs for supporting cross-border data sharing and collaboration. Although these do not necessarily focus on the silver economy, they can be potentially leveraged in this area.

One data intermediary in the Nordic-Baltic region is the X-Road. The X-Road data exchange layer is the key technical backbone for cross-border data exchange between Estonia and Finland. It enables seamless and secure data exchange between systems and organizations. The governance of the X-Road core software is overseen by the nonprofit Nordic Institute for Interoperability Solutions (NIIS, 2024), which receives funding from the Estonian and Finnish Ministries of Finance. Estonia, Finland, and Iceland are all members of the NIIS. This indicates a broader regional collaboration in interoperability solutions. While the NIIS governs the overarching framework of the X-Road core software, the respective national authorities manage individual national X-Road instances. These national instances facilitate interoperable data exchange between public and private organizations of each country, and they can be federated to handle cross-border data exchange. They ensure compliance with legal requirements, establish central trust services, manage organizational security servers, and facilitate the necessary agreements between service consumers and producers.

An important rising DM player for cross-border data sharing in the region are common European data spaces. These data spaces will incorporate a federated, interoperable cloud data-sharing infrastructure with embedded data governance principles for eight sectors ranging from health care to cultural domains (Scerri et al., 2022). In addition, the next version of the X-Road has strategic plans to be compatible and interoperable with data spaces technically and supportively. This could provide easier access for SMEs in the region to data spaces due to the geographical proximity of the X-Road ecosystem and its stakeholders. Particularly in the Nordic-Baltic region, where aging has acute effects, the ability to harness data sharing for increasing innovation is still at a nascent level, and how SMEs can leverage some DISPs to increase business capacity remains to be determined.

Recommendations for Nordic-Baltic SMEs in the Silver Economy

Figure 1 presents a lightweight framework for understanding the role of DISPs and the impact of the DGA on SMEs in the Nordic-Baltic Silver Economy. The top-down Data Governance Act regulates and requires both DISPs and SMEs to navigate this legislation through various regional contexts, institutional policy coordination and compliance mechanisms discussed in the next section. As the DGA regulates how Nordic-Baltic SMEs may utilize data intermediaries, SMEs and DISPs will need to establish feedback loops with policymakers, as shown in Figure 1.

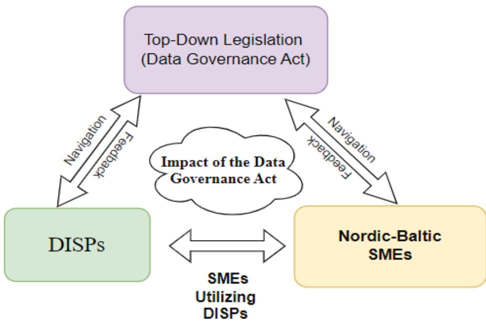

Figure 1: Impact and Navigation Framework

Nordic-Baltic SMEs face a plethora of challenges in cross-border data sharing, especially in a cross-sectoral domain such as the silver economy. To tackle these issues, SMEs must first familiarize themselves with the DGA and use compliance checklist tools that are tailored to organizational business processes. SMEs should also establish internal organizational data governance policies and protocols that not only protect data but also enable data sharing and data quality assessment. A data protection officer can be appointed to help facilitate these processes and implement such policies and protocols.

Contractual agreements between stakeholders are central to engendering trust in data intermediation. Contracts should be developed to be as transparent as possible and clearly elucidate data-sharing purposes, types, protection measures, and liabilities if something goes wrong. Furthermore, engaging in Nordic-Baltic cross-border collaborative projects and partnerships such as the European Health Data Space can help SMEs find a legitimate entry point into data-sharing ecosystems for innovation. SMEs must have internal feedback loops and auditing mechanisms for data management. Inherently, this requires a smart strategy for planning and allocating financial and human resources to achieve strong data governance mechanisms for extracting as much value as possible from data.

CONCLUSION

Ultimately, the concepts of data intermediation are novel; thus, the ramifications of the DGA on SME business processes for data sharing are constantly evolving. Stimulating and integrating data sharing into the European data sharing ecosystem will be a difficult proposition for SMEs given their limited resource and legal capacity. This study is an initial exploratory step to understanding the state of play for data intermediation in the Nordic-Baltic region for SMEs. Future work on this issue entails further investigation into policy interventions under the dynamics of the DGA and the creation of a holistic explanatory model that incorporates cross-border data-sharing intermediaries and data governance in relation to SME business processes and objectives.

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Curriculum Vitae

Personal Data

Name	Eric Blake Jackson
Date and place of birth	23 October 1991, Kirksville, Missouri, United States
Nationality	American

Contact Information

Address	School of Information Technologies, Tallinn University of Technology Akadeemia tee 15a, 12618 Tallinn, Estonia
E-mail	eric.jackson@taltech.ee

Education

2020–Current	Next Generation Digital State Research Group Tallinn University of Technology, School of Information Technologies
2010–2014	MSc. e-Governance Technologies and Services, Tallinn University of Technology, School of Information Technologies
2010–2014	B.Political Science Nebraska Wesleyan University Department of Political Science

Language Competence

English	Native
Estonian	Basic Level

Professional Employment

2020–Current	Early Stage Researcher, Next Gen Digital State Research Group, Department of Software Science, Tallinn University of Technology
2015–2016	Fulbright English Teaching Assistant, US State Department, Batumi Shota Rustaveli University, Batumi, Georgia
2014–2015	Analyst, e-Governance Academy

Voluntary Work

2023–Current	Founding board member of Kristiine Rotary Club

Honours and Awards

- 2024, University Award, "Research article of the year award in the social sciences and humanities category” Tallinn University of Technology, Tallinn, Estonia

- 2021, Tallinn City Award, “Successful supervision of Tallinn City Council scholarship master’s thesis” Tallinn City Council, Tallinn, Estonia

- 2015, Fulbright Scholarship Recipient, Department of State, United States

Defended Theses

- 2020, Design of a Remote Emotional Requirement Elicitation Feedback Method, MSc e-Governance Technologies and Services, supervisor Prof. Dr. Alex Norta, (Tallinn University of Technology), School of IT

Fields of Research[1]

- 4.6. Computer Science
- 4.7. Information and Communications Technologies

Scientific Work Papers

1. E. B. Jackson, R. Dreyling, and I. Pappel, "A historical analysis on interoperability in estonian data exchange architecture: Perspectives from the past and for the future," in *Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance*. Association for Computing Machinery, 2022, p. 111–116
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[1] Estonian Research Information System (ETIS) fields of research

Elulookirjeldus

Isikuandmed

Nimi	Eric Blake Jackson
Sünniaeg ja -koht	23. märts 1991, Kirksville, Missouri
Kodakondsus	Ameeriklane

Kontaktandmed

Aadress	Tallinna Tehnikaülikool, Infotehnoloogia teaduskond, Tarkvarateaduse instituut, Infosüsteemide rühm, Akadeemia tee 15a, 12618 Tallinn, Estonia
E-post	eric.jackson@taltech.ee

Haridus

2020–	Järgmise põlvkonna digitaalse riigi uurimisrühm, Tallinna Tehnikaülikool, Infotehnoloogia teaduskond, doktoriõpe
2018–2020	MSc. e-valitsemise tehnoloogiad ja teenused, Tallinna Tehnikaülikool, Infotehnoloogia teaduskond
2010–2014	B. Political Science Nebraska Wesleyan University politoloogia osakond

Keelteoskus

inglise keel	emakeel
eesti keel	põhitase

Teenistuskäik

2020–	Järgmise põlvkonna digitaalse riigi uurimisrühm Tarkvarateaduse instituut, Tallinna Tehnikaülikool
2015–2016	Fulbright English Teaching Assistant, Ameerika Ühendriikide välisministeerium Batumi Shota Rustaveli University, Batumi, Georgia
2014–2015	Analyst, e-Governance Academy Tallinn, Estonia

Vabatahtlik töö

2023–Current	Kristiine Rotary Klubi asutajaliige

Autasud

- 2024, Ülikooli auhind, "Aasta teadusartikli auhind sotsiaal- ja humanitaarteaduste kategoorias" Tallinna Tehnikaülikool, Tallinn, Eesti
- 2021, Tallinn City Award, “Use of ICT in Education for Online and Blended Learning” Tallinn City Council, Tallinn, Eesti

- 2015, fulbrighti stipendiumi saaja, Ameerika Ühendriikide välisministeerium, Ameerika Ühendriigid

Kaitstud lõputööd

- 2020, Design of a Remote Emotional Requirement Elicitation Feedback Method, e-valitsemise tehnoloogiad ja teenused, supervisor Dr. Alex Norta, (Tallinna Tehnikaülikool), Infotehnoloogia teaduskond

Teadustöö põhisuunad[2]

- 4.6. Arvutiteadused
- 4.7. Info- ja kommunikatsioonitehnoloogia

Teadustegevus

1. E. B. Jackson, R. Dreyling, and I. Pappel, "A historical analysis on interoperability in estonian data exchange architecture: Perspectives from the past and for the future," in Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance. Association for Computing Machinery, 2022, p. 111–116.
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[2] Eesti Teadusinfosüsteemi (ETIS) teadusvaldkondade ja -erialade klassifikaator

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