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FINDING ALTERNATIVE USE CASES FOR ESTONIA'S GOVERNMENTAL ELECTIONS SOFTWARE

Master's Thesis

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PhD

Tallinn 2024

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

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RIIKLIKE VALIMISTE TARKVARA ALTERNATIIVSETE KASUTUSJUHTUDE LEIDMINE

Magistritöö

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Tallinn 2024

Author's Declaration of Originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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15.12.2024

Abstract

This thesis explores the potential for repurposing Estonia's governmental election software, originally developed for national elections, to support non-governmental and alternative use cases. Estonia's globally recognised internet voting systems, the Electronic Voting System (EHS) and Elections Information System (VIS), serve as the focal point of this research. These systems, designed with significant investments to ensure security, transparency, availability and accessibility, currently cater exclusively to national elections. However, their limited application highlights an opportunity for broader usage in diverse contexts.

The study combines a comprehensive analysis of Estonia's current electoral framework, a thematic review of qualitative data from stakeholder interviews, and an evaluation of technical and organisational requirements. Through this, the research identifies the potential user base, acceptance criteria, and challenges associated with extending these systems to alternative uses, including internal elections within political parties, university governance, and citizen-driven initiatives.

Findings reveal that existing systems meet many technical and operational requirements for broader use but face challenges related to user readiness, governance, and adaptability to varied contexts. The study provides recommendations for enhancing system interoperability, usability, and scalability to accommodate these new use cases. It concludes that with strategic modifications, Estonia's election software could serve as a robust foundation for fostering democratic participation beyond governmental contexts, contributing to the broader vision of digital governance innovation.

The thesis is written in English and is 88 pages long, including 9 chapters, 15 figures and 23 tables.

Annotatsioon

Käesolev magistritöö uurib võimalusi Eesti riiklike valimiste tarkvara taaskasutamiseks alternatiivsetel kasutusjuhtudel. Uurimuse keskmes on Eesti rahvusvaheliselt tunnustatud valimiste tarkvarasüsteemid, mis on arendatud spetsiaalselt Eesti riiklike valimiste läbiviimiseks: Elektrooniline Hääletamissüsteem (EHS) ja Valimiste Infosüsteem (VIS). Nende süsteemide väljatöötamiseks on tehtud märkimisväärseid investeeringuid, et tagada turvalisus, läbipaistvus ja töökindlus Eesti riiklikel valimistel. Sedavõrd kõrgetele standarditele vastavate süsteemide puhul loob nende piiratud kasutusjuhtude olemasolu võimaluse laiemate rakendusviiside uurimiseks erinevates kontekstides.

Uurimus ühendab endas põhjaliku analüüsi Eesti valimissüsteemi hetkeolukorrast, kvalitatiivsete andmete temaatilise ülevaate sidusrühmade intervjuudest ning tehniliste ja organisatsiooniliste nõuete hindamise. Selle tulemusena määratletakse potentsiaalne kasutajaskond, aktsepteerimiskriteeriumid ja väljakutsed, mis kaasnevad nende süsteemide laiendamisega uutele kasutusvaldkondadele, nagu näiteks poliitühenduste valimised, ülikoolide juhtimine ja kodanikualgatused.

Tulemused näitavad, et olemasolevad süsteemid vastavad paljudele tehnilistele- ja operatiivsetele nõuetele, kuid nende rakendamisel uutes kontekstides esineb väljakutseid, mis on seotud kasutajate valmisoleku, juhtismismudelite ja kohandatavusega. Uuring pakub soovitusi süsteemi koostalitlusvõime, kasutajasõbralikkuse ja skaleeritavuse parandamiseks, et toetada uusi kasutusvõimalusi. Kokkuvõttes järeldatakse, et strateegiliste muudatustega võiks Eesti valimistarkvara olla tugev alus demokraatliku osaluse laiendamiseks väljaspool riiklike valimiste konteksti, aidates kaasa innovatiivse digitaalse valitsemise visiooni elluviimisele.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 88 leheküljel, 9 peatükki, 15 joonist, 23 tabelit.

List of Abbreviations and Terms

AD	Active directory
API	Application programming interface
CERT-EE	Computer Emergency Response Team - Estonia
CIA	Criticality, integrity, availability
e-ID	Electronic identity
EHS	Elektrooniline Hääletussüsteem (Electronic voting system)
EIF	The European Interoperability Framework
ELVL	Eesti Linnade ja Valdade Liit (Union of Estonian cities and parishes)
EMB	Electoral management body
EP	Euroopa Parlament (European Parliament)
ESB	Enterprise service bus
EU	European Union
IaaS	Infrastructure as a service
IAM	Identity and access management
ICT	Information and communications technology
IP	Intellectual property
IS	Information system
IVXV	Estonian internet voting system
KOV	Kohaliku omavalitsuse volikogu (Local municipality council)
MKM	Majandus- ja Kommunikatsiooniministeerium (Ministry of Economic Affairs and Communications)
MVP	Minimum viable product
OSSD	Open source software development
REST	Representational state transfer
RH	Rahvahääletus (referendum)
RIA	Riigi Infosüsteemi Amet (Information System Authority)
RIT	Riigi IT Keskus (Estonian IT Centre)
RK	Riigikogu (Parliament of Estonia)
RQ	Research question
RVT	Riigi valimisteenistus (State Electoral Office of Estonia)
SaaS	Software as a service

SLA	Service-level agreement
SOA	Service-oriented architecture
SQ	Sub-question
TARA	Riigi autentimisteenus (State authentication service)
UI	User interface
UX	User experience
VIS	Valimiste Infosüsteem (Elections Information system)
VOLIS	Kohalike omavalitsuste istungite infosüsteem (Local municipality councils sessions information system)
VVK	Vabariigi Valimiskomisjon (National Electoral Committee)

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1 Introduction

Estonia is a global pioneer in digitalizing its election system, being the first nation to implement internet-based voting across all governmental and national elections. Estonia has developed two foundational information systems over the years: the Electronic Voting System (EHS) and the Elections Information System (VIS). Developing and maintaining these systems required multimillion-euro investments, focused exclusively on national elections, which occur less than once annually on average. These systems serve as the bedrock for orchestrating Estonia's national elections, meticulously designed and scrutinised to meet the highest standards [1].

1.1 Motivation of research

The State Information System Authority of Estonia (RIA) has played a pivotal role in the development of the Elections Information System (VIS), offering critical technical expertise for the operation and maintenance of both VIS and the Electronic Voting System (EHS). Recently, a new voting method enabling voters to cast their ballots via mobile devices has been proposed and advanced to the proof-of-concept stage[1]. Furthermore, RIA has explored the potential of existing technologies to propose an innovative national service, 'elections/voting as a service'.

The Digital Society 2030 development plan, outlined by the Ministry of Economic Affairs and Communications (MKM), identifies the underutilisation and reuse of state-developed services and information systems as a significant challenge [2]. This recognition has spurred an exploration of opportunities to revitalise these technologies, emphasising innovation and efficiency as cornerstones of Estonia's digital future. While still in its conceptual phase, the initiative envisions Estonia, potentially through the State Information System Authority (RIA), offering a government-certified service that enables citizens and residents to conduct elections or votes on various topics. However, progress on advancing the project to the next stage has been impeded by uncertainties regarding the potential user base and their readiness to adopt such a service, leaving the initiative largely conceptual and undeveloped.

The author's motivation originates from their professional role within RIA's election

[1] https://ria.ee/riigi-infosusteem/kesksete-riiklike-infosusteemide-arendus/valimiste-infosusteem-ja-e-haaletamine

software development department, where they are tasked with developing, managing, and operating election information systems, as well as investigating and analysing potential innovative technological solutions. Their responsibilities include overseeing and coordinating the development, analysis, operation, and innovation of the systems examined in this study.

1.2 Problem statement

Despite political and innovative enthusiasm to design a 'voting system for everybody,' there is a notable lack of understanding regarding the potential user base and the service's viability. Designing a new service requires addressing key questions:

- Who are the potential users of a proposed service?
- What are the business needs of the users?
- What are the technological requirements for satisfying the needs?
- How can current technological solutions be leveraged to satisfy those needs?

Although Estonia has a central organization responsible for addressing these questions for governmental elections, there is minimal coordination among potential participants in democratic practices within the non-governmental sector [3].

1.3 Research goal

The primary objective of this research is to identify the core user base, their needs, and the potential use cases for the proposed service. In the form of a case study about current Estonia's governmental elections software solutions, it further seeks to analyse and validate the potential reuse of existing software, systems, or components for alternative election types. The primary audience for this study comprises policymakers who drive the innovation and development of democratic technology tools. In addition, the identified parties of interest or, on a larger scale, the Estonian public may benefit from this research.

Although the broader project of discovering and implementing alternative use cases for Estonia's governmental elections software spans at least a few years, this research zeroes in on the foundational aspects of the project. The central research question (RQ) guiding this study is: ***RQ. How to use Estonia's governmental elections software for alternative use cases?***

The alternative use cases will be explored and studied by finding answers to the following sub-questions (SQ):

- ***SQ1. Who could be potential users of the election software?***
- ***SQ2. What is the required acceptance criteria for potential adoption of alternative solutions?***
- ***SQ3. What are the limitations/considerations of expanding the existing software/system to meet the criteria?***

1.4 Thesis outline

The thesis is organised into nine chapters. Chapter 1 provides an introduction, outlining the motivation, purpose, and objectives of the study. Chapter 2 reviews the most relevant related work in the field of internet voting, offering a foundation for the research. Chapter 3 defines the theoretical framework, establishing the boundaries of the study and presenting the key theories and models used. Chapter 4 describes the research methodology, detailing the approach and techniques employed in the study.

Chapter 5 examines the current state of elections in Estonia and the software supporting them, presenting a comprehensive overview of the as-is situation. Chapter 6 analyses the results of the conducted interviews, providing insights into stakeholder perspectives and practical considerations. Chapter 7 discusses the findings, integrating insights from earlier chapters to address the research objectives. Chapter 8 outlines the limitations of the study and presents recommendations for future research. Finally, Chapter 9 concludes the thesis with a summary of key insights and contributions.

2 Related work

This chapter reviews existing research and developments in the field of internet voting, with a focus on the theoretical and practical frameworks that inform secure and transparent digital election systems. It examines key studies and projects relevant to Estonia's governmental election software and explores how advancements in e-governance and service design can guide the adaptation of these systems to alternative use cases. By situating this study within the broader academic and practical context, the chapter establishes a foundation for the subsequent analysis and recommendations. The initial relevant previous studies were found through the works and references of relevant authors and key researches within the field through author's direct knowledge and involvement. Further studies were identified through academic library search engines like TTÜ's PRIMO [1] and Google Scholar [2]. Where applicable, more recent studies were preferred, as especially technological trends and advancements may change rapidly.

The Estonian internet voting phenomenon has been studied extensively from different aspects ranging from effects on voter turnout [4] and threat models [5] to cost [6] and administrative burdens [7]. The initial beginning of the system is well-documented in studies, that explore the underlying concepts and prerequisites, that are necessary for a nation to adopt the concept of internet voting and why to date, Estonia is still the sole nation, that does this in the world [8], [9].

In 2022, a comprehensive study was published examining Estonia's internet voting system from 2005 to 2019 [1]. The article provides an in-depth analysis of various aspects of the system, including its general usage, the selection of technologies, public trust, security, transparency, privacy measures, operational processes, and its evolution over time. Additionally, it explores potential future developments for internet voting in Estonia. The article provides valuable insights into the prerequisites, challenges, and limitations of implementing internet voting, offering lessons not only for Estonia but also for other nations exploring similar initiatives. Drawing on the experience of 11 governmental elections held during this period, the article identifies five key takeaways, three of which are particularly pertinent to the present study:

Firstly, the success of nationwide internet voting in Estonia is attributed to three foundational elements: robust technological infrastructure, legislative support, and strong

[1] https://taltech.ee/raamatukogu-portaal
[2] https://scholar.google.com/

political will coupled with public trust. These elements are critical enablers, without which the transition to internet voting or the adoption of technology-driven election solutions is unlikely to progress beyond experimental stages. This insight underscores the necessity of a well-established digital ecosystem and governance framework for the effective implementation of internet voting.

Secondly, the study cautions against the misconception that internet voting is primarily a tool to reduce the administrative burdens associated with traditional paper-based voting. While it might appear to simplify election management, internet voting is better understood as an advanced digital service offered by a mature digital government. Such a service assumes that the fundamental requirements for conducting traditional elections are already met. For alternative use cases, this distinction is significant. If reducing administrative costs is a primary acceptance criterion for adopting new electoral technologies, policymakers should be aware that internet voting may not inherently fulfil this expectation.

Thirdly, the article finds that internet voting does not necessarily lead to a significant increase in voter turnout compared to traditional voting methods. If the primary objective of implementing internet voting is to enhance electoral participation, its impact may be limited. However, internet voting may be more effective for dispersed electorates, where accessibility challenges might otherwise discourage voter engagement.

As Estonia is effectively the global leader in implementing internet voting as a viable option for casting votes in governmental elections, there exists limited similar extensive experience-based research from other countries on comparable cases [10]. The limited scholarly work highlights the novelty and complexity of Estonia's approach, establishing it as a pioneering model. While there is some research emerging from developing countries, much of it is superficial or not relevant in this study's case. These studies often lack consideration for critical aspects such as high-level software development practices, system security, and organizational processes [11], [12]. Furthermore, varying definitions and applications of terminology exacerbate the challenge of drawing meaningful comparisons. Terms such as 'e-voting', 'electronic voting', 'internet voting', 'i-voting' and 'online voting' are often used interchangeably in the literature and may refer to exact same or vastly different technologies, features, or systems, leading to significant semantic and conceptual inconsistencies [13], [1], [14], [11].

This study focuses specifically on internet voting systems that allow users to cast their votes via personal computers or mobile devices using electronic means. This distinguishes the discussion from systems commonly studied in the United States, which

predominantly centre around voting machines used at polling stations and are often referred to as 'electronic voting systems'. Unlike the U.S. model, Estonia's system distributes voting software directly to voters' devices over the internet, fundamentally changing the dynamics of voter interaction with the electoral process [15].

However, several comprehensive works evaluate other countries, that are in different stages of considering the use of internet voting[16], [14]. As an example, in addition to Estonia, Switzerland has explored internet voting since as early as 1998, employing principles similar to those used in Estonia. A notable consideration from Swiss research is the risk of 'de-ritualising' voting, which raises questions about the potential cultural and societal impacts of transitioning to internet-based electoral processes. [17].

Other countries, such as Germany, have also investigated the use of electronic means for voting. However, their focus has often been motivated by the need to manage the logistical challenges posed by their complex ballot structure. German ballots are substantially larger and allow for multiple choices, in contrast to Estonia's simplified system, where voters typically indicate a single candidate number on the ballot [18]. In Czechia, a study on internet voting's impact on voter turnout found limited support, suggesting the effects may be context-specific [13].

It is important to note that most research on internet voting focuses predominantly on internet voting as a phenomenon, with the systems discussed in these studies almost exclusively addressing voting information systems. Election information systems are rarely, if ever, examined as distinct entities. While some studies from Estonia [19], [20] and Finland [21], [22] cover election information systems, that refer to information systems that are used for central elections management by the elections organisers, their relevance to the present research is minimal.

Although Estonia's governmental elections software has gained international recognition for its architecture and design, security, and transparency, there remains a significant lack of research on its potential for multi-purpose applications beyond traditional electoral contexts. This gap highlights the need for an in-depth investigation into the feasibility, challenges, and benefits of leveraging Estonia's election software for broader societal applications, including public polling, citizen engagement platforms, and other decision-making processes.

3 Theoretical background

This study is centred around two key theoretical areas: democratic processes and service design. Democratic processes, primarily social mechanisms and principles, form the foundational framework that drives the need for service-oriented systems and technologies. These processes underscore the societal requirements for transparency, inclusivity, and participation, which are essential in shaping digital governance tools [8]. In contrast, service design, including interoperability and service architecture address the practical and technical dimensions necessary to enable the development of a versatile, multi-purpose solution [23]. Together, these theoretical areas provide a comprehensive lens through which to analyse and conceptualise the adaptation of Estonia's governmental election software for alternative use cases.

3.1 Democratic processes

Democracy, at its core, is often associated with majority rule, but it also serves as a safeguard against the concentration of power in the hands of a few entities. By distributing decision-making authority, democratic systems promote inclusivity, accountability, and equitable governance. One of the most prominent, and in the context of this thesis, central, democratic processes is elections. Elections are comprehensive events that frequently include voting as a sub-process. However, it is essential to distinguish between the two, as they fulfil different purposes. Elections encompass a broader set of activities aimed at selecting representatives or making collective decisions, while voting represents the specific act of expressing a preference or choice. Importantly, elections can occur without involving voting, and conversely, voting does not always lead to an outcome in which something or someone is elected [24].

Another significant democratic process relevant to this study is citizen initiatives. These initiatives enable groups of individuals to voice their concerns or propose ideas outside the routine operations of elected representatives. In some cases, citizen initiatives are supported by governmental frameworks that formalize and empower their influence. In Estonia, for example, collective proposals must be addressed by the Riigikogu if they garner at least 1,000 signatures [25]. Similarly, local municipalities are required to respond to proposals that receive signatures from at least 1% of the local population [26]. These mechanisms exemplify how democratic processes can extend beyond traditional electoral systems, offering citizens additional pathways to participate in governance

and decision-making.

H. Blumer identified already in 1948 that public opinion polling is shaped by the formation of functional groups within society. These groups leverage available tools and communication channels to express and act upon their collective ideas and interests [27]. This characterisation underscores the dynamic interplay between societal structures, technological tools, and collective behaviour in shaping public opinion and its measurement. An example of a functional group being provided with a platform to express their opinions is Rahvaalgatus.ee, a web platform that enables individuals with an Estonian e-ID to draft and digitally sign proposals directed to the Estonian Parliament (Riigikogu) [28]. The platform is managed by the Estonian Cooperation Assembly, which, in collaboration with the Finnish Innovation Fund Sitra, has published an extensive analysis on the state of citizen initiatives in Finland and Estonia [3]. The analysis highlights several advantages and disadvantages of systems with clear state ownership. On the one hand, being independent and not directly affiliated with central government structures may foster greater autonomy, agility, and potential for innovation. On the other hand, state ownership offers benefits such as enhanced stability, accountability, and long-term sustainability. These findings underscore the trade-offs inherent in the governance of citizen initiative platforms, providing valuable insights for designing systems that balance independence with institutional support.

3.1.1 Principles of internet voting

In 2005, the e-Governance Academy introduced the 'Principles of Fair i-Voting', a comprehensive framework aimed at ensuring the integrity, transparency, and fairness of internet voting systems. Recognizing the transformative potential of digital voting in enhancing accessibility and efficiency, the Academy outlined these principles to safeguard democratic processes in Estonia. Over the years, these principles have been consistently updated to reflect advancements in technology and changes in societal expectations. Furthermore, the Academy actively encourages political parties in Estonia to uphold their commitments to these principles, which remain a cornerstone of the nation's digital democracy [29].

The "Principles of Fair i-Voting" emphasise several core tenets:

- Transparency and Clarity: The organization of the internet voting process must be transparent and easily understandable to voters. This includes ensuring that all aspects of the process comply with established election laws, thereby fostering trust in the system and its outcomes.

- Voter Autonomy and Freedom: A critical component of fair i-voting is the protection of voter autonomy. Voters must have the ability to make their choices independently, without any form of coercion, intimidation, or undue influence from external parties, including individuals or political organizations.
- Auditability and Verification: To maintain confidence in the internet voting system, the process must be fully auditable. This means that independent verification mechanisms should be in place to allow scrutiny of the system's functionality and integrity. Additionally, voters themselves must be able to verify that their votes have been cast and recorded accurately, ensuring their will is correctly represented [30].

P. Wolf introduces the concept of the 'E-voting Pyramid of Trust,' as illustrated in Figure 1. This framework categorises the e-voting ecosystem into three interdependent layers: the credible electoral process, the socio-political context, and the operational/technical context. It posits that the overarching objective of any electronic voting system is to foster trust and confidence in the electoral process. Achieving this requires the appropriate alignment of political governance, societal expectations, and inclusivity. The socio-political context is supported by a foundational layer that integrates operational capacity building, well-defined legal frameworks, robust commercial arrangements, and a transparent, auditable ICT infrastructure. Given sufficient time for proper implementation, these elements collectively enable the system to realise its ultimate goal of cultivating trust [31].

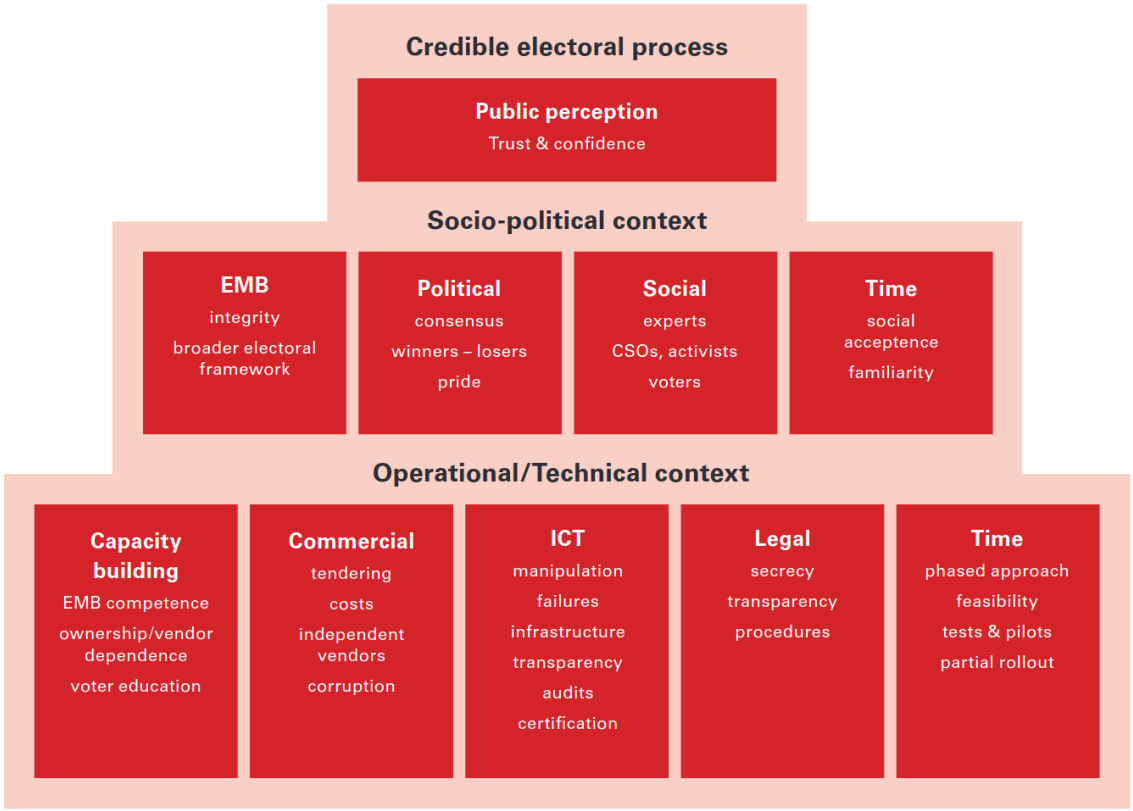

Figure 1. The E-Voting Pyramid of Trust [31]

These principles could also serve as a model for other organisations seeking to implement secure and equitable online voting systems and should be taken into consideration, especially when developing the new governance models and processes supporting alternative elections use cases.

3.2 Service design

An important distinction to make is the difference between product and service design. Products are usually satisfying the need for a single specialised feature or set of features that are marketed or sold to potential customers at as-is state and are managed and serviced by the customer. The services on the other hand offer a more ambiguous good, that is composed of multiple features and characteristics from different related areas, such as lifecycle management and technical support. Service tends to evolve over time and is often wholly or partially centrally hosted by the service provider. The general trend in software starting already in the early 2000s has been moving from product-centric model to service centric model with emphasis on the software as a service (SaaS) model [32].

A proposed defining key aspect of offering a service in an article by Susan Meyer Goldstein et al is 'service concept' [33]. The argument is, that potential customers are more likely looking for a whole package of features and background technologies, that together offer a holistic experience as opposed to a pre-defined set of features, that must be accepted by the customer and configured within confined boundaries to fit their needs. The article also proposes four underlying ideas or crucial areas, that in theory should be all complemented by the service concept to enable providing a holistic and complete service as designed.

The ideas are depicted on Figure 2 and notably proposes, that service concept should firstly be aligned to the strategic intent of the organisation providing or designing the service, while meeting the needs of customer and solving all the questions of what and how to design between them.

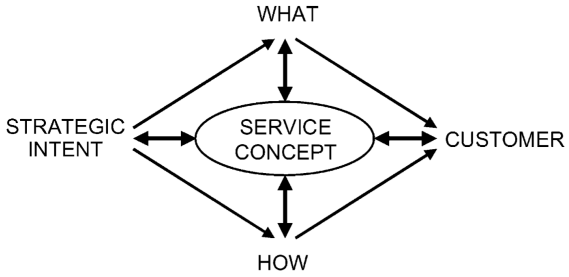

Figure 2. Service concept [33]

There are two broad frameworks for designing e-services, bits of which are well applicable to the present research. Estonia's 'E-service design toolbox' [1] and EU's 'European Interoperability Framework' (EIF) [2]. The European Commission's 'eGovernment Benchmark 2024 Insight Report' highlights interoperability, digital sovereignty, and digital resilience as key priorities within the current EU digital policy framework [34]. These priorities are closely aligned with the objectives of the Interoperable Europe Act, which aims to establish a structured EU cooperation network. This network facilitates collaboration among various public and private stakeholders to share and reuse solutions, primarily open-source technologies, while being supported by innovation and assistance measures. These measures are designed to enable the joint development of technological projects across different governance levels [35]. The overarching framework for this initiative is the European Interoperability Framework (EIF), which seeks to harmonise public sector organisations and services across various levels to enhance interoperability. The EIF defines four key dimensions of interoperability: legal, seman-

[1] https://digiriik.eesti.ee/en/frontpage
[2] https://interoperable-europe.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/european-interoperability-framework-detail

tic, organisational, and technical. Further details on these dimensions are presented in Figure 3 [36]. In addition to the four layers, the framework lists underlying principles and 47 recommendations (listed in Appendix 5) to the policymakers and designers of new digital public services. These layers and principles help to set the general areas of consideration for the further discussion in this study.

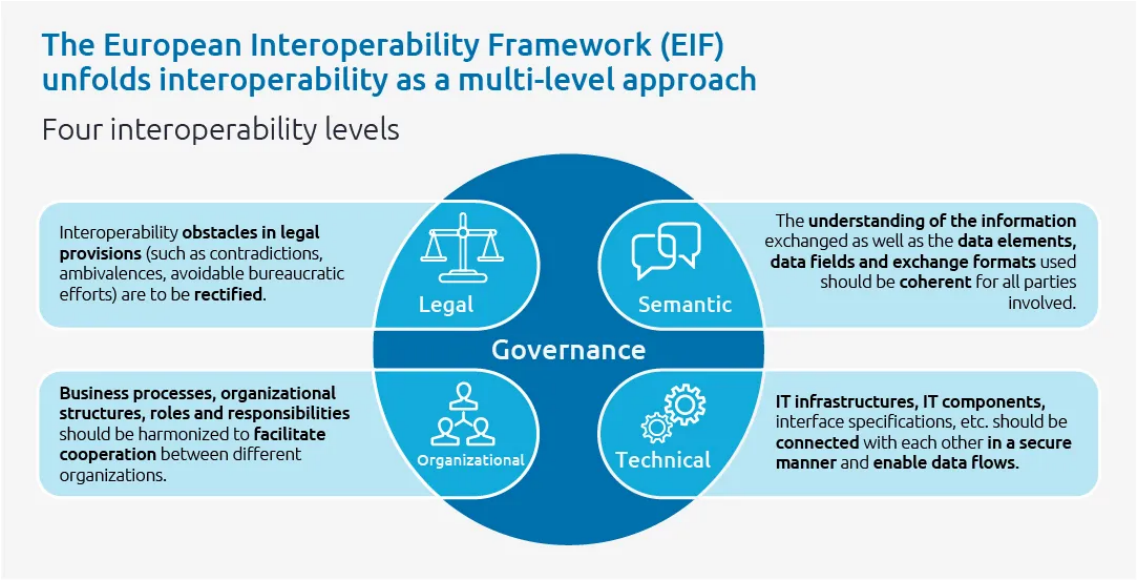

Figure 3. EIF interoperability levels [36]

Estonia's E-service Design Toolbox, built on the Estonian Interoperability Framework (which adheres to the principles of the European Interoperability Framework), provides a comprehensive set of tools and methods to guide service designers in developing new e-services. The framework encompasses the entire lifecycle of a service, clearly distinguishing between operation and development cycles. The development cycle itself is further divided into six stages [37]:

Understanding and choosing a focus: Analyse current processes to identify areas for improvement, determine the scope of the project, and align objectives with both organisational goals and user needs.

Solving: Engage stakeholders to brainstorm and develop innovative solutions, considering legal constraints and data protection requirements, and clearly define the desired service outcomes.

Testing the solution: Develop prototypes and conduct user testing to validate assumptions, gather feedback, and refine the service to better meet user expectations.

The development of IT-solution: Create a detailed development plan, assemble the technical team, and implement the IT solution, ensuring alignment with the service design and organisational standards.

Commissioning: Launch the service to the public, monitor its performance, and make necessary adjustments to ensure it operates effectively and meets user needs.

Sharing experiences: Document lessons learned, share best practices, and gather feedback to inform future projects and promote continuous improvement in service design.

While a whole project design should cover all of the stages, this study specifically focuses on the first two of understanding and choosing a focus and solving stages. This includes mapping and analysing the existing as-is processes and capabilities, brainstorming ideas and avenues to explore, talking to the related parties and identifying their needs and expectations. The latter stages can use the results of this study as a baseline for further work.

3.2.1 Service architecture

Modern service architecture increasingly leverages cloud-based infrastructure to achieve scalability, flexibility, and efficiency. This paradigm shift is driven by the adoption of Software as a Service (SaaS) and Infrastructure as a Service (IaaS) models, which abstract traditional IT complexities and offer services on-demand. SaaS provides end-users with ready-to-use applications accessible via the internet, eliminating the need for extensive local deployment. IaaS, on the other hand, supplies virtualised computing resources, allowing organisations to outsource hardware management while retaining control over application development and deployment. Organisations typically choose between public clouds, where resources are shared among multiple users, and private clouds, which offer dedicated infrastructure for enhanced security and compliance. These decisions are guided by the principles of confidentiality, integrity, and availability (CIA), which are critical to ensuring secure and reliable service delivery. Confidentiality safeguards sensitive data against unauthorized access, integrity ensures the accuracy and consistency of data across systems, and availability guarantees that services remain accessible and operational under varying conditions [38].

A key characteristic of modern service architecture is its division into microservices. Unlike monolithic systems, microservice design decomposes applications into smaller, independently deployable services. Each microservice focuses on a specific business

capability and communicates with others through lightweight protocols, such as REST APIs or messaging queues. This architectural approach aligns seamlessly with cloud environments, as it facilitates horizontal scaling, resilience, and rapid development cycles. In comparing Service-Oriented Architecture (SOA) to microservice architecture, both focus on service modularity but differ in their implementation and granularity. SOA emphasises reusability and integration, often relying on centralized governance and enterprise service buses (ESBs) for communication. Microservices, in contrast, favor independence and decentralisation, with each service managing its own database and leveraging lightweight communication protocols. This results in greater flexibility, faster deployments, and improved scalability, though it can introduce challenges in managing distributed systems [39].

3.3 Key theoretical considerations

In summary of the theoretical background and frameworks, this study considers several key concepts in its later chapters to explore the design of a modular and adaptable framework for alternative use cases of existing services. These concepts include the principles of democratic processes and internet voting, the definition of core service concepts within service-oriented design, and the operation of services within the framework of interoperable e-government systems. Additionally, the study examines the integration of SaaS and IaaS models, cloud-based and microservice architectures, and the application of CIA principles to ensure secure and efficient service delivery.

4 Research methodology

Given the objective of expanding an already established service and its associated functioning system, a case study approach is well-suited to this exploration. This is further supported by several key principles, including that the study focuses on the preliminary stages of a concept, examines a distinguishable entity within a relatively fixed environment, and evolves over time, with the exact boundaries being defined as the work progresses [40].

This research focuses on a phenomenon that is primarily a software engineering problem, interwoven with aspects of political and social sciences. Due to the limited existing research, an exploratory case study methodology was chosen as the foundational approach. The research employs qualitative data gathering and analysis methods to explore the theoretical application of software technology, aiming to establish a baseline for potential new service designs [41].

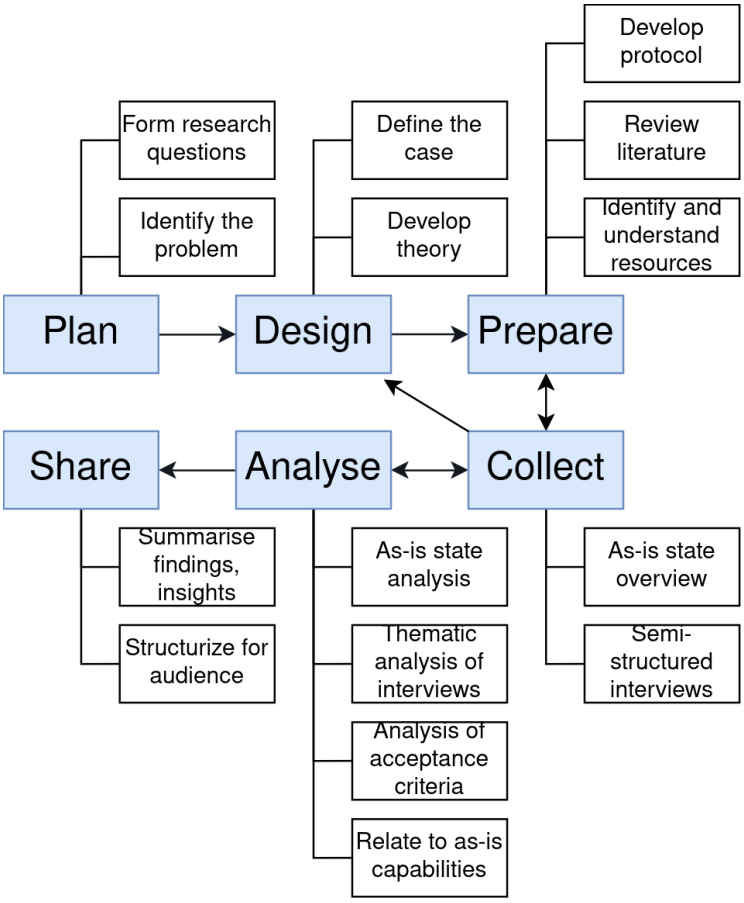

Figure 4. Applied research process

The research process follows the general principles of Robert K. Yin's case study research design. Through initial planning and designing, aided by literature review and further domain analysis, that build upon existing knowledge and assumptions within the field and area of research, the structure of the methodology is formed. This structure assists to set the main research question and sub-questions as the drivers of the study, that are eventually answered through the analysis and summarisation of the collected information [42]. The design of this research is also depicted on Figure 4. Due to lack of central collection or existing database of elections and voting related stakeholders existing in Estonia, qualitative data gathering approach using focused interviews to explore further potential key aspects and parties is deemed well fitting [43].

4.1 Secondary data sources

Secondary data sources are used to describe the current state of the election process and the capabilities of the software in use. Information about governmental elections is documented precisely in elections laws [44],[45],[46],[47]. The statistics and historic data about the past elections is mostly in uniform format with the exception, that over the years some aspects have changed. The public information about the governmental elections organisers is just as well documented on the organiser's public pages [1], that contain references to all the necessary documentation in the governmental document registries.

Documentation, architectural design papers and work process regarding the existing software vary. IVXV protocol and EHS documentation is completely public with the exception of the voting app [2]. This is, however, enough for this study. The documentation regarding VIS is not public, but the author has access to this through professional relationship with RIA. The code and documentation revealed here does not contain any classified or for internal use only information and is generalised to an extent. A noteworthy portion of the knowledge and specifics regarding existing software solutions has been obtained first-hand, lacks formal documentation, and may therefore be somewhat biased.

Other non-governmental software, such as VOLIS [3] and rahvaalgatus.ee documentation and analysis documents are publicly available [4]. The analysis documents of VOLIS2 give a relevant and high quality data to refer to in this study [48], [49].

[1] https://www.valimised.ee/
[2] https://github.com/valimised/ivxv
[3] https://koodivaramu.eesti.ee/elvl/volis
[4] https://github.com/rahvaalgatus/rahvaalgatus

4.2 Primary data sources

Main primary data collections source for the study are semi-structured interviews, since they are well suited for open ended topics such as exploring potential new use cases and acceptance criteria. Some interviews had more than one participants with differing backgrounds, which similarly to holding focus group meetings brought out characteristics or input, that could be conflicting or otherwise not transformable into uniform data [50].

The selection of interviewees was done based on as-is model of current and publicly known elections related software developers and users (including potential ones), who are already either involved in the development, are actively using some or have shown previous interest in potentially using either elections or voting software, or were further identified in the exploration exercise. During the exploration exercise, each candidate group was given based on author's personal experience and connections within the sector a potential relevance ranking on the scale of 'low', 'medium' and 'high'. The results of the interview candidate exercise are brought out in Appendix 3. Those, who were deemed to have 'high' potential relevance were considered for interviews.

The potential interview candidates were separated into three groups based on their stakeholder position. An organisation or candidate is not limited to a single stakeholder position and may hold multiple at the same time. The groups were:

- Organisers and owners. The stakeholders, that hold key responsibility in providing a service. Often business owners.
- Users and clients. End users of a given solution or service.
- Support and expertise. Stakeholders, that have a specialised expertise in a certain field, that is applicable to elections and voting software, technologies and their support.

Best suited stakeholders were listed as shown in Table 1.

Organisers/owners	Users/clients	Support and expertise
Ministries	Universities	RIA
Governmental elections organisers	Political parties	Nortal AS
City councils and local municipalities	City councils and local municipalities	Cybernetica AS
ELVL	Prosecutor's Office	ELVL
Unions of organisations	Unions of organisations	RIT
Estonian Cooperation Assembly	Bar Association	

Table 1. Interview candidates grouped by stakeholder position

Of the identified candidates, at least 4 from each group were selected to be asked to be interviewed. Candidates, who fit into multiple categories were preferred, as they could provide views from multiple stakeholder positions. A total of 12 organisations were contacted and inquired about the willingness to conduct an interview. 10 of them responded positively and 2 gave no answer. Of the 10 respondents who showed interest in the topic, 9 in total were confirmed to have adequate background and could provide useful and insightful input into the study.

The interviews followed a systematic approach to ensure consistency and thoroughness across all sessions. The main goal of the interviews was to gather data, that would assist in answering the RQ and SQs of this research. The process consisted of the following steps:

1. **Initial contact:** Potential interview candidates were contacted via email or direct messaging, providing a brief description of the study and inquiring about their interest in participating.
2. **Participant selection:** Candidates who responded positively were assessed for their relevance and expertise. Organisations with representatives fitting multiple stakeholder categories were prioritised to provide diverse perspectives.
3. **Interview preparation:**
   - Details regarding the project, study objectives, and the specific insights sought from each participant were shared in advance.
   - Participants were encouraged to include colleagues or additional experts to enrich the discussion.
   - The publicly available information about the interviewed organisations and their relation to elections was gathered and based on that, the general interview questions were adjusted. The specific topics covered with each

organisation are brought out in Appendix 2.

4. **Scheduling and logistics:**
   - Interviewees were offered three options for conducting the interview:
     (a) Physical meetings at the interviewee's location.
     (b) Physical meetings at RIA's office.
     (c) Virtual meetings via Teams or similar service.
   - The date, time, and location (or platform) were confirmed, along with a list of participants.
5. **Conducting interviews:**
   - At the start of each session, participants were provided with a brief introduction to the study and its objectives.
   - Verbal consent was obtained for recording the session and the use of collected data was explained to the interviewees.
   - Interviews began with pre-determined topics and adapted dynamically to explore relevant side topics based on the insights given by the interviewees.
6. **Reflection and final thoughts:** At the end of the session, participants were invited to share any additional thoughts or perspectives that might not have been covered during the formal discussion.
7. **Recording and transcription:**
   - Sessions were recorded using a mobile phone voice memo application or similar tools for virtual meetings.
   - Transcriptions were processed using the Tekstiks.ee platform and manually reviewed for accuracy [51].
8. **Post-interview processing:**
   - Transcriptions were edited to remove filler words, pauses, and incomplete thoughts.
   - Names and other identifiers were anonymised to maintain confidentiality.
   - Incomplete or unclear sentences were rephrased for clarity, and non-verbal responses were annotated where relevant.

This structured process ensured that the data collected was comprehensive, relevant, and aligned with the study's objectives.

Using this process, a total of 9 interviews were carried out in October and November of 2024. All interviews were held in Estonian. 4 of the interviews were held in person in the interviewee's office or location and 5 were held virtually. 4 of the interviews were held as a dialogue between the interviewer and interviewee and 5 had multiple interviewees, where interviewees either decided among themselves, who was the most competent to answer or discuss a specific topic asked by the interviewer or gave multiple perspectives

from different people to the same question or topic.

The list of interviewed organisations, number and background of participants and duration of the interviews is brought out in Table 2. The duration indicates the length of the recorded parts of the interviews, some interviews lasted nearly 2 hours, when counting in the discussion and reflections. The interviews are in order of their occurrence. The order is important to note, as the knowledge about the topic grows in the process and as per the nature of qualitative research, new insights could be discovered midway, that the interviewee could not have been aware of during the earlier interviews [41].

Organisation	**Interviewee(s)**	**Duration (minutes)**
Tallinn Technology University	2 experts on university elections	32
The Estonian Cooperation Assembly	2 experts on rahvaalgatus.ee and citizen initiatives	48
The Right Party (Erakond Parempoolsed)	3 representatives of the party and experts on internal elections	47
Estonian University of Life Sciences	1 expert on university elections	26
Union of Estonian cities and parishes	1 expert on VOLIS	50
Estonian Reform Party (Eesti Reformierakond)	1 expert on party internal elections	44
Cybernetica AS	1 expert on EHS and private elections software	39
Nortal AS	3 experts on VIS	31
Tallinn City Government	6 experts on Tallinn city elections, IT, citizen initiatives and social matters	35
Total:	**20 interviewees**	**352 minutes**

Table 2. Summary of carried out interviews

4.3 Data analysis

The analysis is divided into three main parts. The first focuses on the current state of governmental elections in Estonia, summarising the solutions and processes to provide an overview and establish a baseline reference.

The second part conducts a thematic analysis, that examines the qualitative data collected from interviews with stakeholders involved in the adoption, governance, and development of central election software systems. The analysis identifies and synthesizes

recurring themes, providing a structured understanding of stakeholder perspectives across diverse sectors, including academia, government, and the private sector. The study focuses on key areas such as system adoption, governance challenges, trust dynamics, and the adaptability of software to alternative use cases. By consolidating these insights, the analysis provides a foundation for addressing stakeholder needs in future implementations [52].

Reanalysing the data from varied perspectives enables the identification of detailed criteria and key considerations for adopting electronic voting solutions. These criteria are essential for transitioning to the third part, which establishes a baseline for applying current capabilities to desired functionalities and proposes alternative use cases for governmental election software.

The analysis methods provide foundational areas of importance, key concerns, limitations and possibilities, that help to address the research- and sub-research questions of this study. Enabling to conclude with suggestions and recommendations to assist policymakers and service designers in finding common ground and mitigating potential challenges when developing future election software solutions for non-governmental purposes.

The understanding of interviewee readiness and openness to the idea of centrally provided election or voting software usage answers the SQ1, while understanding the needs and concerns helps to establish the potential adoption criteria raised in SQ2. Finally, using the analysed data, SQ3 can be answered when comparing the interview data to existing system capabilities.

During the writing of this paper, ChatGPT AI assistance tool was used [53]. The tool was used primarily for improving language and quality of the wording due to author's limited vocabulary and English language not being the primary spoken language. The tool was also used for assisting with large scale text editing, formatting, proofreading and analysis of the raw interview data.

5 Analysis of as-is state

This chapter provides a brief overview of Estonia's governmental elections, focusing on the key organisers and the software solutions that support these processes. It examines the legal framework, organisational roles, and the purpose, design, and architecture of the systems currently in use, setting the stage for the subsequent analysis of alternative use cases. It additionally explores a variety of non-governmental elections and brings out some notable examples.

5.1 Governmental elections in Estonia

The Economist Intelligence Unit classifies Estonia as a flawed democracy in its Democracy Index 2023 report, ranking the country 27th globally. This ranking places Estonia just below the threshold for categorisation as a full democracy. According to the report, Estonia, along with several other nations, continues to struggle with weaknesses in institutions and political culture. However, Estonia is noted for its strong performance in areas such as electoral process and pluralism and civil liberties [54].

Estonia conducts four distinct types of governmental elections: Parliamentary elections, Municipal Council Elections, European Parliament Elections and Referendums. All of these elections adhere to five core principles that form the foundation of Estonia's electoral system, aiming to safeguard democratic values and ensure the integrity of the electoral process:

- **Free**. Eligible voters must be able to cast their votes freely and according to their own will.
- **General**. The eligibility criteria for voters are minimally restrictive and comply with election laws.
- **Uniform**. Each voter has one equal vote, and all candidates have equal rights and conditions for election.
- **Direct**. The election results directly reflect the votes cast by the electorate.
- **Secret**. Votes must remain confidential, ensuring that they cannot be traced back to the voter against their will [55].

General parliamentary elections in Estonia determine the 101 members of the Riigikogu (RK), the nation's legislative body. These elections are held every four years on the

first Sunday in March and have been conducted regularly since 1992, following the restoration of Estonia's independence and the adoption of its Constitution [56]. Both voters and candidates must meet eligibility criteria: they must be Estonian citizens and at least 18 years of age to vote and 21 to apply as a candidate on the day of the election [44].

Local municipal council elections in Estonia, like parliamentary elections, are held every four years. However, they take place on the third Sunday in October. During these elections, residents elect members of their local municipality councils, which form the governing authorities for their respective municipalities. Eligibility for voters is broader than in parliamentary elections, as it includes not only Estonian citizens but also EU citizens and other residents of the municipality who hold a long-term residence permit or permanent right of residence. Additionally, the voting age is lowered to 16 and minimum age for candidates to 18. Candidates must also be the residents of the municipality, where they run as a candidate. Historically, local municipal council elections attract the largest number of candidates and eligible voters [45], [56].

Following Estonia's accession to the European Union in 2004, the first European Parliament (EP) elections were held that same year. Unlike parliamentary and municipal council elections, EP elections occur every five years, with the election period determined by the Council of the European Union. These elections are conducted within a single national district, and both voters and candidates may be citizens of Estonia or any other EU member state who permanently reside in Estonia. The age restrictions are the same as with RK elections [46].

The least frequently utilised form of governmental elections in Estonia is the referendum. Since the restoration of independence, referendums have been held only twice: in 1992, to adopt changes to the Constitution, and in 2003, to decide on the nation's accession to the European Union [57]. In 2020, there was a significant possibility of a referendum on the issue of marriage rights; however, the initiative was ultimately discontinued [58]. As a result, no referendums of this kind have been held for over 20 years as of 2024. The Riigikogu possesses the authority to call a referendum on any matter, provided it receives majority support from the representatives. Certain topics, however, are excluded, such as taxation, budgeting, fiscal policies, international treaties, the declaration of a state of emergency, and issues related to national defence. Voting in referendums, like in parliamentary elections, is restricted to Estonian citizens who are at least 18 years old on the day of the vote [47].

All of the aforementioned elections also support the action of repeat voting, in case

there are severe violations of the principles of the elections and the VVK decides so. The summary of the governmental elections is brought out in Table 3.

Election type	**RK**	**KOV**	**EP**	**RH**
Regularity	Every 4 years in March	Every 4 years in October	Every 5 years in late spring or early summer	Irregular
Number of districts	12	Number of local municipalities. Cities with population over 300 000 are divided into 8 districts	1	1
Citizenship eligibility for voting	Estonian citizens only	Estonian residents	Estonian and EU citizens residing in Estonia	Estonian citizens only
Minimum age for voting	18	16	18	18
Citizenship eligibility for candidacy	Estonian citizens only	Estonian and EU citizens only	Estonian and EU citizens only	N/A
Minimum age for candidacy	21	18	21	N/A
Number held since adoption of Constitution in 1992 [56]	9	9	5	1 (2 if including the referendum on adopting the Constitution)

Table 3. Summary of governmental elections

5.2 Elections organisers

Depending on the classification, the organisation and management of governmental elections in Estonia involve four to six distinct groups or entities, as defined by election laws. These include: National Electoral Committee (VVK), State Electoral Office (RVT), rural municipality and city secretaries, rural municipality or city electoral committees, voting district committees and vote counting committees [44], [45], [46], [47].

The National Electoral Committee (VVK) plays a critical role in overseeing and ensuring

the legitimacy, compliance, and validity of the electoral process and its guiding principles. The primary organiser of elections is the State Electoral Office (RVT), which is tasked with responsibilities such as election preparation, overall coordination, budgeting, and providing guidance and supervision. Additionally, RVT is responsible for developing and managing the technical solutions required for conducting elections. The VVK comprises seven members appointed for a four-year term, while RVT employs 11 full-time or part-time staff at the time of writing. Unlike VVK and RVT, which are established solely for managing elections, rural municipality and city secretaries primarily handle other daily responsibilities. In the context of elections, they play a significant role in managing the process at a local level, including issuing instructions to the voting district committees [59], [44].

Voting district committees, formed by the municipal council, consist of at least five members. These members may be appointed either by the council itself or by participating political parties, with each having the right to appoint up to half of the committee members. The committees are responsible for conducting voting at their respective polling stations, following the instructions provided by the central election organisers. During the most recent elections, the 2024 European Parliament elections, there were 377 polling stations across the country [60].

The functions of vote counting committees during Riigikogu (RK), European Parliament (EP), and referendum (RH) elections are carried out by rural municipality or city electoral committees. For municipal council elections (KOV), however, a separate rural municipality or city electoral committee is formed. These committees are led by the municipal or city secretary and comprise five members. They assist RVT in tasks such as candidate registration and verifying election results at the local level [44], [45].

In summary, the organisers and managers of governmental elections in Estonia operate in a hierarchical structure. At the top, VVK oversees the overall process, ensuring compliance and integrity. RVT serves as the central organising body, while rural municipality and city secretaries manage operations at a more local level. Finally, voting district committees interact directly with voters at polling stations, representing the most visible element of the electoral framework. The summary of the organisers is brought out in Table 4

Hierarchy Level	Responsibilities	Number of Members
1. National Electoral Committee (VVK)	Oversees overall elections, ensures compliance and validity.	7 members (appointed for 4 years)
2. State Electoral Office (RVT)	Main organiser: preparation, budgeting, technical solutions, and supervision.	11 full or part-time employees
3. Rural Municipality/City Secretaries	Manages elections locally, issues instructions to voting district committees.	1 secretary per municipality/city
4. Municipal Electoral Committees	Assists RVT locally, registers candidates, verifies results in municipalities.	5 members per committee
5. Voting District Committees	Conducts voting at polling stations, implements organisers' instructions.	At least 5 members per committee

Table 4. Summary of elections organisers

5.3 Other elections

In addition to governmental elections, various elections with differing levels of importance, legal frameworks, and organisational structures are also present. These include elections organised by non-governmental organisations, professional associations, educational institutions, political parties, citizen groups, unions, institutions etc. Understanding the presence of variety of elections is essential for exploring the broader potential of repurposing Estonia's governmental election software, particularly in identifying commonalities and technical requirements that could support non-governmental use cases. The organisation and execution of non-governmental elections in Estonia vary significantly depending on the context. Table 20 in Appendix 3 provides a brief summarising overview of various organisations and entities conducting elections or voting processes in Estonia, with four examples explained further below.

One of the more notable ones are Estonia's presidential elections, which are indirect, with candidates nominated and votes cast by members of the Riigikogu. In cases where the Riigikogu fails to elect a president, an electoral body comprising municipal council representatives is convened. These elections rely on paper ballots, and discussions around transitioning to direct elections or digital voting have not gained sufficient political traction [61] [62]. While the system is currently outside the scope of governmental election software, potential future reforms could benefit from digital solutions, particularly for convening electoral bodies.

As another example, university rector elections at Estonian universities are significant for institutional governance. Voting bodies typically include council members, faculty representatives, and other stakeholders. Some universities, such as the University of Tartu, already use web-based voting platforms like TIVI, developed by Cybernetica [63]. This demonstrates the feasibility of adapting governmental election software to meet the technical and organisational needs of academic institutions.

Third example is The Estonian Bar Association, which employs a democratic governance model, holding elections for positions such as the President, Board members, Audit Committee, and Ethics Tribunal. These elections, governed by the Bar Association Act, are conducted during General Assembly meetings. The structured nature of these elections and their reliance on transparent processes make them suitable candidates for digitalisation using adaptable governmental election software [64] [65].

As the last example, platforms such as Rahvaalgatus.ee exemplify citizen-driven initiatives where individuals can digitally sign and propose legislative actions. While these platforms are currently independent of governmental election software, integrating such tools could provide a more robust and scalable infrastructure, particularly for verifying user identity and managing digital signatures [28].

5.4 Existing technical solutions

Governmental elections are supported by two core information systems: the Elections Information System (VIS) and the Electronic Voting System (EHS). In addition, they are supported by their inter-system communications protocols, elections information web pages and technical support regarding the infrastructure and digital space organisation.

5.4.1 Elections information system

The statute of Estonia's Elections Information System (VIS) defines it as a 'work environment for organising elections and referendums,' serving as a central hub for electoral management. VIS has several critical functions designed to ensure the smooth operation of electoral processes [66]. These are listed in Table 5.

Category	Purpose
Data Management	▪ Ensure data exchange between election organisers. ▪ Maintain records of election organisers' information. ▪ Process and manage candidacy data. ▪ Enable the submission of candidacy applications. ▪ Assign identification numbers to candidates.
Voting Process Support	▪ Provide an overview of election progress. ▪ Enable the use and management of voter lists. ▪ Maintain voting records for accuracy and transparency.
Result Processing	▪ Determine voting results efficiently. ▪ Finalise and publish official election results.
Data Utilisation	▪ Generate and prepare data for: – Publication (to provide public transparency). – Archiving (to ensure long-term accessibility). – Discarding (following legal and procedural requirements).

Table 5. Main purposes of the Elections Information System (VIS)

VIS employs a microservice-based architecture, comprising 15 distinct logical modules. The names of the modules and their descriptions are summarised in Table 6. A general diagram of the whole system and its' relation to actors and supporting systems is depicted on Figure 5. The modules operate separately and communicate to each other mainly over API protocol. The division of modules is based for the most part on business logic and type of tasks, that they perform in the election process, for example candidacy module handles candidate related tasks while election result module handles election and voting calculations. Others are designed based on their technical characteristics, such as monitoring or logging module. Each module is developed, built and deployed as a separate entity. The code and documentation of VIS is not public.

Name	Description
Candidacy module (KAN)	Candidate registration handling. Serving the information to other modules.
Electoral roll module (NIM)	Handling electoral roll, management of polling station voter facing actions and paper vote collection
Access right module (PAS)	Management of system users and roles and access rights
Session management module (SEA)	Handles TARA interface and user session creation and storage
Statistics module (STAT)	Generation of various statistics for elections organisers
Notification module (TEA)	Handles system notifications and delivers them to the required users based on defined rules
Logging module (LOG)	Collects logging data from other modules and allows parsing and viewing the collected logs
Monitoring module (MON)	Monitors health and metrics of services or modules
Election event module (VAL)	Election main information creation and management. Polling station and district management. Serving the information to other modules
Election map web application (VKR)	Handling the visual representation of polling stations information regarding active elections in a web application
Election result publication module (VTA)	Generation of data for the elections public web application, including current progress of voting and count of votes
Election result module (TUL)	Collection and calculation of voting results. Both electronic and paper votes
VIS3 database	Main database for stored data
VIS3 static content server (WEB)	Common web application components for other modules
Development support tools	Otherwise non-categorised tools, such as performance testing, mocking or development sandboxes.

Table 6. Summary of VIS modules

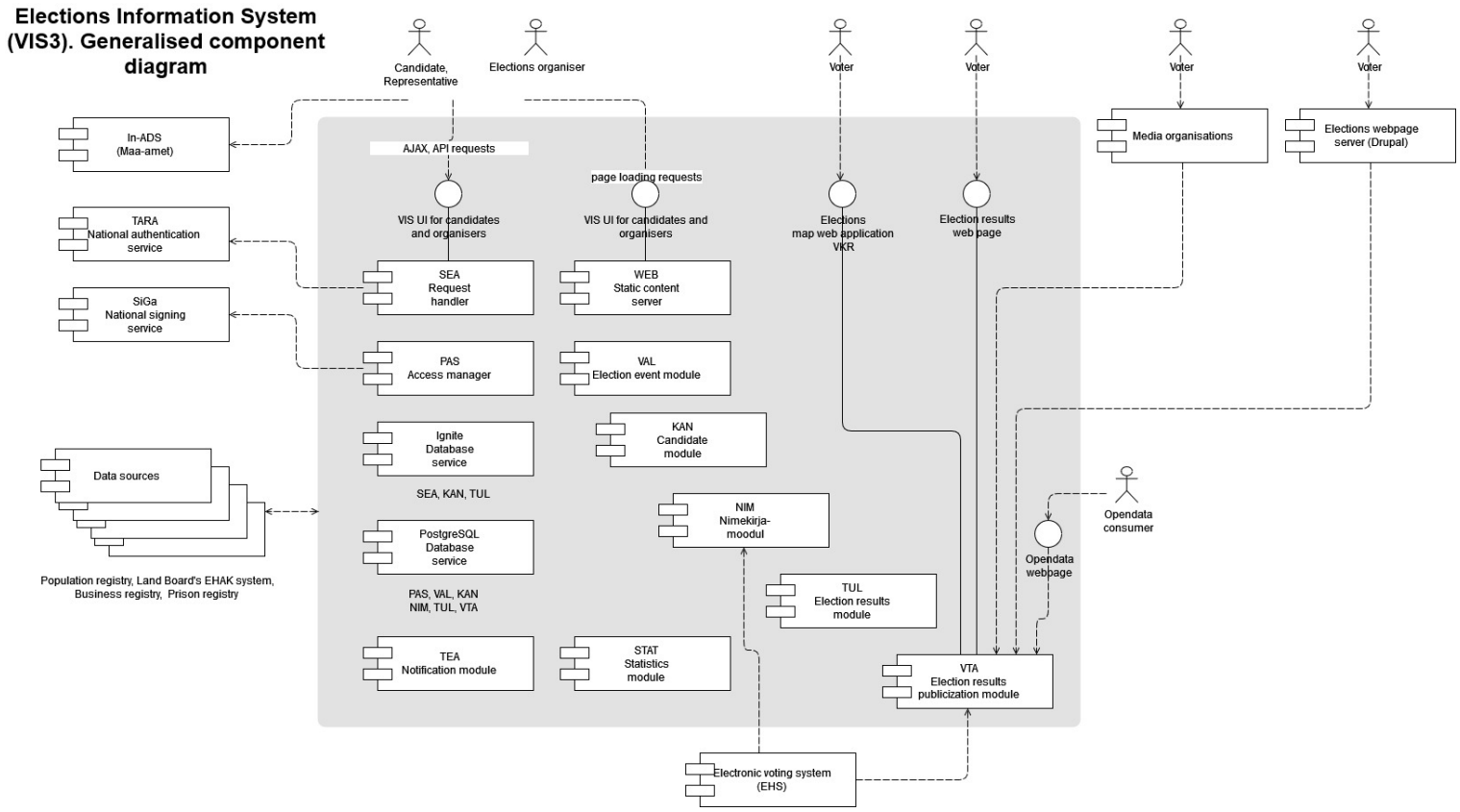

Figure 5. VIS generalised component diagram. Diagram taken from RIA's VIS documentation and translated to English

5.4.2 Electronic voting system

Electronic voting system (EHS) - current version also known as IVXV, is according to its' statue an electronic system, that is used during the elections and referendums to enable electronic voting, store electronic votes and tally the electronic votes [67]. The system's general framework identifies as part of the EHS seven components shown in Table 7 [68].

Name	Description
Voting application	Runs in the voter's device, communicates with the collection service an allows the voter to cast a vote.
Verification application	Allows the voter to use a separate device from where the voting application runs to verify, that the vote has reached collection service correctly.
Key application	Used for generating vote encryption and decryption keys. Allows vote counting and result calculation.
Collection service	Supports voter in compiling the vote and registers it to electronic ballot box.
Processing application	Used for verifying the integrity of individual votes and e-ballot box. Dismisses repeat votes, and releases voters list and anonymised votes.
Mixing application	Mixes the anonymised encrypted votes.
Auditing application	Auditor's tool for ensuring the correctness of mixing and tallying of the ballots.

Table 7. Summary of EHS modules

The central key component, collection service, is additionally divided into multiple microservices as defined in the IVXV architecture [69]. The division into microservices is depicted on Figure 15 in Appendix 4. In addition to the function-specific microservices, the architecture also contains specialised components or tools for external interfaces, monitoring and administration.

EHS-VIS integration

Part of the governmental elections whole system is the integration and communication between two of the main systems, VIS and EHS. They use HTTPS, human and X-road interfaces to exchange data between the two systems. The data exchanged is depicted on Figure 6. On VIS side, the communication is established between a specific module only, that services specific type of data [1].

[1]VIS3-EHS liideste spetsifikatsioonid - https://github.com/e-gov/VIS3-EHS

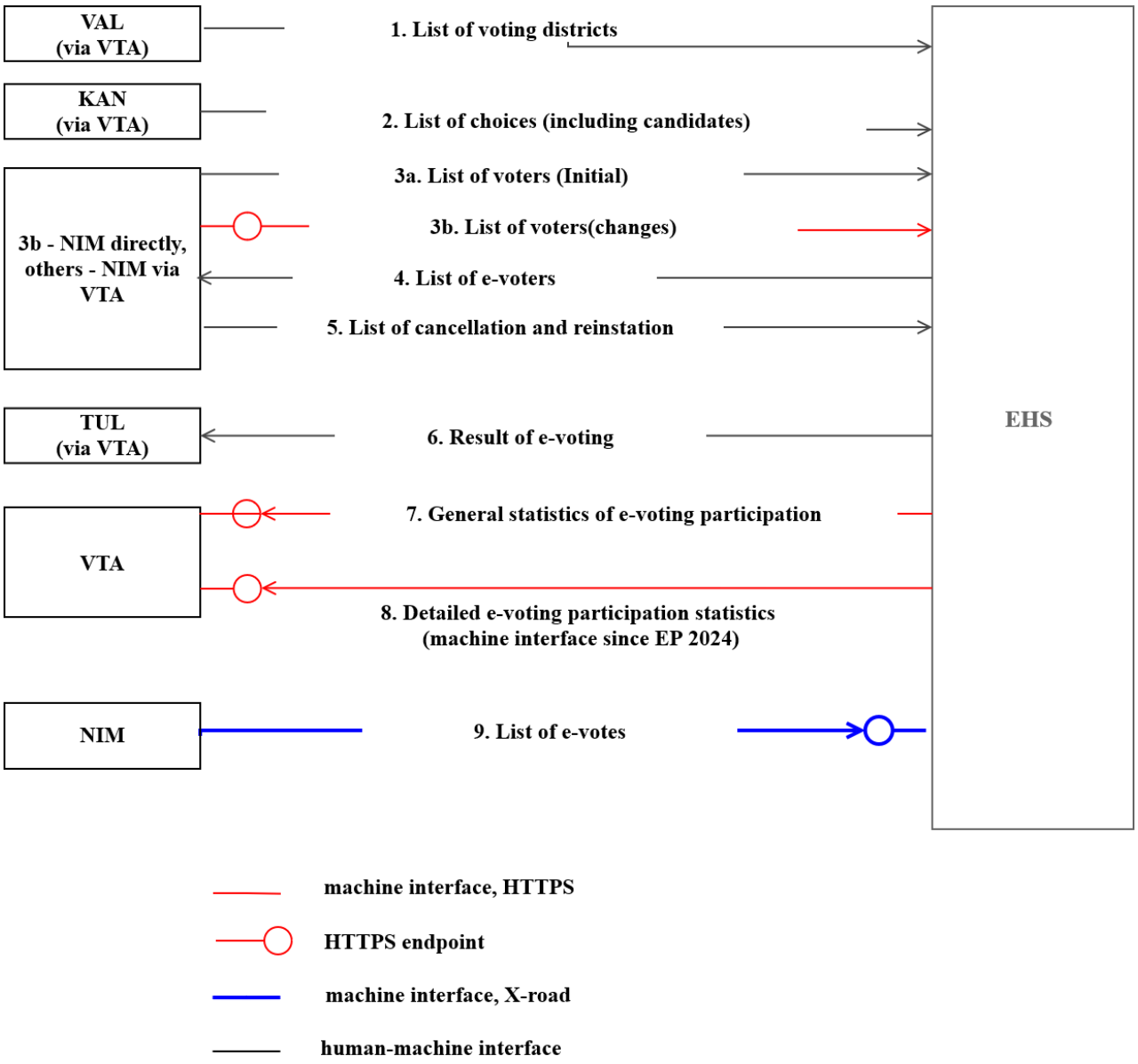

Figure 6. VIS-EHS interface diagram. Diagram taken from EHS public documentation and translated to English

Mobile voting

The feasibility of using mobile devices for casting a vote during governmental elections was extensively studied and analysed in 2020 in a 'Mobile voting feasibility study and risk analysis' [70]. The actual prototyping development started in 2022, which aimed to develop the voting application to two new operating systems - Android and iOS. The applications use the same back-end and protocol as desktop voting applications.

To date, the applications are not approved for being used for governmental elections due to concerns regarding the publishing and distribution of the applications via the

Google and Apple controlled application stores, that is cited as the highest concern in recent risk analysis by Estonian Academy of Sciences [71].

The prototype of the application has been, however, tested and is usable for casting votes similarly to desktop application. While governmental elections use cases have not been approved, alternative use cases could be considered, that could utilise the technological solution without the concerns regarding the publishing methods crucial for governmental elections. The illustrating UI components of the application are displayed on Figure 7.

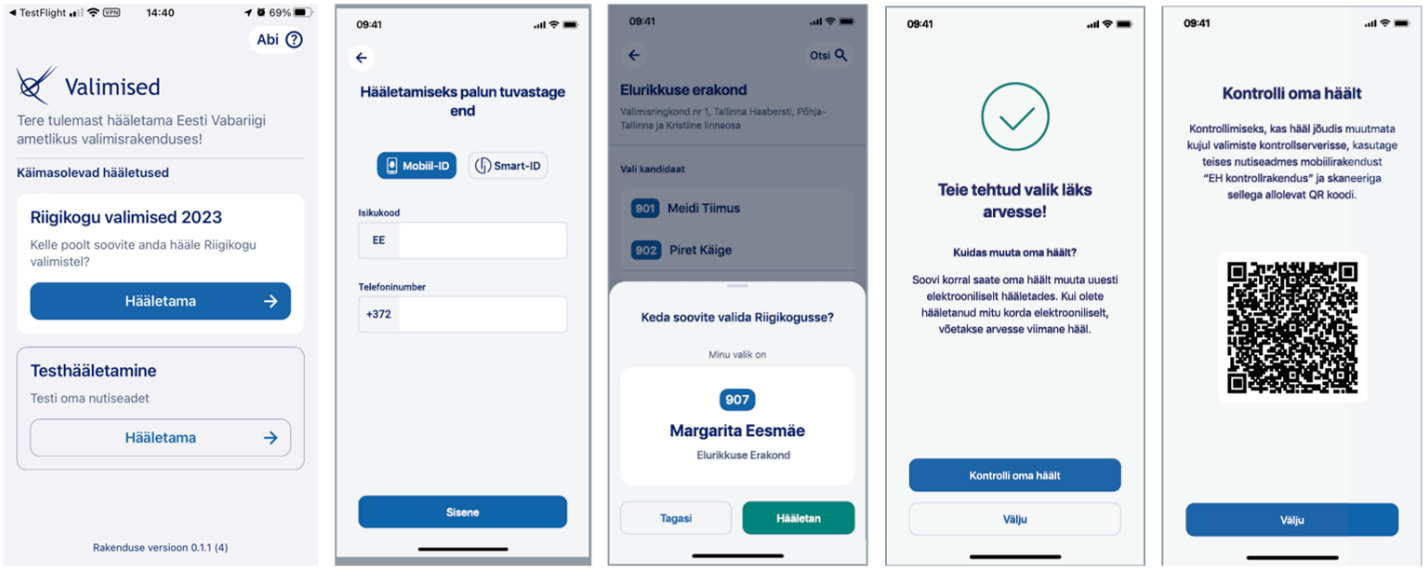

Figure 7. Mobile voting application UI screen shots

Vote verification application

To enhance the security and verifiability of the voting process, a separate mobile application called 'EH kontrollrakendus' is used. The application allows the voter to verify, that the vote that was cast by them electronically using the voting application was correct. The application is developed and published for Android and iOS operating systems. After casting a vote using voting application, voter is displayed a QR code, that can be then scanned using the application. As this requires the user to use two separate devices, it also addresses an attack vector, where voter's voting device might be infected with malware and the vote is not being cast as the voter desired [72].

5.4.3 Elections web page

RVT manages a central web page for all elections related information at www.valimised.ee. The web pages shows primarily information about currently active, most recently ended or imminently upcoming election. Election event specific subpages, such as rk2023.valimised.ee and ep2024.valimised.ee are served by VIS. VIS also serves the opendata public page and content via a separate subdomain opendata.valimised.ee. Opendata is provided in .csv and .xml formats about the polling stations, candidates, voting statistics, election results etc. The general architecture and structure of the election result publication module VTA is depicted on Figure 8.

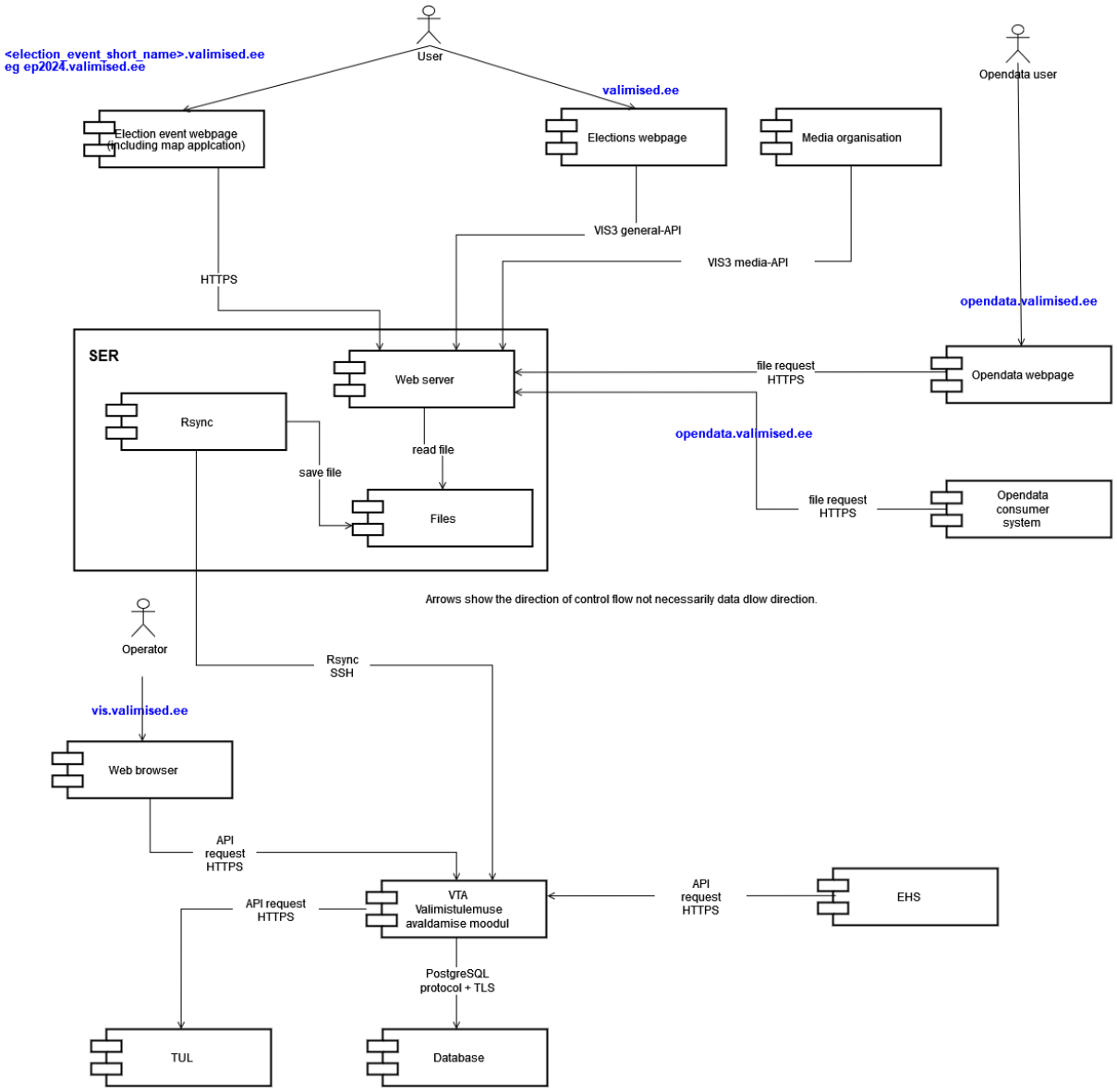

Figure 8. Election results publication and web page serving architecture from VIS documentation translate to English

During the active electronic voting period, the web page also acts as a distribution channel for voting applications, where .exe, .dmg and .bin files with respective checksums are uploaded. In addition to a specific election statistics and information, the page also has references to archived elections, information and documentation about electronic voting and other general news and information about governmental elections in Estonia [73].

5.4.4 Polling stations and technical support

During the elections week, all of the physical polling stations need to be equipped with necessary hardware. This includes laptops, printers, peripherals, barcode scanners, network capabilities etc. The laptops are used by the polling station workers to access and interact with the elections information system. The computers are centrally prepared, managed and monitored. The access to the computers is also centrally managed and the input for it received from VIS' access right module (PAS), that specifies the user rights within a specific election event. The list of rights are exported regularly from VIS to a central identity and access management (IAM) system, that uses active directory (AD) or similar service to provision and keep an up to date list of elections organisers, who can have access to the computers [74] [75]. A simplified creation and provisioning of user rights is shown on Figure 9.

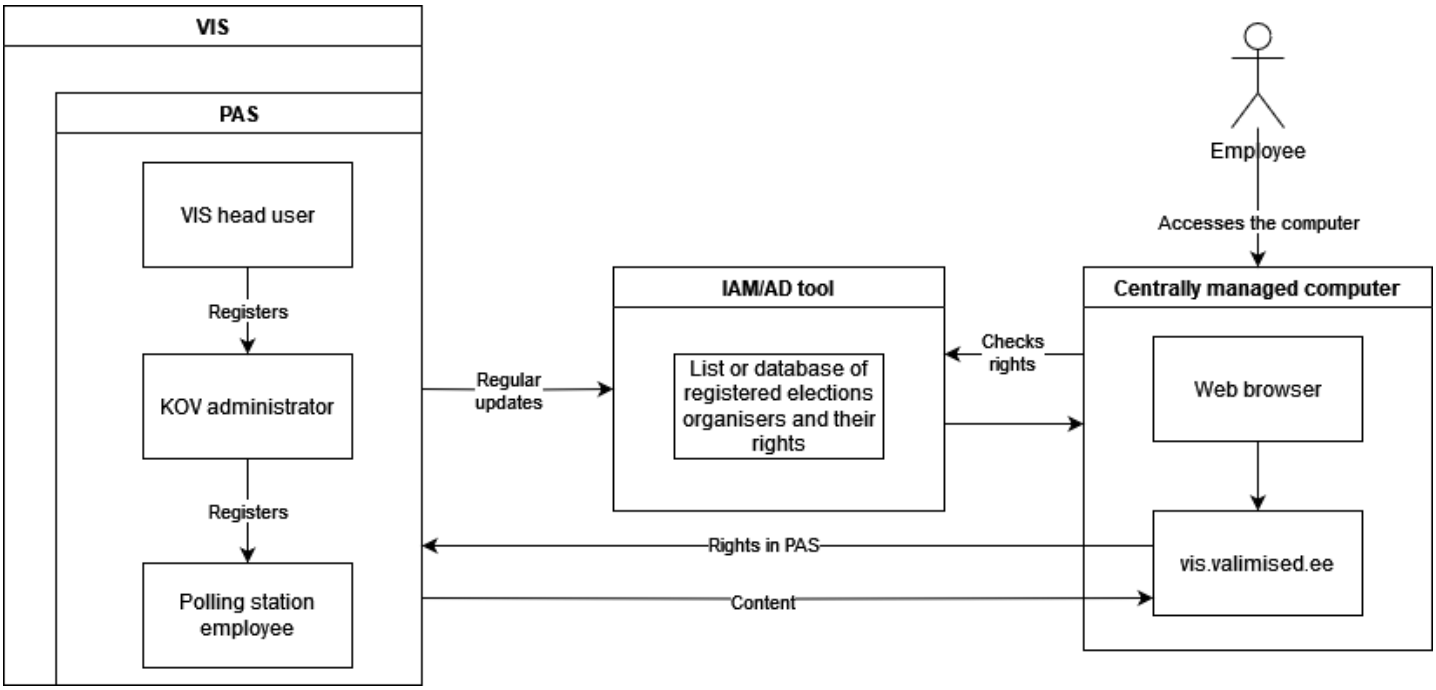

Figure 9. Overview of user rights creation

All of the elections organisers have access to multiple levels of technical support throughout the elections period. As per 2023 Parliamentary elections, Estonian IT centre (RIT) had 10 IT specialists supporting from distance, while private telecom company Telia was providing the on-site support for the polling stations with as many as 48 IT specialists across the country. VIS-specific and general technical know-how support is provided by RIA, including additional monitoring and cyberspace scanning support by CERT-EE. [74].

5.4.5 VOLIS and VOLIS2

The Estonian Association of Cities and Municipalities (Eesti Linnade ja Valdade Liit, or ELVL), an organization that consolidates and represents Estonia's local municipalities, manages and develops an information system known as the "Local Municipality Councils Sessions Information System" (VOLIS). While the primary purpose of VOLIS is to function as a council meeting information system, it also includes a significant feature that facilitates public polling at the local municipal level [76]. Due to its publicly available codebase, VOLIS has also been adopted to varying degrees in Georgia and Sweden [77].

Since the initial development of VOLIS in 2011, ELVL has initiated plans to create a second-generation iteration of the system, referred to as VOLIS2. To support this effort, ELVL has commissioned extensive market research and analysis regarding the design and architecture of the proposed system. One report provides a comprehensive overview of the envisioned functionality of VOLIS2 [48], while another focuses specifically on the minimum viable product (MVP) for the public polling feature [49].

The analyses conclude that no suitable alternatives to VOLIS currently exist in the market. The alternatives evaluated, which include Electric Vote, Citizen OS, TEELE, VOLI, and Rahvaalgatus.ee, were deemed insufficient, primarily due to their inability to combine functionalities in the way VOLIS does. Notably, software and technologies used for governmental elections were excluded from the scope of the evaluation. The primary limitation of the alternatives lies in their lack of integrated functionality, a key strength of the current VOLIS system.

6 Interview results analysis

Chapter 6 delves into the analysis of interview data collected from diverse stakeholders engaged with the adoption, governance, and development of Estonia's electoral software systems. This chapter synthesises insights across multiple themes, ranging from system adoption and governance challenges to trust dynamics and scalability for alternative applications. The analysis further evaluates acceptance criteria, comparing stakeholder expectations against the existing software capabilities. By consolidating these perspectives, the findings form the basis for actionable recommendations and potential directions for broadening the software's applicability.

6.1 Thematic analysis results

The analysis identifies five distinctive and recurring themes and 10 subthemes, that were identified through coding and analysing the interview transcripts. The themes along with some subthemes or keywords are shown in Figure 10 and discussed further below.

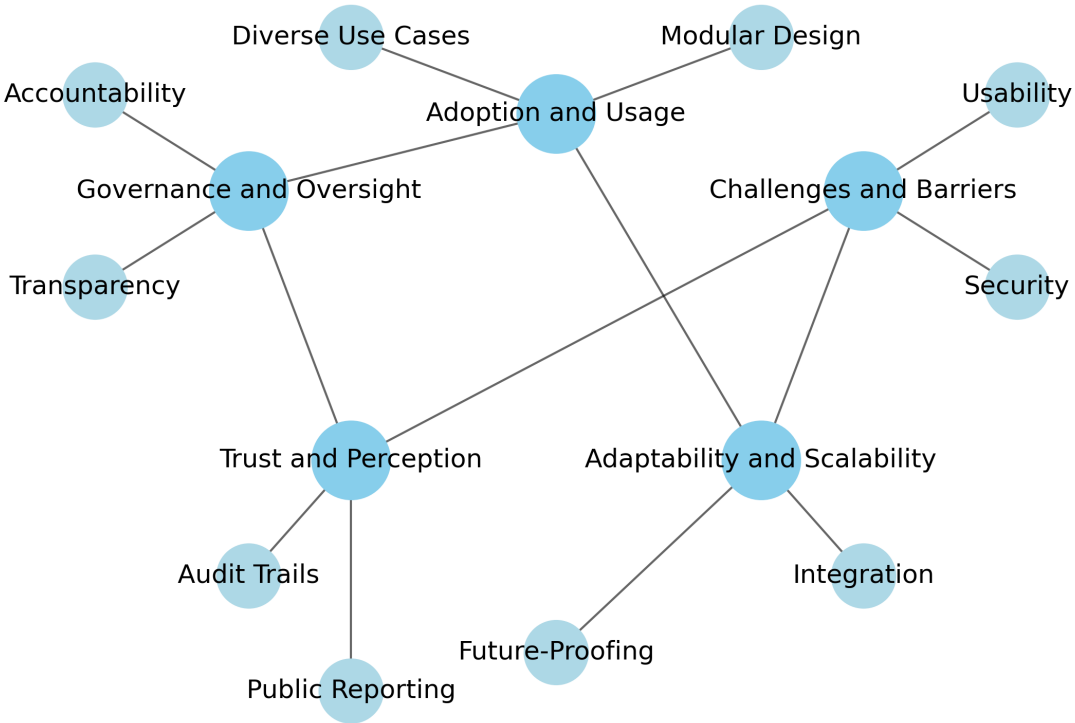

Figure 10. Thematic map of the interviews

6.1.1 Adoption and usage

Adoption and usage of digital election and voting systems vary across organisations, there is a variety of platforms in use ranging from public solutions like VOLIS, private ones like electionBuddy and mainly in-house developed solutions to meet their specific needs. These systems have proven adaptable, supporting diverse use cases such as rector elections, student council voting, and public consultations. Their design allows customisation, enabling institutions to align the software with their specific workflows. However, the degree of adoption often correlates with the clarity of governance structures and the availability of technical expertise within the organisation.

Despite the successes, adoption remains uneven due to differences in institutional readiness and resource availability. Larger organisations with established governance frameworks are more likely to integrate these systems effectively, while smaller or less-resourced entities face challenges in utilising them fully. This highlights the need for scalable solutions that can bridge organisational disparities, ensuring consistent functionality across various contexts.

There are clear recurring reasons for organisations having adapted to using digital voting or elections software. Some have made clear decision from the beginning, to be fully digital due to organisation's scattered model and otherwise uncomfortable and administratively burdening traditional solutions. It often directly scales with the amount of participants within an election or voting, where decision being made in small circles may not require the use of digital means. Another significant group have been driven by unexpected disruptions like COVID to adapt to the change in people's behaviour.

Oftentimes the voting or election system is not a standalone system, but rather a module or feature extended to an already existing system, such as document management system or organisation central information system. This is reasoned by allowing for easier and better integration to already existing frameworks and less of an administrative burden of multiple systems.

6.1.2 Governance and oversight

Governance and oversight are pivotal to the effective implementation and operation of digital election systems. Stakeholders consistently emphasised the importance of external validation mechanisms, such as audits, to establish trust and legitimacy through transparency. Internal governance roles, such as procedural accountability and re-

sponsibility allocation, also play a critical role in ensuring system reliability. However, the absence of a unified governance framework often leads to inconsistencies and inefficiencies, particularly when systems are used across multiple organisations.

A recurring theme is the tension between centralised and localised governance. While some institutions advocate for centralised oversight to ensure uniformity, others highlight the need for autonomy in managing localised workflows. This dichotomy suggests the potential value of a hybrid governance model, balancing central mandates with localised flexibility. Such a framework could address accountability concerns while respecting the unique needs of diverse stakeholders.

6.1.3 Challenges and barriers

Digital election and voting systems face significant challenges, most notably in the areas of security, usability, and resource allocation. Security concerns are paramount, with stakeholders highlighting the need for robust authentication mechanisms, data privacy protections, and secure handling of sensitive votes. Usability issues, particularly for non-technical users, further hinder adoption, as overly complex or outdated systems can alienate participants and reduce trust.

As opposed to general direction in government provided services, some organisations need to have an alternative authentication method to Estonia's electronic identity formats. This is especially prevalent in universities, which have foreign students using their systems and potentially participating in voting.

Financial constraints also emerged as a recurring barrier, with many organisations struggling to allocate sufficient resources for system maintenance and upgrades. Additionally, technical rigidity in existing platforms limits their adaptability to complex voting scenarios, such as multi-round elections or weighted decision-making.

6.1.4 Adaptability and scalability

Adaptability and scalability are critical to the success of digital election systems, enabling them to meet evolving organisational and societal needs. Many interviewees highlighted the importance of systems that can integrate seamlessly with existing tools, such as municipal registries or ID-based authentication frameworks. Future-proofing, through modular designs and flexible configurations, was also identified as essential for accommodating new use cases and broader applications.

Scalability is particularly important for institutions with episodic election demands, such as universities and local governments. These organisations require systems that can scale up during election periods while remaining cost-effective during downtime. A recurring recommendation is the development of interoperable platforms that allow for incremental adoption, ensuring that both small and large organisations can benefit from the technology.

6.1.5 Trust and perception

Building trust in digital election systems is fundamental to their broader acceptance and use. Transparency mechanisms, such as audit trails and public reporting, are crucial for fostering legitimacy and addressing skepticism among both users and the general public. Privacy concerns, especially for sensitive votes, further complicate trust-building efforts, necessitating systems that balance openness with confidentiality.

Public perception often hinges on visible accountability measures, with stakeholders advocating for open analyses and reporting of system vulnerabilities and improvements. For example, the publication of VOLIS2's analysis was cited as a positive step toward transparency. Addressing these trust and perception challenges requires a holistic approach, combining robust technical features with clear communication strategies to engage and reassure users.

It is notable, that most of the organisations consider their elections or votings to be unimportant enough for the general public (when comparing to governmental elections), that high level of security can often be dismissed in favour of ease of operation. While there are procedures and four-eye principles in place at some processes, they do not come close to the required level of auditability, as in governmental elections.

6.2 Acceptance criteria

The interviews were analysed through multiple perspectives, allowing the identification of critical acceptance criteria for using centrally provided governmental software solutions. These criteria reflect a wide range of requirements, from political considerations to specific technical functionalities. For clarity and comparison to the as-is state, the criteria relevant to election software are categorised as follows:

1. **Usability and accessibility (UA)**. These criteria focus on user-centric features, such as intuitive workflows, real-time voting insights, and compliance with acces-

sibility standards. Table 8.

2. **Security and privacy (SP)**. Key concerns in this category include robust authentication mechanisms, vote integrity, and data privacy. Table 9.
3. **Interoperability (IO)**. This category highlights the need for seamless integration with external and internal systems, as well as modular design capabilities. Table 10.
4. **Technical aspects and scalability (TS)**. These requirements pertain to system scalability, mobile compatibility, and adaptability for simultaneous elections across organisations. Table 11.
5. **Other (OT)**. Standalone or unique requirements that do not fit neatly into other categories, such as cost-effectiveness and legal compliance. Table 12.

The detailed criteria are outlined in respective tables, grouped under their respective categories to provide a structured overview.

ID	Requirement	Description
UA-1	Provide customisable workflows	Workflows must adhere to organisation-specific needs.
UA-2	Handle simultaneous paper and electronic voting	Paper ballot vote counting and electronic vote counting must both be possible during the same election event.
UA-3	Allow creation of public reports	Creation of reports (including legal) that confirm the correctness and validity of election or voting results.
UA-4	Clear and user-friendly UI and UX	The UI and UX must use modern frameworks and adhere to accessibility standards. Many of the users might not be technologically savvy.
UA-5	Allow public polling	System must allow the creation of public polling events, where defined voters can freely participate.
UA-6	Incorporates dispute resolution mechanisms	Submitting and resolving a dispute should be part of the system or a separate module.
UA-7	Real-time voting insights	System must provide real-time progression of voting progress and display it on a public page.
UA-8	Advanced analytics	System users may be provided with further analytical data about voters' statistics, such as age, place of residence, etc.
UA-9	Support for advanced voting scenarios	In addition to existing ones, preference-based and multi-round elections.
UA-10	Reusability of previous events	Administrators should be able to reuse existing election or voting event data as much as possible.

Table 8. Usability acceptance criteria

ID	Requirement	Description
SP-1	Handle Estonian ID based authentication methods	System must be accessible using Estonian state provided e-id solutions such as TARA.
SP-2	Handle non-Estonian ID based authentication methods	Some users are not holders of Estonian electronic ID and need to use alternative methods (eg e-mail links).
SP-3	Allow creation of audit trails	Another organisational or external member must be able to audit actions done within the system.
SP-4	Guarantee data privacy	User data must remain private to best data privacy practices.
SP-5	Guarantee vote secrecy	Vote must remain secret and not be accessible by administrator or anyone else.
SP-6	Guarantee vote integrity	The vote must be in no way manipulated with.
SP-7	Allow for vote data termination	After a specified time or with a specified event, vote data must be deleted completely.

Table 9. Security and privacy acceptance criteria

ID	Requirement	Description
IO-1	Allow integration with external registries and databases	For example Population registry over X-Road.
IO-2	Allow integration with internal registries and databases	For example university internal document registry system or party intranet.
IO-3	Allow modular design	Organisations may want to use the elections or voting features as separate modules, that could complement their existing systems.
IO-4	Open source code	The code must be public and free to use, so that the organisations can make their own changes, if they wish.

Table 10. Interoperability acceptance criteria

ID	Requirement	Description
TS-1	Scalability to election size	Some of the elections or votes may have only a few participants, while others 10s of thousands.
TS-2	Must be a web application	The service must be accessible via popular web browser and not require additional software.
TS-3	Must be mobile device compatible	The service must be accessible via mobile web browsers.
TS-4	Must be provided as SaaS model	No on-site hosting for the users or organisers.
TS-5	Scalability to organisations simultaneous elections	Simultaneous votings or elections may be occurring either between or within organisations.

Table 11. Technical aspects and scalability acceptance criteria

ID	Requirement	Description
OT-1	Organisational control over business logic	Organisations want to maintain the control over the business logic of their processes.
OT-2	Cost-effectiveness	The pricing of the solution cannot exceed current expenses.
OT-3	Legal compliance	The use of the services must have clear binding legal boundaries and agreements.

Table 12. Other acceptance criteria

6.3 Comparison to VOLIS analysis

VOLIS2 public polling analysis discovered a total of 27 key expectations and acceptance criteria for its' users. In the table below are the ones, that are relevant to this study and not too detailed or VOLIS2-specific. Some of the criteria are also consolidated, as they were for example multiple variations of suggestions for better UI or UX experience using different examples from the existing system. The acceptance criteria from VOLIS2 public polling functionality analysis is brought out in Table 13 [49].

ID	Criteria	Description
VOLIS-1	Comfortable and modern UI	Including mobile accessibility
VOLIS-2	Separate views for municipalities	Each municipality must have its' own view or design of the central system
VOLIS-3	Personalised design availability	Each municipality must be able to use their own logos and colours on the public application
VOLIS-3	Intuitive UX	With emphasis on management of users.
VOLIS-4	Visibility of voting activity	The progression and results of the votes must be visible to the public. The exact time of the publication must be configurable
VOLIS-5	Usage of previous data	When creating a new voting event, have templates to use previous data.
VOLIS-6	Handle Estonian ID based authentication methods	Implement an authentication solution like TARA
VOLIS-7	Support of simultaneous events	Each should be clearly separately manageable and should not interfere with other active events
VOLIS-8	Extensive control over the system through UI	There must be minimal to no need to access or change anything directly through database

VOLIS-9	Transparent voting process	The information regarding the process must be publicly accessible and easily locatable
VOLIS-10	Compliance to accessibility rules	The web application must adhere to accessibility rules on both, desktop and mobile version of the web application
VOLIS-11	Support for commenting	There must be a selectable feature, that allows the adding of comments to events.
VOLIS-12	Map support	The suggestions must be displayed on a web application based map
VOLIS-13	Generation of statistical data	Reports including the age and gender distribution of the voters
VOLIS-14	Support for non-personal voting device	The voters must be able to cast their vote from a municipality office, using a local device, that is administered and supported by a local worker.

Table 13. VOLIS2 acceptance criteria

To verify the relevancy of the gathered acceptance criteria from the interviews carried out in this study, they are compared to the acceptance criteria of a similar system of VOLIS2 public polling functionality. For each criteria from VOLIS2 public polling analysis, the closest match is found from the ones identified from this study's interviews. The match is commented and reasons given. The comparison is done in Table 14.

VOLIS ID	**Matching analysis criteria ID**	**Comment**
VOLIS-1	UA-4	Direct match. both emphasise the need for clear and well accessible UI and UX
VOLIS-2	TS-5, IO-3, OT-1	Partial match, in line with different organisations requiring some personalisation or self-customisation of flows and designs.
VOLIS-3	UA-4	Direct match. Intuitive UX has been overarchingly brought out everywhere.
VOLIS-4	UA-7	Direct match, live tracking of event progress is identified in both cases.
VOLIS-5	UA-10	Direct match. Both analysis identify, that users should not create new events from scratch, but be allowed to either re-use existing event data or be able to define some templates.

VOLIS-6	SP-1	Direct match. Some form of handling Estonian e-id based authentication and signing is required. TARA is the most likely candidate.
VOLIS-7	TS-5	Direct match, the need to be able to run multiple election or voting events at the same time either in general or within organisation is required.
VOLIS-8	UA-4	Partial match, UA-4 is the closest, as clear and user-friendly UI should satisfy the need, but not necessarily.
VOLIS-9	UA-3, SP-3	Partial match, the combination of UA-3 and SP-3 could satisfy the needs. Depends on the organisation specific processes and needs.
VOLIS-10	UA-4	Direct match. Sub-criteria of UI and UX improvements, where among others must adhere to some accessibility standards.
VOLIS-11	N/A	No match. No such need was brought out in interviews. Likely very VOLIS-specific or could be a sub-criteria of UA-5.
VOLIS-12	N/A	No match. No specific need was brought out for a need of map, that display the location of ongoing voting or election events.
VOLIS-13	UA-8	Direct match, both noted the need for some form of statistical reporting or use of analytical tools within the system.
VOLIS-14	N/A	No match, no such criteria was mentioned in interviews.

Table 14. Comparison to VOLIS2 acceptance criteria

Based on the comparison, VOLIS2 key criteria are relatively similar, with 8 of the 14 being direct matches to the ones identified during the interviews, 3 of 14 being partial matches and 3 being no matches. The ones not matching at all are rather specific for the system and would be either irrelevant or low priority in the alternatives being discovered in this study. With 79% of the criteria directly or partially matching with the ones discovered in the interviews, it could be said, that the discovered criteria from the interviews can be considered fairly relevant and accurate.

6.4 Acceptance criteria comparison to current as-is

The next piece of analysis tries to find, how well the current existing governmental elections software solutions match to the acceptance criteria discovered from the interviews. For each discovered criteria, a match is found and presented in the table below with relevant comments. The requirements are considered jointly from VIS and

EHS perspective. A requirement can either be met (Yes), not met (No) or partially met (Partially). For each requirement, a short comment is also given. The comparison results are brought out in Table 15, Table 16, Table 17, Table 18 and Table 19.

ID	Relevant to	Req. met?	Comment
UA-1	VIS, EHS	No	The current systems do not provide customisable workflows. The workflows are very governmental election specific.
UA-2	VIS	Yes	The system consolidates the results of paper and electronic votes to a central system.
UA-3	VIS	Yes	System has all the validity checks and reports that are required for election organisers to confirm the outcome of the results.
UA-4	VIS, EHS	Yes	Both use modern UI frameworks and adhere to WCAG accessibility standards.
UA-5	VIS, EHS	Partially	The referendum is in essence similar, but has its' limitations.
UA-6	VIS	No	No such feature is available.
UA-7	VIS, EHS	Yes	Live data about voting is fed to public website.
UA-8	VIS, EHS	Yes	The systems allow superusers to perform more detailed statistical reports either through UI or from database.
UA-9	VIS, EHS	No	Only strictly formatted governmental election types are supported.
UA-10	VIS, EHS	Partially	Some of the data from previous election events can be re-used, such as polling station information.

Table 15. Usability and acceptance requirement fulfilment

ID	Relevant to	Req. met?	Comment
SP-1	VIS, EHS	Yes	Both use TARA authentication.
SP-2	VIS, EHS	No	No alternative authentication methods are in place
SP-3	VIS, EHS	Yes	System activities are logged. Some are accessible to superusers and auditors or can be requested on demand.
SP-4	VIS, EHS	Yes	Both adhere to E-ITS.
SP-5	VIS, EHS	Yes	Core requirement for both of the systems.
SP-6	EHS	Yes	Core requirement of EHS. Paper ballot integrity is guaranteed outside of the systems.
SP-7	EHS	Yes	Core requirement of EHS. Paper votes are destroyed outside of the system.

Table 16. Security and privacy requirement fulfilment

ID	Relevant to	Req. met?	Comment
IO-1	VIS, EHS	Yes	Both are integrated to external systems
IO-2	VIS, EHS	Yes	Both allow for integration to internal systems
IO-3	VIS, EHS	Yes	More relevant to VIS, but both have modular architecture.
IO-4	VIS, EHS	Partial	VIS is private, EHS is open source, but developed privately with publication done at set times.

Table 17. Interoperability requirement fulfilment

ID	Relevant to	Req. met?	Comment
TS-1	VIS, EHS	No	Elections up to Estonian governmental elections sizes are supported. There is limited downscaling possibilities. Overhead is large.
TS-2	VIS, EHS	Partial	VIS is entirely web application, but EHS is standalone.
TS-3	VIS, EHS	Partial	VIS is mostly mobile browser compatible, but not entirely designed for mobile use. EHS has mobile application, but no web-browser support.
TS-4	VIS, EHS	Partial	Both are provided similarly to SaaS models, but to only one client.
TS-5	VIS, EHS	No	Very limited support for simultaneous elections.

Table 18. Technical aspects and scalability requirement fulfilment

ID	Relevant to	Req. met?	Comment
OT-1	VIS, EHS	Yes	Business logic is defined by owner, but limited to one owner only.
OT-2	VIS, EHS	No	Availability, security and confidentiality are valued over cost-efficiency
OT-3	VIS, EHS	Yes	Systems adhere to elections laws and are provided as a service according to SLA-s.

Table 19. Other requirement fulfilment

6.5 Analysis summary

The analysis conducted in Chapters 5 and 6 provides a comprehensive understanding of Estonia's electoral software capabilities and its potential for alternative use cases. The examination of Estonia's Elections Information System (VIS) and the Electronic Voting System (EHS) revealed robust infrastructure designed to support transparent and secure elections. Key findings include:

- **Core Functions:** VIS enables seamless data exchange, voting progress tracking,

and result validation, while EHS ensures secure electronic voting processes.

- **Scalability Challenges:** The systems demonstrate a capacity for flexibility; however, adaptations for non-governmental or complex multi-round elections may require significant development efforts.
- **Reusability Potential:** Existing infrastructure can support reuse in contexts like referendums or private-sector decision-making, provided that accessibility and legal compliance are met.

Interviews with stakeholders highlighted the practical considerations for adopting Estonia's election software in alternative scenarios. Key themes include:

- **Acceptance Criteria:** Usability, security, interoperability, and scalability were identified as critical factors. Stakeholders emphasised the need for intuitive interfaces, real-time insights, and advanced analytics.
- **Trust and Governance:** Transparent processes and robust communication are essential to address public trust concerns, particularly in electronic voting mechanisms.
- **Alternative Applications:** The software's potential for non-governmental elections (e.g., university or organisational voting) is promising but requires tailored modifications to meet unique stakeholder needs.
- **Operational Barriers:** Challenges such as ensuring compatibility with existing systems and managing diverse voting requirements across organisations were recurrently noted.

The findings collectively demonstrate that Estonia's election software systems are highly capable yet require targeted enhancements to support broader applications. Emphasis on trust, accessibility, and customisation will be crucial in overcoming technical and governance challenges. By addressing these factors, the systems can evolve into versatile tools for democratic and organisational decision-making. Based on these results, the ideas are explored further in the next chapter.

7 Alternative use cases proposals

Using the information gathered in this study, this chapter proposes ideas and aspects to consider for using the existing governmental election software for alternative use cases. It also attempts to give some structure or format to follow for further work, that explores this topic or attempts to build on it.

7.1 Governance model

Estonia currently lacks a dedicated organisation or governmental body tasked with overseeing central democratic procedures and governance. This includes the development and innovation of technical and software solutions for it. The closest equivalent to such a body is the State Electoral Office (RVT), whose mandate is strictly confined to governmental elections. To equip policymakers with tools for additional central democratic services, a distinct mandate has to be given. When mandating a governmental body with such task, the delicate balance of division of power must be considered. Although centralisation could reduce costs and improve efficiency, it may also raise concerns of perceived authoritarianism among certain stakeholders. Thus, if the need is deemed great enough, the first key decision should be to establish a political or governmental position on high level structure of division elections and voting solutions. Either going with centrally mandated entities, that are already responsible for governmental elections or separating them on a business ownership level, while consolidating some technical or other capabilities. A complete separation is accepting the status quo, where each actor operates within their own domains with very limited to no collaboration or interoperability.

For illustration, the current governance models in use are depicted on Figure 11. The governmental elections follow the 'current governance model 1', where separate organisations handle the governance (Gov1) and technology (Tech1) with both, the organisation and technology, created strictly for specific purpose (Election1). Other election organisers use either of the other two depicted models, 'current governance model 2' or 'current governance model 3'. In model 2 the technological solutions and governance are managed by the same governing body, while model 3 uses external technology, that is managed by their own governance to the extent, that the technological solution allows.

Two potential alternative governance models are depicted on Figure 12. The 'alternative governance model 1' unifies the underlying technologies of different governing models. This model allows for complete independence of different governing bodies, while consolidating technological capabilities. Due to lack of central governance, this model has a considerable chance of resulting in a series of conflicts of interest, if remaining unmanaged, might eventually result in different parties drifting from the consolidated technological model to own separate solutions as is today with larger local municipalities in Estonia, who have the capabilities to run their own models and technologies. The 'alternative governance model 2' would address this lack of central governance and adds a mediator between all the sub-governments, similarly to VOLIS and its' users today, who in their business actions are independent, but adhere to the governance of central body, when it comes to design of underlying processes and technological capabilities. This model could likely be more stable, while becoming less dynamic and responsive to the needs of separate elections organisers.

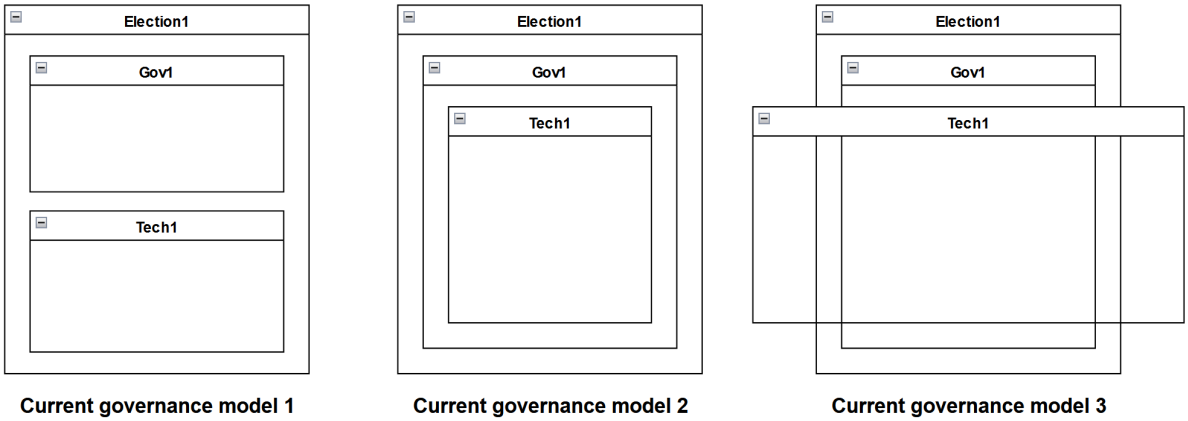

Figure 11. Current governance models

It is also important to note, that while not analysed thoroughly, there seems to be little to no cooperation between the potential alternative users of the solutions. While different parties might know more or less, what others in similar positions are using for voting and election software, they have no desire, tools or means to cooperate in those areas. This could be down to the core lack of actual need or justification for two or more seemingly similar organisations to pursue a joint development, as it never outweighs the pros of organisation specific approach.

Regardless of the path chosen, as per the E-Voting Pyramid of Trust [31], the credible electoral process can only be achieved by competent and structured electoral management body, which is backed by political consensus and support by the wider society. Should the trust of governmental elections be floundering, this could have effect on alternative governing bodies as well.

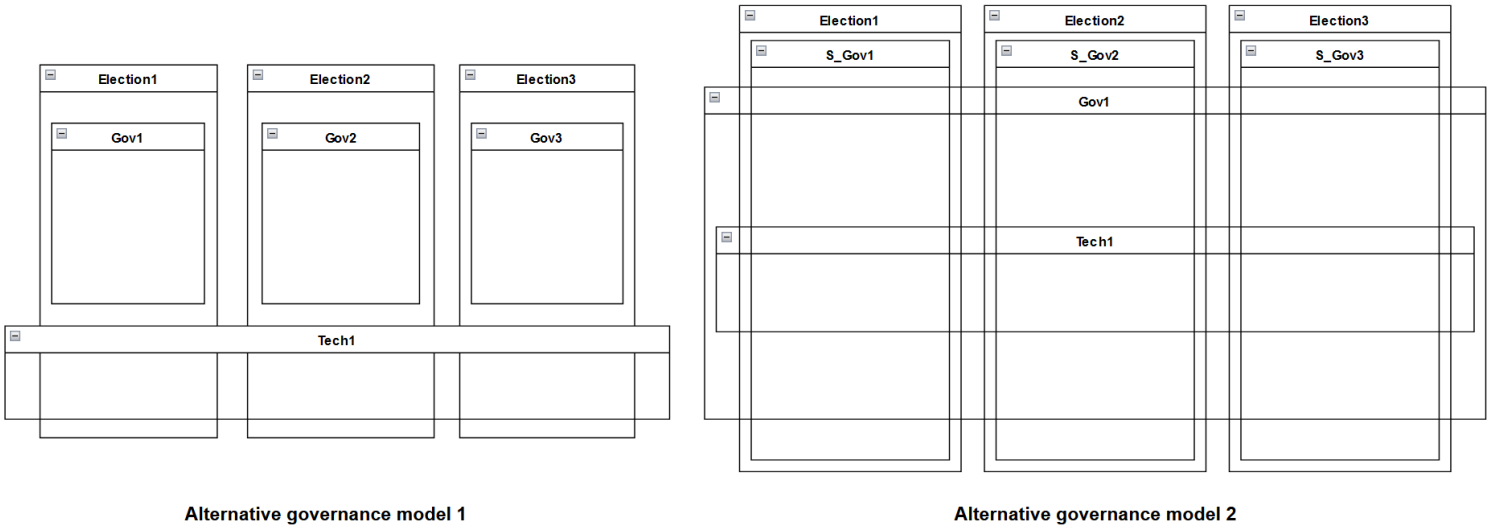

Figure 12. Alternative governance models

7.2 Alternative use cases for EHS

The design and need to be a stand-alone desktop or mobile application is so integrated to the specific needs of Estonian governmental elections, that it is extremely inflexible. This is further supported by that despite the code being public (apart from the voting app itself), no attempts of alternative uses have been implemented by the wider community. In contrast, a rather old and amortised VOLIS has been used by other nations successfully. The developers of EHS agree, that at least from their perspective, the market is looking for either 'one size fits all' or custom designed and built (like current IVXV) type of solutions.

While the mobile application was not analysed in depth, since it is in rather early stages of its' life and has not had any practical use yet, it might solve the issue of distribution and usability, as it would satisfy the need for mobile accessibility, but it still requires a separate app to be downloaded and installed to the device, with a back-end of a very limited scalability handling the rest of the EHS.

Due to unison desire for the voting application to be part of the whole elections information system, the current desktop version of EHS at its' as-is state is unfit to be used for any clear alternative purposes or if the means to achieve it were identified, they would likely not justify the goal of reusability, which is to save costs and administrative burdens of operating multiple similar systems simultaneously.

For EHS to become a potentially centrally managed and suitable for alternative use

cases, it would rather need to be implemented as a web application or offer a different vote casting model, that could be something similar to bank transactions in modern shopping or payment solutions, where the merchant might be running their own shop within their framework and business model, but implements a payment module, that takes the client out of the merchant's ecosystem and completes the transaction in a separately serviced environment and returning the signed and trusted outcome of the transaction. This would require a thorough revision of the current EHS modularity, but the complexity of it would need to be analysed further.

However, there was agreement from the interviews, that using the current solution of EHS for alternative use cases could allow for finding potential issues or bugs more frequently, as the current use of the system in full scale is very rare due to the low frequency of governmental elections occurring.

7.3 Alternatives use cases for VIS

The most limiting expansion of VIS and using it for alternative use cases is the lack of scalable voting engine. For VIS to become a central election management engine, it has to incorporate some alternative voting engine first, by either building a new module, that handles everything voting related or using another solution from the market, that would be compatible with the system. As per the previously explored mobile application analysis, it explicitly states, that web-based solutions are considered less controllable, auditable and secure.

7.3.1 Voting engine

Incorporating a separate voting engine into VIS would effectively mean a forking of two directions. If governmental elections must strictly follow a separate application path and alternative use cases absolutely require web-application, this will remain a foundational conflict of requirements. If this conflict cannot be overcome, there is very limited chance of adaptation to the proposed service, as the inconvenience would outweigh any potential gains for the users. As an alternative solution, VIS should either accept the electronic voting results from another voting engine and be interfaced to it or add an additional module to it, that works as stand-alone voting engine. The current and two potential alternative models are also depicted on Figure 13.

The 'alternative model 1' would keep the same architectural model, but replaces the EHS with some other web-based solution or on the figure 'ALT_EHS'. The alternative

voting engine could be some open-source developed web-based application or built in house. This would, however, mean running a completely separate system outside of VIS. The 'alternative model 2' appends the voting engine within VIS. This way, the electronic votes would have to be kept in either VIS main database or preferably a separate one. With the 'alternative model 2', the main purpose and criticality expand even further, as then the entirety of the election software would be running effectively on one single, albeit modular, system.

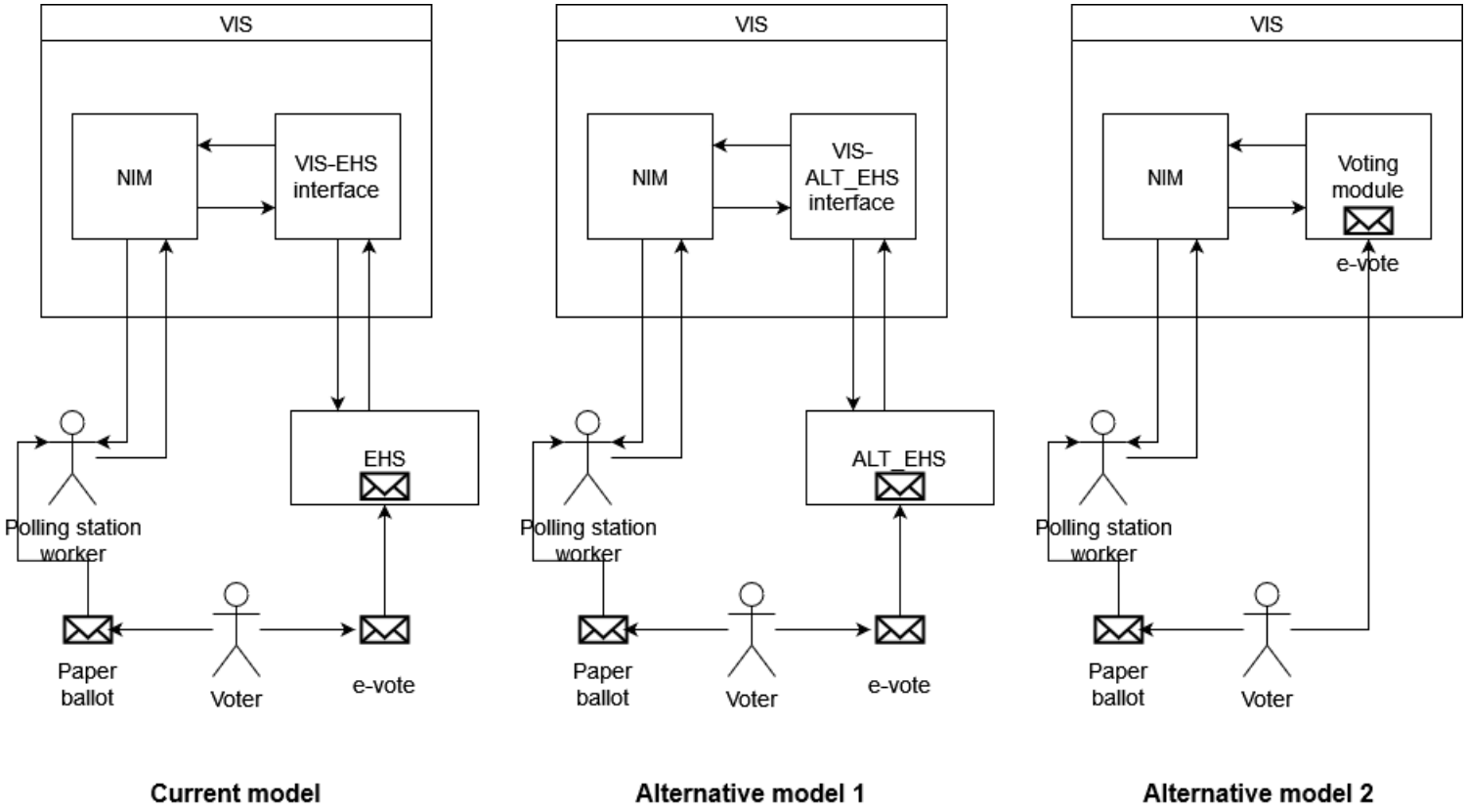

Figure 13. Current and alternative VIS voting engine interface models

7.3.2 Development model

Incorporating a different voting engine and additionally allowing for greater modification for different parties, will inevitably lead to a different project development model. Taking into the account two aspects of making the codebase open-source or even publicly developed and potential separation of the codebase to core- and optional models.

Open source code

To increase the transparency, auditability, trustworthiness and potentially naturally increasing the code user-base, VIS code should be made public. Publication can be done similarly to EHS, where at regular intervals, a new version of the code is pushed to a public repo. The regularity needs to be agreed on and preferably tied to development cycle. This way, any potential user or person in understanding the system can have a look at the implementation. This, however, does not ensure, that the code used in the actual system is the same, that is publicised. To further improve the trust and auditability of the system integrity, an auditable process should be set, that would give confirmation, that the code running on the system is in fact the same, that is published to the public site. Some procedures from the auditability of current EHS could be adapted to VIS to solve this.

Open source software development

In addition to making the code open source it could be considered to change the development model to open source software development model (OSSD) or some hybrid format between it and the current one. This would allow the system to be developed by a community of participants, where decisions are made by either consensus or organisational managers. In theory, this would allow the issues most prevalent in the active community to be worked with and with large enough community, would restrict the project from becoming too dictated by a single interest group. It could also help in bringing down development costs, as it would help to utilise open community contribution and avoid vendor locks. This solution would however come with its' own challenges and the size of the community would very likely be too small to gain the advantages of such model [78].

Core modules and forking

Another aspect to consider in order to make VIS more suitable for alternative use cases is to split the current code-base to separate levels. For example two levels of core- and optional modules. Core module level would contain base components, such as the web framework, access and user management, paper ballot core handling logic etc. Optional level could include modules or parts of code, that each organisation can change or develop further the way they wish to or continue using the versions provided by the core developers. This solution could potentially allow for multiple versions of the system to grow, but in turn creates the risk of different forks becoming too independent or different from the core modules. Even to an extent, that they start requiring different conflicting changes to core modules or forks being abandoned due to changes within user base and unmanageable dependencies by organisations on them.

7.3.3 Simultaneous election models

With centrally provided solution for alternative use cases, one of the key obstacles to tackle is handling a number of simultaneous different organisations, types of elections and number of elections running at the same time. This could be solved with either changing the behaviour of the current system and how it handles simultaneous events or by the system deployment model. All of the further discussed models are depicted on Figure 14. The 'current model' allows limited running of simultaneous governmental elections within the same system within one deployed instance of the system. This model could be used for serving alternative elections as well as depicted in 'Extended current model', but might have availability or confidentiality effects on running national elections, if the resources are not allocated appropriately or the access management has excessive cross-access between alternative and governmental elections. While with sufficient risk management the model could be used, it would be advised to adopt an alternative approach to minimally separate the instance of VIS, where governmental elections are held from the ones, where alternative ones are running.

Here, three alternatives are proposed. Extending from the current model, the easiest change would be to use 'Alternative model 1'. In this model, two instances of VIS run within the same infrastructure. Effectively, the current VIS remains in its' as-is state and keeps serving governmental elections. A second instance of VIS is created, that has no interface or connection to the governmental VIS, but serves all alternative organisations within the same system.

'Alternative model 2' would separate VIS into different infrastructure spaces. This could for example be achieved by using a containerisation technology, that allows the instances run on a same underlying infrastructure, but effectively creates a sub-infrastructure for the system to be running within a container. This would allow each instance of VIS being created for example for each organisation, who wishes to use the system. Using this approach, each organisation can have their own configuration of the running instance. This however increases the number of parallel instances, which all need to be interfaced to other systems. While a common interface module could be considered as well, it is not analysed further here.

'Alternative model 3' additionally proposes a new containerised instance of VIS for each election. While this allows for the most separation of elections and most dynamic resource management and scalability, it creates the largest number of instance and interface management need.

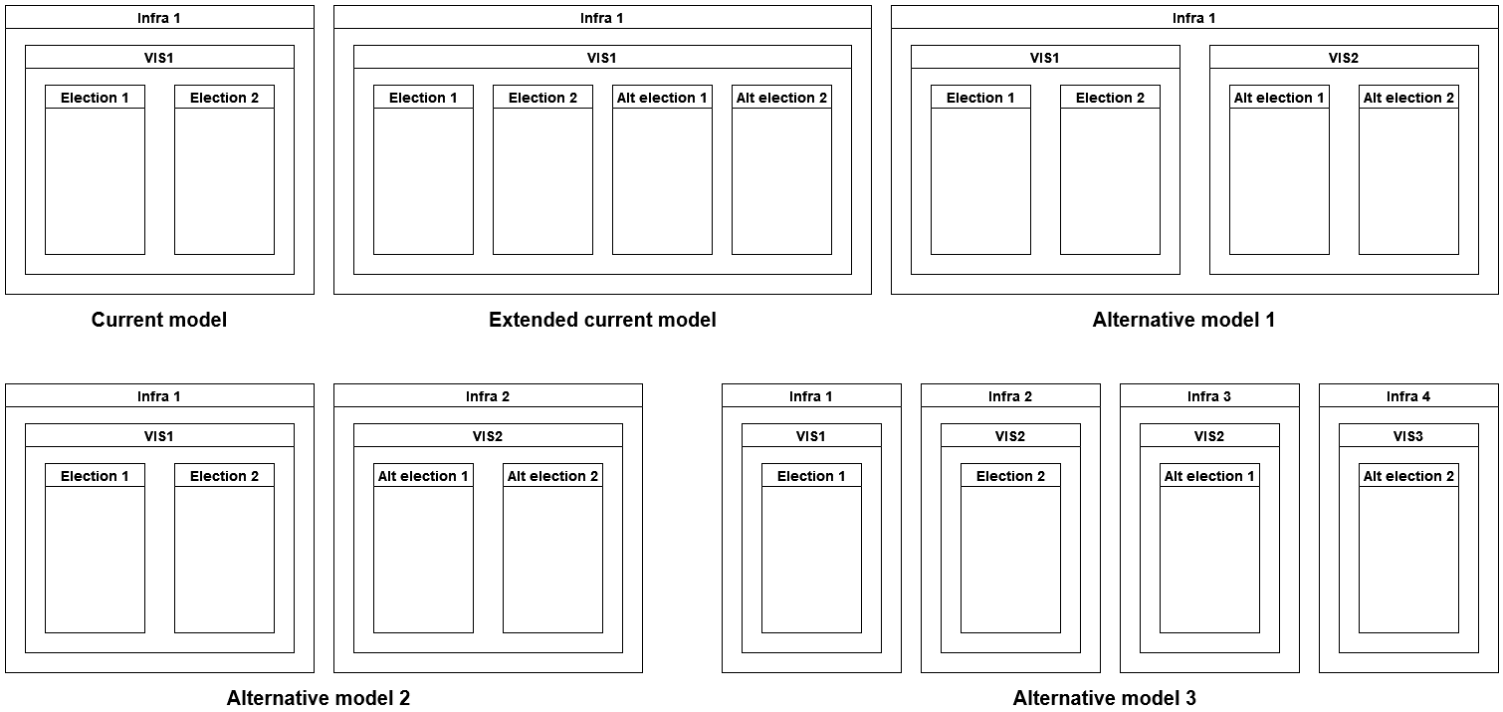

Figure 14. Current and alternative VIS deployment models

8 Limitations and future work

A chapter covering key limitations, that may have affected the outcome and results of the study, and ideas and suggestions for future work.

8.1 Limitations

With the formation of 54. Estonia's government, the position of minister of economy and information technology was made redundant. The highest level of governance of information technology was moved from MKM to the Ministry of Justice with the creation of role of Minister of Justice and Digital Affairs [79] [80]. During the time of writing, the exact lower levels of governance were in the state of unclear. While with the previous governments, the political backing and promotion for innovative voting solutions was strong and vocal, the future is unclear. There is a considerable chance, that the whole idea could fade, as the main driver has not been an actual and studied need, but political slogan. Additionally, as Estonia is experiencing a significant economic recession and the general outlook for the current economy is rather negative. This likely has an all round negative effect on the stance and willingness of spending on novelty services. If the interviews were carried out during the times of more positive economic situation, the willingness to adopt new ideas and features might have been viewed with greater optimism by potential alternative users.

Whenever a new stone is turned, some new need, idea, requirement or limitation might be discovered. Due to that, this study has remained on very generalised level. The amount of specific documentation and details, that exists about the existing technological solutions is vast and to propose more insightful alternative use cases, they should be looked at module by module. The sub-criteria and detailed analysis for each module of a single system could merit another analysis equivalent to the one done in this study. This would then need to be verified against every potential alternative user. This coupled with likely unavoidable conflicts of interest between various potential users would eventually mean, that critical design decisions need to be made centrally that would unfortunately not satisfy all the parties. The inherit ideal of trying to create a system, that 'fixes all problems' is near impossible.

The author has access to some intellectual property (IP), that is currently not made public. This includes mainly the code, documentation, plans, discussions, knowledge

and configurations, that have a varying level of confidentiality. The resources and knowledge used for this study (especially regarding VIS) is a summarisation, that does not interfere with any confidentiality restrictions of RIA. For another researcher to gain access to the same resources, they would need to request them from the owners of the IP. This could however be complex and incomplete, as the external researcher could be denied access to specific documentation or code, or would not have the prerequisites and knowledge about what possible sources are available.

8.2 Future work

As the main goal of the research was to provide baseline knowledge and foundation for future work, there are some immediate key points, that could be followed up on. Additionally, multiple new ideas and avenues were discovered during this research, that could be studied further. Initial focus could be put on understanding the existing capabilities and readiness to impose a governance model, that would acknowledge the wider need for governance of democratic processes and their technological advancements. This study should focus more on political and governance levels and study the models in place in other countries, such as Finland and compare it to Estonia's current capabilities to understand, what challenges lie ahead and what changes need to be made to advance the model.

It could be a perspective future work to study in detail the potential of building a government organisation backed voting engine, that would work similarly to bank links in online retail sector.

A proof of concept model could be designed with one of the potential alternative users. This could aid in identifying any further needs and criteria, that need to be fulfilled in reality and also brings out the areas, that were not covered in this study, eg customer support and SLAs.

Further effort could be put into researching the recent developments of a project called 'Riigi koosloome keskkond' to see, if there could be any overlapping components, processes or ideas with the technologies and software solutions covered in this study. Multiple mentions of the project were brought out during the interviews. It seems to tackle some similar issues, however, the project page has not been updated for the past two years at the time of writing [1].

[1] https://www.just.ee/oigusloome-arendamine/riigi-koosloome-keskkond

9 Summary

This thesis has investigated alternative use cases for Estonia's governmental elections software, focusing on the Electronic Voting System (EHS) and the Elections Information System (VIS). While these systems have been pivotal in establishing Estonia as a global leader in digital governance, their current application is limited to infrequent governmental elections. By exploring their potential for broader societal use, this study aimed to maximise their utility and relevance in diverse contexts.

The research began with a detailed analysis of the existing capabilities and architecture of EHS and VIS. Secondary data highlighted their robust design, modularity, and capacity for integration. These strengths position the systems as promising tools for non-governmental applications. However, challenges such as governance gaps, scalability, and stakeholder trust must be addressed to unlock their full potential.

Primary data collected through semi-structured interviews provided valuable insights into stakeholder expectations and acceptance criteria. Key themes such as usability, security, transparency, and interoperability emerged as crucial factors for successfully repurposing the software. Stakeholders expressed interest in applications ranging from university rector elections to organisational voting and public referendums, underscoring the need for systems' versatility.

The study also revealed that without a clear mandate or changes in the governance model for non-governmental elections, coordinated progress among stakeholders is unlikely. Organisations often prioritise ease of implementation over cost-effectiveness or long-term value, limiting the potential for collaborative, innovative projects. To overcome this, governmental institutions must first understand the needs of potential users before designing solutions, ensuring that the service concept aligns with strategic goals. This approach prioritises the client and their requirements over retrofitting existing tools to ill-defined problems.

In conclusion, this thesis demonstrates the potential for Estonia's election software to extend its impact beyond governmental elections, offering valuable tools and frameworks for policymakers to conceptualise innovative solutions for diverse democratic and organisational processes. While the main research question (RQ) has been largely addressed, further work is needed to fully explore the scope of potential users identified

in sub-question one (SQ1). Nonetheless, the study effectively answers SQ2 and SQ3 by identifying acceptance criteria for adoption and the limitations of current technological solutions, providing a strong foundation for future research.

Although challenges remain, the findings pave the way for a more inclusive and efficient digital ecosystem. The author concludes that the research has achieved its objectives and provides meaningful contributions to the field.

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Appendix 2 - Interview topics and questions

Interview nr 1: Tallinna Tehnikaülikool (TTÜ)

- Types of elections conducted at TTÜ (rector elections, student council elections, doctoral committees).
- Use and history of electronic voting systems (ElectionBuddy).
- Details of the transition from paper-based to electronic voting in 2018.
- Processes for initiating and managing electronic votes.
- Verification and security of voter eligibility.
- Legal and procedural guidelines for elections.
- Challenges in electronic voting adoption and its practical implementation.

Interview nr 2: Eesti Koostöö Kogu

- Overview of Rahvaalgatus.ee as an e-democracy platform.
- The gap in state support for digital democracy initiatives.
- Issues with integrating e-petitions and collective participation platforms into government structures.
- International comparisons, e.g., Finland's Sitra model.
- Organizational limitations and lack of strategic alignment for supporting public participation platforms.
- Discussion on privacy, security, and the saliency of digital signatures.

Interview nr 3: Erakond Parempoolsed

- Complete adoption of electronic voting in party operations.
- Use of VOLIS platform for elections and decision-making.
- Challenges with legal recognition of electronic operations (e.g., Business Register integration).
- Benefits of an electronic-only approach in terms of efficiency and member participation.
- Observations on limitations in existing state-level infrastructure for digital party governance.

Interview nr 4: Eesti Reformierakond

- Digital strategies for party governance and internal decision-making.

- Levels of adoption of electronic voting within the party structure.
- Comparing traditional voting processes versus electronic systems.
- Evaluation of voter participation in digitally mediated decisions.
- Technological limitations and dependencies on third-party tools.

Interview nr 5: Eesti Maaülikool

- Adoption of e-tools in academic and organizational governance.
- Discussion on electronic voting in university-level decision-making.
- Challenges in managing digital processes in academia.
- Balancing traditional and electronic governance methods in a hybrid system.
- Institutional resistance to fully electronic transitions.

Interview nr 6: Eesti Linnade ja Valdade Liit

- Role of VOLIS in municipal decision-making.
- Implementation of electronic voting and decision-making at the municipal level.
- Balancing legal requirements with the flexibility of electronic platforms.
- Challenges in educating local government personnel about digital systems.
- Potential improvements in electronic governance frameworks.

Interview nr 7: Cybernetica AS

- Technical and cybersecurity challenges of electronic voting platforms.
- Innovations in secure authentication methods for voting systems.
- Recommendations for future developments in e-voting.
- Observations on systemic vulnerabilities and risk management in digital elections.
- Potential for Estonia's e-governance model to influence global practices.

Interview nr 8: Nortal AS

- Perspectives on private sector contributions to public e-governance systems.
- Case studies of collaboration between Nortal and state entities for digital transformation.
- Challenges in scaling electronic governance systems.
- Integration of diverse digital platforms into cohesive frameworks.
- Importance of user experience and accessibility in designing public platforms.

Interview nr 9: Tallinna Linnavalitsus

- Adoption and impact of electronic systems in municipal governance.

- Examples of e-services introduced to improve citizen engagement.
- Challenges in implementing electronic solutions at the city administration level.
- Strategies for enhancing public trust in digital governance.
- Future plans for expanding electronic participation and service delivery.

Appendix 3 – Exploration of additional election types

Category	Examples of elections/votes	Potential relevance
Public governance	Presidential elections, local council elections [2], regional referendums on boundaries [3], audit committee members [4]	High
Professional associations	Bar association elections, medical board elections, engineering board elections [5]	High
Educational institutions	University rector elections [6], student body elections	High
Non-governmental organisations (NGOs)	NGO leadership elections [7], shareholder voting, union leader elections	Medium
Religious organisations	Election of clerics [8], church boards, councils	Low
Cultural and community organisations	Sports federation leadership elections [9], local housing association votes [10], community polling [11]	Medium
Political parties	Party leadership elections [12], candidate selection	High
Citizen initiatives, digital participation	Proposals on citizen initiatives [13], legislative petitions, local citizen referendums	High
Cooperative and business organisations	Board elections [14], foundation trustee elections	Medium
Trade unions and labour groups	Leadership elections [15], collective bargaining agreement votes	Medium
Healthcare and social institutions	Hospital board elections [16], votes on social welfare policies	Medium
Youth and grassroots movements	Youth parliament elections [17], school or class representative elections	Medium

Table 20. Potential categories for reuse of governmental election software

[2]https://www.err.ee/1609537600/narva-linnapea-jaan-tootsi-umbusaldamine-kukkus-labi
[3]https://maaleht.delfi.ee/artikkel/64607724/valdade-uhinemine-aegviidu-laheb-rahvakusitluse-teed
[4]https://adr.novian.ee/jarva$_{v}ald/dokument$/6241322
[5]https://eetel.ee/eesti-elektritoode-ettevotjate-liidu-pohikiri/
[6]https://oigusaktid.taltech.ee/valimiseeskiri/
[7]https://eestimetsad.ee/wp-content/upload/2019/08/pohikiri-umo-15.12.2017.pdf
[8]https://eelk.ee/kiriku-korraldus/valimised/
[9]https://www.eok.ee/organisatsioon/uudised/eesti-olumpiakomitee-presidendiks-valiti-kersti-kaljulaid
[10]https://www.riigiteataja.ee/akt/109052017014?leiaKehtiv
[11]https://sakala.postimees.ee/8138859/haaletus-mis-voiks-olla-viljandimaa-vabakonna-aasta-tegu
[12]https://tartu.postimees.ee/8118337/uus-erakond-erk-valis-vastsele-ringkonnale-esimehe
[13]https://rahvaalgatus.ee/
[14]https://harjuelekter.com/et/as-i-harju-elekter-noukogu-esimehe-valimine/
[15]https://ehl.org.ee/2021/07/02/ehl-i-valimised-esinduslikem-opetajate-organistsioon-sai-uued-juhid-ja-arengusuunad/
[16]https://parnu.postimees.ee/7173766/parnu-haigla-otsib-konkursi-teel-uusi-juhte
[17]https://www.haapsalu.ee/haapsalu-noortevolikogu-valimised-2021

Appendix 4 – IVXV collection service microservice architecture

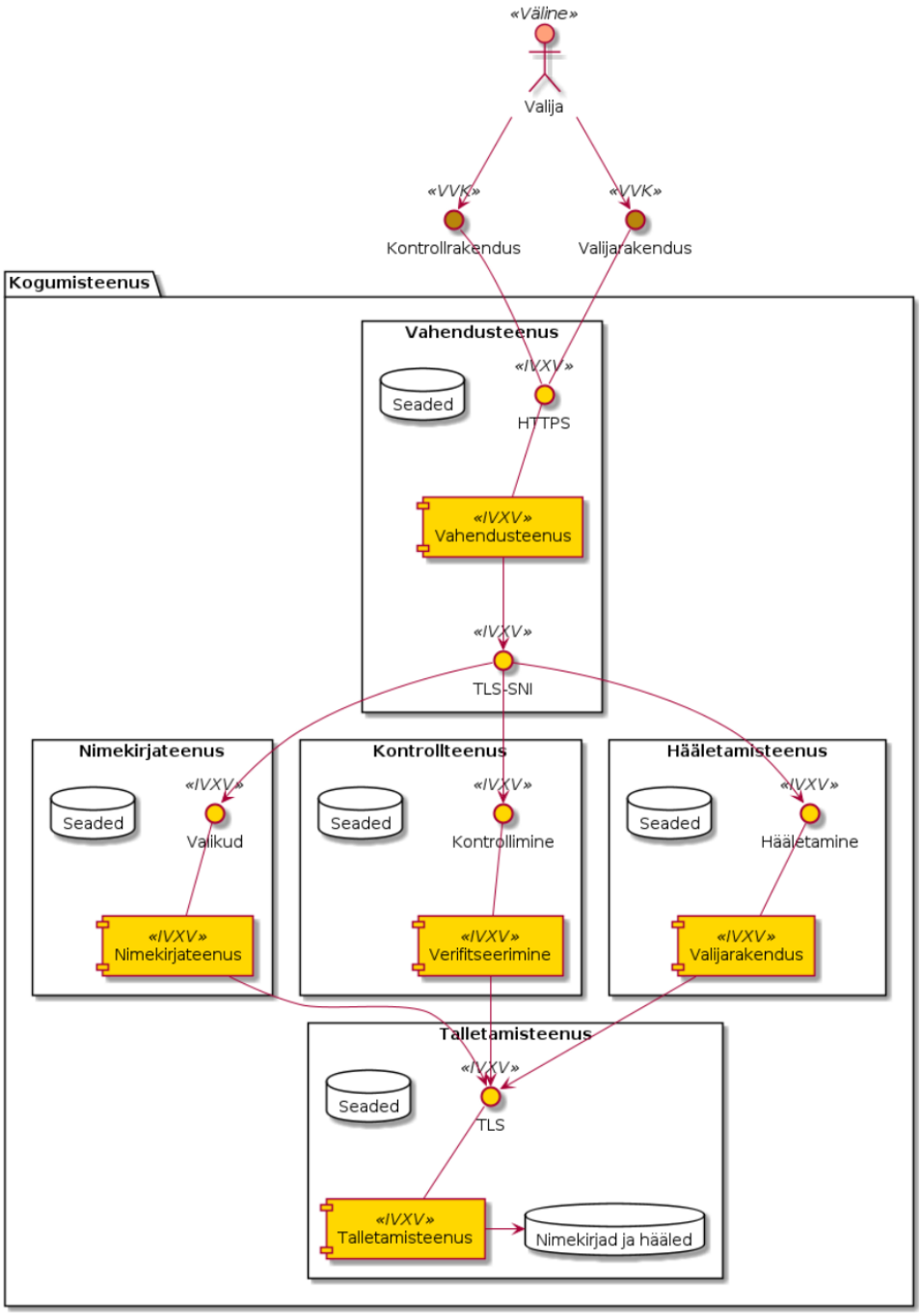

Figure 15. IVXV collection service microservice architecture [69]

Appendix 5 – European Interoperability Framework recommendations

Principle	Recommendations
Subsidiarity and Proportionality	1. Ensure that national interoperability frameworks and interoperability strategies are aligned with the EIF and, if needed, tailor and extend them to address the national context and needs.
Openness	2. Publish the data you own as open data unless certain restrictions apply.
	3. Ensure a level playing field for open source software and demonstrate active and fair consideration of using open source software, considering the total cost of ownership.
	4. Give preference to open specifications, taking due account of the coverage of functional needs, maturity, market support, and innovation.
Transparency	5. Ensure internal visibility and provide external interfaces for European public services.
Reusability	6. Reuse and share solutions, and cooperate in the development of joint solutions when implementing European public services.
	7. Reuse and share information and data when implementing European public services, unless certain privacy or confidentiality restrictions apply.
Technological Neutrality and Data Portability	8. Do not impose any technological solutions on citizens, businesses and other administrations that are technology-specific or disproportionate to their real needs.
	9. Ensure data portability, namely that data is easily transferable between systems and applications supporting European public services without unjustified restrictions.
User-Centricity	10. Use multiple channels to provide European public services to ensure users can select the channel that best suits their needs.
	11. Provide a single point of contact to hide internal administrative complexity and facilitate access to European public services.
	12. Put in place mechanisms to involve users in analysis, design, assessment, and further development of European public services.
	13. Ask users of European public services for once-only and relevant-only information, as far as permitted by legislation.
Inclusion and Accessibility	14. Ensure that all European public services are accessible to all citizens, including persons with disabilities, the elderly, and other disadvantaged groups.
	Digital public services should comply with widely recognised e-accessibility specifications.
Security and Privacy	15. Define a common security and privacy framework and establish processes for public services to ensure secure and trustworthy data exchange.
Multilingualism	16. Use information systems and technical architectures that cater to multilingualism when establishing a European public service, based on users' needs.
Administrative Simplification	17. Simplify processes and use digital channels whenever appropriate for the delivery of European public services to reduce administrative burdens on users.
Preservation of Information	18. Formulate a long-term preservation policy for information related to European public services, especially for information exchanged across borders.
Assessment of Effectiveness and Efficiency	19. Evaluate the effectiveness and efficiency of different interoperability solutions and technological options, considering user needs and cost-benefit balance.

Table 21. EIF underlying principles recommendations

Layer	Recommendations
Interoperability Governance	20. Ensure holistic governance of interoperability activities across administrative levels and sectors.
	21. Put in place processes to select relevant standards and specifications, evaluate them, monitor their implementation, check compliance, and test interoperability.
	22. Use a structured, transparent, objective, and common approach to assessing and selecting standards and specifications.
	23. Consult relevant catalogues of standards, specifications, and guidelines at national and EU levels when procuring and developing ICT solutions.
	24. Actively participate in standardisation work relevant to your needs to ensure requirements are met.
Integrated Public Service Governance	25. Ensure interoperability and coordination over time when delivering integrated public services by establishing necessary governance structures.
	26. Establish interoperability agreements at all layers, complemented by operational agreements and change management procedures.
Legal Interoperability	27. Ensure legislation is screened by means of 'interoperability checks' to identify barriers and perform a 'digital check' when drafting legislation for European public services.
Organisational Interoperability	28. Document your business processes using commonly accepted modelling techniques and agree on how these processes should align to deliver European public services.
	29. Clarify and formalise organisational relationships for establishing and operating European public services.
Semantic Interoperability	30. Perceive data and information as public assets to be appropriately managed, shared, and preserved.
	31. Develop an information management strategy to avoid fragmentation and duplication.
	32. Support sector-specific and cross-sectoral communities to create and share open information specifications.
Technical Interoperability	33. Use open specifications, where available, to ensure technical interoperability when establishing European public services.

Table 22. EIF interoperability recommendations

Component	Recommendations
Internal Information Sources and Services	34. Use the conceptual model for European public services to design or reengineer services and reuse existing components.
	35. Decide on a scheme for interconnecting service components and maintain the necessary infrastructure for European public services.
Base Registries	36. Develop a shared infrastructure of reusable services and information sources for all public administrations.
	37. Make authoritative sources of information available to others, implementing security and privacy controls.
	38. Develop interfaces with base registries and publish semantic and technical documentation needed for reuse.
	39. Include appropriate metadata for each base registry, including descriptions, assurances, licences, and glossaries.
	40. Create and follow data quality assurance plans for base registries and master data.
Open Data	41. Integrate the opening of data into business processes, working routines, and new information system development.
	42. Publish open data in machine-readable, non-proprietary formats with high-quality metadata.
	43. Clearly communicate the right to access and reuse open data and promote standardised licences.
Catalogues	44. Put in place catalogues of public services, public data, and interoperability solutions, using common models for descriptions.
External Information Sources and Services	45. Where useful and feasible, use external information sources and services when developing European public services.
Security and Privacy	46. Identify and implement specific security and privacy requirements for public services based on risk management plans.
	47. Use trust services according to the Regulation on eID and Trust Services as mechanisms for secure and protected data exchange in public services.

Table 23. EIF conceptual recommendations