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Metamodel and method for e-health systems landscape mappings

Master's Thesis

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Metamudel ja meetod e-tervise süsteemide maastiku kaardistamiseks

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Abstract

Background: Understanding the comprehensive state of the e-health landscape, encompassing both public and private systems, is currently a formidable global challenge. No existing mapping solutions are high quality or gather all systems in one platform. Despite recognition by specialists of the significant potential benefits of such a mapping tool for advancing the e-health landscape, there is a notable lack of investment in the development of system mappings. This gap is largely due to a lack of awareness among decision-makers about its importance and need for funding. Highlighting the value of landscape mapping and devising an optimal method for its implementation is crucial to kickstart its development process. **Aim:** This research aims to develop an optimal method and a metamodel for mapping e-health systems enabling healthcare practitioners, organisations, developers, and policymakers to make informed decisions about the selection, integration, and optimisation of software solutions to enhance the e-health landscape. **Methods:** A four-staged mixed study combining qualitative content analysis and design research to conduct 12 interviews with e-health professionals for requirement engineering, create a prototype of a mapping, implement 30 students for populating the prototype with data, and conduct review interviews with the initial e-health professionals. **Results:** Key identified requirements included system integrations and interoperability, comprehensive technical documentation, functional capabilities, and a review mechanism. In total 85 requirements. Findings indicated that the prototype platform Notion is not ideal for this purpose, and the functionalities of the HL7 standard in its current form are also unsuitable. For the mapping to be sustainable, it is essential to have a reliable platform manager, regular updates, and active participation from system owners, especially in the public sector, where there is currently a reluctance to contribute data to the mapping. Additionally, a repository of requirements has been compiled to aid in constructing the optimal mapping solution. **Conclusions:** The study underscores that a mapping is an invaluable tool for enhancing the e-health landscape and should be prioritised for development. The methodology and requirements identified in this research can guide the creation of such a mapping.

This thesis is written in English and is 53 pages long, including 6 chapters, 3 figures and 10 tables.

Annotatsioon

Taust: E-tervise maastiku kaardistamine, mis hõlmaks kõiki lahendusi nii era kui ka avalikus sektoris, on suur väljakutse nii kohalikul kui ka rahvusvahelisel maastikul. Olemasolevad platvormid ei ole kõrge kvaliteediga ega ei kaasa kõiki süsteme. Vaatamata spetsialistide tunnustusele, et kaardistus on oluline töörist e-tervise maastiku edendamisel, on nende arendustesse investeerimine puudulik. Mis on tekkinud tänu otsustajate teadlikkuse puudumisest tööriista märkimisväärsest olulisusest ja rahastuse vajadusest. Teadlikkuse tõstmine e-tervise maastiku kaardistuse väärtusest ja optimaalse meetodika väljatöötamine selle rakendamiseks, on oluline selle arendusprotsessi käivitamiseks. **Eesmärk:** Uurimistöö on suunatud optimaalse meetodi ja metamudeli väljatöötamisele e-tervise süsteemide kaardistamiseks, võimaldades tervishoiutöötajatel, organisatsioonidel, arendajatel ja poliitikakujundajatel teha informeeritud otsuseid tarkvaralahenduste valiku, integreerimise ja optimeerimise kohta e-tervise maastiku edendamiseks. **Metoodika:** Neljaastmeline uuring, mis kaasab nii kvalitatiivset sisuanalüüsi kui ka disaini analüüsi. Viidi läbi 12 intervjuud e-tervise spetsialistidega nõuete kaardistamiseks, loodi kaardistuse prototüüp, kaasati 30 tudengit prototüübi andmete sisestamiseks ja viidi läbi valideerimine esmaste spetsialistidega. **Tulemused:** Peamised tuvastatud nõuded hõlmasid süsteemide integratsiooni ja koostalitlusvõimet, põhjalikku tehnilist dokumentatsiooni, funktsionaalsusi ja hinnangusüsteemi. Kokku koostati 85 nõuet. Leiti, et prototüübi platvorm Notion ei ole kaardistuseks ideaalne ja HL7 funktsionaalsused on samuti ebasobilikud. Selleks, et kaardistus oleks jätkusuutlik, on hädavajalik omada usaldusväärset platvormi haldajat, regulaarseid andmete uuendusi ja süsteemide omanike aktiivset osalust, eriti avalikus sektoris, kus on praegu rohkem vastumeelt andmete sisestamisele panustada. Lisaks on koostatud nõuete kogum, mis aitab luua optimaalset kaardistuse lahendust. **Järeldused:** Süsteemide kaardistamine on e-tervise maastikku edendamisel hindamatu vahend ja selle arendamine peaks olema esile tõstetud, kuid enne on oluline lahendada platvormi jätkusuutlikkus. Uuringus tuvastatud metoodika ja nõuded võivad osutuda vajalikuks tööriistaks, et kujundada kaardistuste loomist.

Lõputöö on kirjutatud inglise keeles ja sisaldab 53 lehekülge põhiteksti, 6 peatükki, 3 joonist ja 10 tabelit.

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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03.01.2024

List of abbreviations and terms

ADM	Architecture Development Method
API	Application Programming Interface is a set of rules and protocols for building and interacting with software applications, allowing different software systems to communicate with each other [64].
EHR	Electronic Health Record
EHR-S	Electronic Health Record-System
e-Health	The use of digital technology and communication tools in healthcare to improve patient outcomes, enhance medical services, and streamline healthcare management [56].
e-Health system	Any software used within the domain of e-Health.
E-ITS	Estonian Information Security Standard [65]
HL7	Health Level Seven is a range of global standards for the transfer of clinical and administrative health data between applications [63].
Metamodel	Framework that outlines the structured approach and tools used to describe the architecture of a system [61].
Notion	Productivity and workflow management platform that combines note-taking, task management, databases, and project tracking into a single, unified workspace [69].
PHR	Personal Health Record
PHR-S	Personal Health Record-System
TOGAF	The Open Group Architecture Framework
UI	User Interface is the visual and interactive component of a digital product or system through which a user interacts, encompassing the design of screens, buttons, icons, and all other visual elements and interactive features [31].
UX	User Experience is the overall experience and satisfaction a person has when interacting with a product or system, particularly in terms of ease of use, efficiency, and overall enjoyment [31].
WHO	World Health Organization
X-road	Distributed data exchange layer for secure interoperability between different information systems [55].

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1 Introduction

The healthcare industry is undergoing a profound transformation, driven by technological advancements and the increasing integration of software solutions into every facet of patient care and healthcare management [1]. The growth of healthcare software systems, encompassing electronic health records [2], telemedicine platforms [3], diagnostic tools, information systems [4], service support tools, patient engagement systems and many other systems, has brought opportunities for improving patient outcomes, enhancing critical workflows, and optimising healthcare delivery [5]. Nevertheless, this digital revolution has also ushered in challenges requiring a comprehensive understanding and systematic approach to navigating the electronic healthcare software landscape.

The sheer abundance of healthcare software systems, which can also be correlated to the field of healthcare data [6], combined with the rapid pace of development, presents organisations, and policymakers with a daunting task – identifying, evaluating, and implementing the right software solutions to address specific clinical, operational, and administrative needs [7]. There is also considerable interest in addressing the challenges associated with implementing e-health initiatives to enhance the performance of health professionals [8]. The need for a structured, systematic method to map and assess the ever-evolving landscape of healthcare software has never been more pressing.

This master's thesis endeavours to fill this crucial knowledge gap by introducing a novel and standardised method for mapping e-health software systems. By doing so, it aims to empower healthcare stakeholders, to make informed decisions regarding the selection, integration, and optimisation of the e-health and therefore the healthcare landscape.

2 Background

The field of e-health emerged in the late 1990s. The term "e-health" was first used in the literature in 1999. It was initially defined as an emerging field at the intersection of medical informatics, public health, and business, referring to health services and information delivered or enhanced through the Internet and related technologies. [11] Since then, e-health has evolved and expanded to encompass various aspects of digitised healthcare delivery, including telemedicine, telehealth, electronic health records, and mobile health (m-health) [2], [13].

E-health policies and regulations play a critical role in shaping the landscape [5]. Governments and regulatory bodies, in particular, are increasingly recognising the importance of e-health in improving healthcare delivery and patient outcomes [44]. However, crafting effective policies and regulations requires resources but also complete information on the healthcare landscape. A method and a standardised catalogue for e-health landscape mapping can provide policymakers with the key research they need to formulate effective regulations. Research helps align policies with the ever-evolving e-health landscape, promoting the adoption of best practices[44], [45]. In the contemporary medical landscape, there is a growing significance placed on information systems and the standardisation of transmission protocols. Consequently, the integration of medical software systems has become a requirement [4]. Integrating systems and even so, large-scale systems not only require standardisation but also compatibility research [47]. A resource such as a catalogue with all of the necessary information could change the time needed to implement integrations significantly.

According to the World Health Organization (WHO), it is crucial to develop fundamental e-health building blocks such as services and applications, infrastructure, standardisation, and interoperability [70]. However, a detailed overview of the current landscape, which could significantly enhance this process, is still a non-existent tool. Although the notion of less detailed variants of e-health system catalogues is well-established, with numerous existing platforms that exhibit varying degrees of quality, standardisation, accessibility, usability, and validity. Many of the recognised catalogues are government-managed [9], [40], [41], [42], while others originate from the private sector [10], [39]. These platforms offer valuable insights into the potential requirements of a catalogue, despite the limited research conducted in this domain.

However, all catalogues have their limitations. For instance, MedCom in Denmark has compiled a database for telemedicine and this database aims to gather and annually present an overview of telemedicine's spread. Yet, they face a significant issue: not all systems are covered due to the voluntary nature of data entry, coupled with the lack of any validation process for the data submitted, which leads to undetected inaccuracies [15]. In addition, the mapping only covers telemedicine and there are many more parts of e-health. Another notable example is the German Digital Health Applications Directory (DiGA), which compiles digital health applications that doctors can prescribe for patients, a concept that is quite revolutionary. While this mapping offers detailed data on the applications, as of 2023, it includes only 58 applications [41], [49]. This limited scope fails to encompass the entire e-health system and is restricted to medical applications only, therefore not providing a comprehensive overview of the entire landscape.

Integrating the diverse features and functionalities of e-health technologies is a necessary step [30]. In the evolving healthcare landscape, as new services and systems are developed, a common issue arises from the lack of clarity on how platforms are similar or different, often due to varying definitions used to describe their functionalities [66]. The adoption of international standards like HL7 for mapping the functionalities of e-health solutions can promote a clearer overview of the landscape, facilitating productive collaboration and bringing benefits to all stakeholders [67], [68]. However, despite their advantages, such standards are often not utilised in mappings [39], leading to a noticeable gap in interoperability, both locally and internationally.

E-health has been developing for years and the amount of solutions has been expanding rapidly around the world [1]. Although this study focuses on the e-health mapping method in the context of the Estonian healthcare landscape the method itself could have more potential on the international scale, being more universal with the functionalities than locked to country-specific standards. The scope of the study is more concise than the international scale because Estonia already has comprehensive and innovative e-health solutions [14] and the author is more familiar with the local e-health landscape.

Research problem

Existing mappings for e-health systems do not focus on all e-health solutions [41], [40], do not use international standards [39], [10], nor do they cover the needs of healthcare professionals [9], mapping and as the healthcare technology development rapidly expands there is a significant need for a structured and standardised method for mapping, evaluating, integrating, and selecting e-health software solutions.

Research aim

The aim of this research is to develop a comprehensive method for mapping e-health systems, enabling healthcare practitioners, organisations, developers, and policymakers to make informed decisions about the selection, integration, and optimisation of software solutions to enhance the e-health landscape. The development of this method includes creating a metamodel.

Research questions

1. What are the essential dimensions and requirements that must be considered when creating an e-health systems mapping?
2. What is the method for creating the most optimal e-health systems mapping?
3. How valid is the use of HL7 standard functionalities for e-health systems mapping?

2.1 Key concepts

This is a study of developing a metamodel and a potential method for e-health software mapping, the present chapter discusses the relevance of core concepts regarding the research. These topics shed light on the motivations driving the research and show the necessity of the aspects that have been examined through a series of interviews and questionnaires.

In the context of this study, it is essential to provide clear definitions for two key terms: "e-health system" and "mapping." The term "e-health" is defined as a software application related to healthcare services supported by digital processes like Electronic Health Records [54]. A multitude of e-health software solutions exist within and beyond the common perception of mobile apps and computer software. Each of them could be considered as a separate “system” on their own. Therefore, in this study, the term "e-health system" encompasses the full spectrum of digital solutions within the healthcare sector. This includes a wide range of both public and private software solutions, such as registries, tools for data exchange support, information systems, specialised software tailored to specific medical fields, as well as innovative solutions like unique applications made by startups, decision support tools, patient empowerment software, and telemedicine applications, among others [7]. In essence, it covers all digital tools used in the electronic healthcare domain regardless of their scale. The term “mapping” in this study has been defined by R. Wieringa in requirements engineering study as a means to create an inventory of items in the topic area [52]. In this study, an inventory is the e-health systems and the topic area is the e-health landscape. “Catalogue” is another term used in the study which is essentially the result of the mapping. A catalogue is considered to be a systematic and organised collection or database of software applications or programs, in our case e-health systems. It serves as a central repository of information about various systems, making it easier for users to discover, evaluate, and select the applications that best suit their needs. [53] The term catalogue is used for the prototype created in the study.

While designing efficient and effective mappings or any other digital platform user-centricity is paramount. In this era the design must go beyond the mere aesthetics and reflect a platform's commitment to meeting user needs and expectations, fostering loyalty and trust [33]. User experience and user interface (UX/UI) are considerable factors in developing any sustainable digital solutions [31]. These two facets are intrinsically linked, as they collectively determine how users interact with and perceive a product or system. A well-crafted user experience ensures that the product or service is intuitive, efficient, and enjoyable to use, promoting user satisfaction and retention. Moreover, a thoughtfully designed interface serves as the bridge between the user and the underlying functionality, guiding users through their journey and making complex tasks accessible [32], [33]. Effective UX and interface design contribute to enhanced usability, reduced errors, and increased productivity, ultimately resulting in a positive impact on a project's success. Therefore, setting up UX/UI design requirements for a mapping will have a considerable impact on its longevity.

While an optimised UX/UI design undeniably enhances the sustainability of the method developed in this study, it is essential to recognise that it is not the only factor for the catalogue's longevity. Returning to the fundamentals of building a robust system, it becomes imperative to understand its intended purpose by use cases. Use cases are commonly embraced and acknowledged as a practical tool for specifying the functional requirements of a software system [34]. By defining and documenting how potential end-users interact with the catalogue and its functionalities, use cases provide a comprehensive analysis of user requirements and expectations [34]. They provide a reference point for making informed decisions about which features to prioritise, modify, or introduce, thus preventing feature bloat and maintaining a streamlined and user-centric catalogue [35].

Enterprise architecture is an emerging and valuable practice that is increasingly recognised as a fundamental competency for organisations. It is now regarded as an essential core capability for businesses, and its applicability extends to various architectural models, including those within the realm of software development [37]. In the context of TOGAF (The Open Group Architecture Framework), a metamodel is a fundamental concept used to define the structure and relationships between various architectural components within an enterprise architecture framework [21]. The metamodel is a critical component of the TOGAF Architecture Development Method (ADM) and helps architects organise and understand the components of an enterprise architecture [21]. Building a metamodel for a healthcare system mapping has considerable potential to make the platform clearer and also more interoperable with other Enterprise Architecture models [12].

Throughout the course of the study, a prototype validation process is introduced. Utilising prototypes for the validation of requirements represents a fundamental and valuable practice in the field of software and system development [28]. Prototypes serve as tangible, interactive representations of a proposed system, enabling stakeholders to visualise and experience its functionality [29]. This proactive approach offers numerous advantages in terms of requirement validation. Facilitating a shared understanding of the system's expected behaviour, allowing for the detection of misunderstandings or missing requirements. This iterative process of refinement results in more precise and complete requirements. Additionally, prototypes provide an opportunity to assess usability, user interface design, and overall system functionality [28], [29].

Understanding the distinctions between systems can be challenging without streamlined documentation or comprehensive mappings [30]. Each system possesses functionalities that may not be immediately apparent without delving into its technical details. Additionally, documentation often varies in clarity and detail, as it is typically written by different authors with varying perspectives, making it difficult to ascertain a system's specific functionalities [66]. To address this, standardisation is necessary for a clearer overview. In this study, we have adopted the HL7 standard to facilitate this understanding.

The HL7 functional model standards for Electronic Health Records represent a crucial step toward achieving interoperability and standardisation within the healthcare domain [3], [36], [50]. Using an international standard helps to connect entities on a global scale. It establishes a uniform framework for developing solutions that align with the foundational model, ensuring consistency across diverse platforms and systems. Standardised functionalities enable a consistent representation of healthcare systems, making it easier to categorise, compare, and evaluate them. The standardisation enhances the clarity, precision, and interoperability of the catalogue, ensuring that users can efficiently locate and comprehend the specific systems within the e-health landscape [3], [38], [50].

While research specific to the development of a software systems catalogue or related methods is lacking, it is important to acknowledge the existence of software mapping solutions in a broader context. These repositories vary considerably in terms of quality and accessibility, and although they may offer insights and potential mapping methodologies, the degree of detail they provide remains a limiting factor. Additionally, paywalls sometimes hinder the exploration of the entire system in detail [39]. This study draws upon references from select catalogues, including Capterra, and the RIHA platform [9], [10], as a means to provide a broader context for the conceptualisation of healthcare landscape mapping.

The method for a system catalogue encompasses eventually creating the catalogue itself which is a software solution, and therefore certain insights in developing a method can be taken from software requirement engineering. Requirement engineering is a crucial phase in software development and systems engineering [27]. It encompasses the processes and techniques used to elicit, document, analyse, validate, and manage the requirements of a system or software application. The primary objectives of requirement engineering in this study are to understand and define the needs and expectations of healthcare professionals, provide a clear and comprehensive specification for system development, and ensure that the final product (the developed prototype) meets these requirements [25], [27].

3 Methodology

This chapter of the paper introduces the methodology of the study. A comprehensive overview is given on the design, data collection and analysis.

3.1 Study Design

This study was conducted using a mixed method of qualitative content analysis (QCA) and design research (DR). The first method is for uncovering patterns and trends within content and the second is for creating user-centered prototypes by efficient requirement engineering.

Conducting a qualitative study offers a valuable means of attaining a detailed understanding of the requirements, given its open-ended approach to data collection. This methodology is particularly advantageous when the subject matter is relatively unexplored [17]. Rather than aiming to validate existing knowledge, the primary objective is to learn new insights by delving into the perspectives of healthcare professionals and potential users of a healthcare catalogue. By employing semi-structured interviews as the data collection method, the researcher gains the advantage of eliciting more in-depth responses [18].

During the interview planning process, specific thematic areas are defined, encompassing general inquiries. It's important to note that while each questionnaire within this study includes predefined questions, the interviewers retain the flexibility to pose additional questions, thereby enabling a more comprehensive exploration of the selected topics. [17], [18] Additionally, this study entails the development of a catalogue prototype for the e-health landscape for verification purposes and for gaining more in-depth perspectives on the findings in the final stage of the study.

During the whole study, the inductive approach was used as it is beneficial for its capacity to explore, discover, and interpret data in a manner that is open to new insights and tailored to the unique characteristics of the research context. It is a bottom-up method where researchers start with specific data and, through a process of coding and categorisation, identify patterns, themes, or concepts that lead to the formulation of broader theories or explanations [22], [23].

The second method implemented in this study is design research (DR) which involves a systematic approach to solving the challenges within a specific topic [50]. This method integrates tools to explore the intricacies of user needs and technological requirements. Activities which include user interviews, observations, prototyping, usability testing and data analysis are essential to DR. Through iterative cycles of (1) research, (2) building, and (3) evaluation, the methodology plays a pivotal role in developing comprehensive and impactful solutions [58] like the e-health systems mapping. This study implements the method in the initial interview process for requirement engineering (research). Based on the gathered information entailing mapping requirements a prototype is built (building). Next, the prototype is reviewed by the initial interviewees (evaluation). Following this review, additional research and analysis are conducted. However, for the purposes of this study, the process stops at this point, and no further iterations are carried out.

This study entailed interviews and review interviews with 12 professionals related to e-health and healthcare, developing a mapping prototype with 60 systems, providing a lecture, instructing and supporting 30 students for data entry to the prototype, requirement engineering and building a resource.

The study design varies around different stages of the paper and therefore the whole process of the study was separated into four stages for clarity, planning and efficiency. The stages were the following:

1. Interviews and data collection. The focus was to find eligible interviewees and conduct the interviews to understand what are the core requirements for the landscape mapping from potential users.

2. Prototype architecture building and prototype preparation. In this stage, the potential architecture for the catalogue prototype was developed based on the results of the previous stage. The guidelines for adding data to the prototype catalogue were created.

3. Mapping prototype development. This stage included creating the catalogue of healthcare software with the help of the data entry team and analysing the whole process.

4. Review interviews and conclusions. The final stage was about reviewing the created catalogue prototype and getting feedback on it from the interviewees from stage 2. The stage concluded with organising and analysing the final data.

Table 1. Summary of the study design per stage of the study

Stage	1. Interviews and data collection	2. Prototype architecture building	3. Mapping prototype development	4. Review interviews and conclusions
Sample	12 professionals related to e-health	-	30 students from Digital Healthcare curricula	9 professionals related to e-health
Methods	QCA, DR	DR	QCA	QCA, DR
Activity	Interviews and questionnaire	Prototype design and development	Data entry and questionnaire	Interviews and questionnaire
Results	1. Prototype requirements 2. Mapping sustainability data	1. Prototype model 2. Prototype instructions and resources 3. Built prototype	1. Prototype with data 2. Info about data entry 3. Validation of Notion (data entry) 4. Validation of HL7 functionalities (data entry)	Validation of : 1. Requirements 2. Notion 3. HL7 standard 4. Additional requirements

The following subchapters explain the specificities in the research design of each stage.

3.1.1 Design of interviews and data collection stage

In order to develop an optimal prototype for an e-health systems catalogue, it is imperative to gain a comprehensive understanding of the requirements and preferences of healthcare professionals who will be the primary users of this catalogue.

Sampling

A total of 12 participants were included in this study, meeting the established inclusion criteria. The process of participant selection took place between January 12, 2022, and February 16, 2022. The selection methods employed a combination of purposive sampling and convenience sampling. Purposive sampling involves the intentional selection of participants by the researcher, based on their knowledge, experience, and expertise relevant to a specific group of interest. These participants were chosen purposefully according to specific criteria. Convenience sampling, on the other hand, included individuals who were readily accessible to the researcher. This approach involved enlisting individuals who were of interest to the researcher and available and willing to participate [18].

The participants were considered to be potential users of the catalogue and most importantly e-health field-related professionals who have the most insight into the requirements of the catalogue. These professionals would have been related to the healthcare field and know it in depth, they would be from different sectors, from different organisations. Three limitations were considered for the sample - sample size based on saturation of answers, the current sector they are working at, and the amount of experience in the healthcare field.

The initial criterion of sample size was the extent of data saturation observed. This criterion defined the number of additional interviews conducted after the minimum number of interviews was done. 10 participants were considered as a minimum to achieve the essential amount of information and a significant variety in answers. Once the minimum criterion was met, further interviews were carried out within the target group. However, in case of the absence of novel insights into the functionalities of the catalogue, it was deemed unnecessary to continue with additional interviews, as they would not yield further substantive findings for the study's objectives [24].

The second criterion taken into account when selecting interview participants was the similarity of their professions. The underlying assumption here was that the catalogue would serve professionals from diverse fields and sectors. Consequently, it was imperative to ensure representation from both the private and public sectors, encompassing individuals in various positions. This approach aimed to capture a broader spectrum of perspectives and needs.

The third criterion considered the level of experience that interviewees had in their respective fields, particularly concerning their potential use of the e-health systems catalogue. The assumption underlying this concern was that the catalogue's users would span a wide spectrum of expertise within the healthcare field. To address this, the author included participants with varying levels of experience, ensuring the representation of both newcomers and seasoned professionals in the study. This approach aimed to accommodate the diverse knowledge backgrounds of potential users.

Data collection and analysis

The interviews took place from January 16, 2022, to April 22, 2022. Prior to commencing the recording of these interviews, participants were provided with a reminder of the study's objectives, the recording process for both audio and video and the intended utilisation of the collected data within the study. The interviewees were asked 9 questions in the interview, which were sent to them before the interview. The interviewees were asked to prepare the answers to the questions beforehand to conduct more concise and informative interviews. The questionnaire for the interview was crafted primarily to validate if a method for a catalogue of e-health systems is necessary and what functionalities it should have. The functionalities of the potential catalogue were the most important topics discussed in the interview. In addition, there were background questions and questions about the longevity of the potential catalogue. Appendix 1 presents an overview of the questions and the validation of why these questions were implemented. Interviewees were given the option to answer the questions in written format by themselves or have an interview in an online video call format. The online interviews were recorded with consent to not miss any details and for the ease of gathering data. Prior to the online call sessions, the interviewers were instructed to go through the questions for a more concise interview. In total 10 of the interviews were done in a video call format and 2 of them sent written answers.

Throughout the analysis inductive research approach was used, as this approach is best when litter prior theory exists about the subject. The replies from the interviews were manually coded into shortened forms based on the topics and keywords mentioned and thematically analysed. With coding, it was possible to count all of the repetitions of the same or similar answers for developing a catalogue. The highest repetitions were deemed as important requirements for the metamodel, although all answers were considered while implementing the architecture. The shortened form information was further categorised into groups under broader topics for better filtering and data visualisation.

The short-form results of requirements were appended to a table which includes descriptions of the requirements for clarity and weight measurement which defined the amount of repetitions or mentions of the same topic. The maximum number of repetitions is correlated with the number of interviews which was 12. The more repetitions the more important the requirement is.

3.1.2 Design of prototype architecture building and preparation stage

In the second stage of the study, the focus was to organise all of the replies and understand which were the most prominent requirements to build the metamodel architecture for the landscape catalogue prototype. Additionally, the guidelines for data entry for the prototype and example data were prepared in this stage.

Setting up guidelines and the preparation of the prototype for data entry required a platform which would have the most optimal functionalities regarding the requirements from the previous interviews. The platform choice was made based on the author's previous experience and testing regarding two platforms: Obsidian and Notion. Obsidian had more technical freedom to construct the necessary architecture but it was also for a more technically adept audience [70]. The selected choice was Notion - a cloud-based workspace for notes, tasks and other activities [69]. The platform was selected for easier usability and for a simpler learning curve by the data entry team (students) to understand. Not only data entry was considered when choosing the platform, but the option to present the metamodel preview to the interviewees in the final stage of the study was simpler to achieve and share using Notion.

The data entry team consisted of students of the 2022 TalTech spring semester lecture IHT1050 Healthcare Data Systems and Analysis. During this stage, the author facilitated a part of a lecture regarding informing the students of upcoming tasks. The lecture consisted of the introduction of the project, the need for the model and what they would learn from completing this part of the curriculum. The guidelines on how to enter the data and how to use Notion were also presented at the lecture in short and students were shared with more detailed instructions. The detailed instructions consisted of text and visual material including instructive videos on how to achieve the desired results. The purpose of detailed instructions was to ease the student's integration with the project and with the platform.

Standard for functionalities

A fundamental element that underpins universal models is the standardisation of information [3]. Given the diverse range of functionalities inherent in e-health systems, it becomes essential to ensure that each of these functions is uniformly defined by the data entry team. Without this standardisation, data management becomes a formidable challenge. In light of this, the present research method embraces the adoption of the HL7 standard [36] functional model for representing system functionalities during data entry into the prototype. The documentation states the functionalities may be present in Personal Health Records systems (PHR-S) and Electronic Health Records systems (EHR-S) [50]. Therefore functionalities may be broader than implementation for only these systems.

The model was chosen because it offers an international standard suitable for a global system and it should present information in a format easily comprehensible to individuals from diverse backgrounds, facilitating the clear articulation of business requirements by users, even those without specialised technical knowledge. [50]

A resource was made by the author to organise all of the standardised functionalities in the Notion platform. Two lists [19, 20] of standards were compiled in a single data set and duplicate codes were removed while prioritising the newest code description. An example of a part of the final list can be seen in Appendix 16. The created list of functionalities contained 456 entries.

The documentation on the functions had statements and descriptions of every function and the selection criteria as shown in the figure.

	of receipt according to scope of practice, organizational policy, and/or jurisdictional law.			
TI.1.6 Function	Secure Data Exchange			1367
	Statement: Secure all modes of PHR data exchange. **Description:** Whenever an exchange of PHR information occurs, it requires appropriate security and privacy considerations, including data obfuscation as well as both destination and source authentication when necessary. For example, it may be necessary to encrypt data sent to remote or external destinations.			
	1. The system SHALL secure all modes of PHR data exchange.			1368
	2. The system SHALL conform to function TI.1.7 (Secure Data Routing).			1369
	3. The system SHOULD provide the ability to de-identify data.			1370
	4. The system SHALL encrypt and decrypt PHR data that is exchanged over a non-secure link.			1371
	5. IF encryption is used, THEN the system SHALL exchange data using recognized standards-based encryption mechanisms according to organizational policy, and/or jurisdictional law.			1372
	6. IF the PHR-S is the recipient of a secure data exchange, THEN the system SHOULD provide the ability to transmit an acknowledgment of the receipt of the data.			1373

Figure 1. Example of one functionality and selection criteria from the HL7 list.

The data entry team was instructed to use the selection criteria as intended in the documentation. If they believe that a system has a functionality then they would have to go through the criteria and make sure that the existing functionality aligns with one of the "SHALL" criteria as marked in the previous figure. The wordings PHR and PHR-S which stood for Personal Health Records and PHR-Systems, were instructed to be considered as generalised e-Health systems.

To analyse how difficult it was to use the HL7 standard of functionalities a questionnaire was made in the next stage of the study for the data entry team to fill and give their rating on the difficulty of using the documentation of functionalities as well as open-ended questions on their experience and any issues they might have encountered.

Prototype architecture

Data collected from the interviews played a pivotal role in shaping the architecture of the catalogue prototype. As a result, the proposed prototype featured a system list or gallery, which included details such as system title, software category, owner, icon, and a brief description for all represented systems. Under each system, two types of data sets were presented: unique and universal. Unique data sets pertained exclusively to the specific system, such as a description tailored to that system. Universal data sets, on the other hand, are applied to all systems. These universal sets allowed for the grouping of similar elements or functionalities shared by multiple systems.

The envisioned prototype also included a back-end resource section responsible for storing all data sets. These resources served the critical function of linking multiple systems to common functionalities, certificates, and other relevant elements. This feature was particularly significant for filtering purposes, enabling the identification of technically or functionally related systems. However, due to constraints related to the Notion platform and considerations for teaching alignment, modifications were made to the prototype's architecture. The final architecture is depicted in Figure 2.

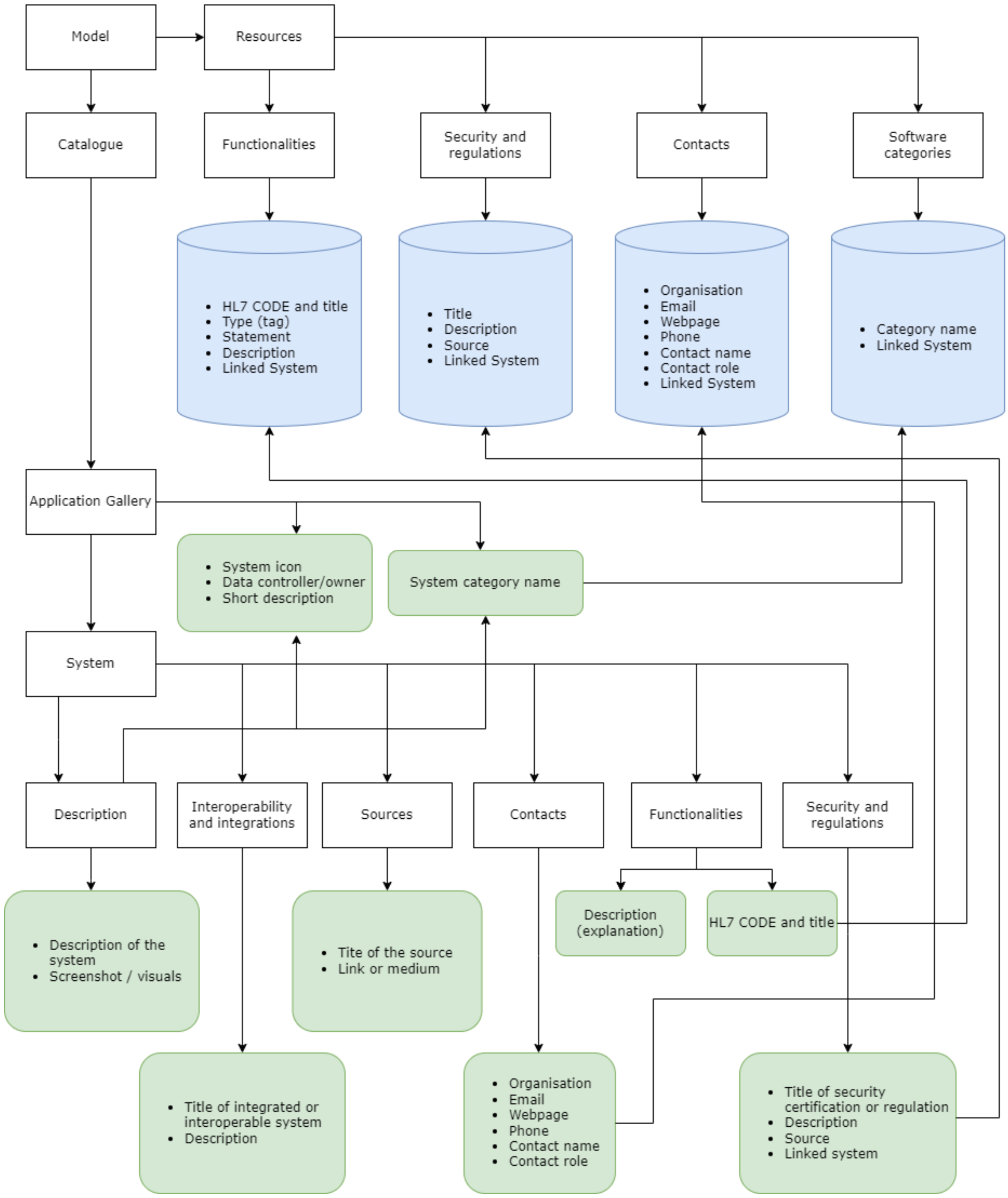

Figure 2. The basic architecture of e-health system mapping prototype. The architecture is based on the capabilities of the Notion platform. The blue cylinders refer to back-end data sets. White boxes are sections, green boxes are data, and the arrows show connections between sections.

3.1.3 Design of mapping prototype development stage

In the data entry phase, the author offered assistance to students who encountered difficulties with the platform or experienced accidental data deletion or overwriting by other users. This support was intentional and played a pivotal role in ensuring the successful execution of data entry. The reason for its significance was the potential ease with which critical components of the prototype structure could be inadvertently overwritten or deleted. Certain sections of the model were interlinked, and any modifications within these areas had far-reaching consequences. The process of restoring this information had to be carried out with great care and swiftness since a rollback would result in the loss of continuous platform additions.

The next phase of this research involved populating the prototype with data, based on the guidelines and architecture developed in the previous stage. The intention was to ensure that the catalogue included data in all sections of systems and encompassed multiple systems. The primary objective was to create a prototype that could be used by the interviewees, allowing them to validate the proposed characteristics.

As previously mentioned the data was entered by the data entry team consisting of students. In total, there were 30 students in the course. Each student was assigned to two systems to populate the data with. The systems were chosen from a list of around 50 to 60 systems collected prior in the course and the students were assigned to the systems on a random basis. However, during the selection of systems students were also given the option to choose systems that they were more familiar with or to choose other e-health systems that were not on the list. All students who were familiar with particular systems selected them to enter into the catalogue. The final list of systems can be seen in Appendix 4.

Data entry was considered an integral part of the method for potential system mapping within this study. Consequently, it was essential to assess the feasibility of the proposed prototype structure for data entry and the suitability of the Notion platform. To gain insights into the data entry process, a questionnaire was administered to the data entry team, providing an analysis of their perspective on the matter. The questionnaire encompassed both quantitative and qualitative inquiries, organised into four distinct sections. A comprehensive list of all the questions can be found in Appendix 5.

The first section of the questionnaire was dedicated to assessing the suitability of Notion as a platform for a catalogue model. It consisted of 7 questions, with 5 adopting a quantitative format and 2 adopting a qualitative format. The second section of questions aimed to gauge the perceived difficulty of third parties in accessing information about systems and to inquire about the anticipated lifespan of the catalogue based on the prototype. Within the section, any additional requirements were inquired that they would like to see in the catalogue to cover their needs as potential users of the e-health system mapping in the future. The section consisted of 4 quantitative questions to give ratings and 3 open-ended questions. The third section delved into the feasibility of HL7 functionalities as a suitable standard for the system mapping catalogue from the standpoint of the data entry team. The idea was to get insight to understanding how easy it is to ascertain the functionalities for a potential average user of the catalogue in addition to how suitable is the HL7 list of functionalities for the systems and how well can the data entry team use the given documentation. In this section, the HL7 list of functionalities was put to the test. The section had 3 quantitative questions about rating the usage difficulty and suitability rating of the list of functionalities. Additionally, 3 open-ended questions were applied to better understand the rating scores and find out what should be taken into consideration when implementing a standardised list of functionalities. The fourth section focused on the academic aspects of the entire process, seeking to gain insights into the student's learning experiences. It should be noted that while this final section was not a definitive part of the study, it aligned with the academic goal of broadening students' perspectives.

Questions that required respondents to rate their responses were presented on a numerical scale ranging from 1 to 5. The results were subsequently analysed by calculating averages. Gathered qualitative data was coded and thematically analysed as it is done throughout the study.

3.1.4 Design of Review interviews and conclusions stage

The final stage of the study encompassed three essential steps: correcting the prototype preview, conducting interviews, and finalising the results.

In preparation for presenting the prototype to interviewees, a preview was created. Given that the data entry team was relatively new to the Notion platform, and with 21 students involved in data entry, the potential for errors was acknowledged. To ensure the prototype's quality, the author meticulously reviewed all sections of the catalogue. This involved addressing issues such as duplicate entries, data misalignment, redundant information, and input errors. Visual enhancements were also made to standardise data representation, preserving the original structure while introducing greater visual clarity. Creating a preview version was imperative to ensure that the prototype was as visually clear and comprehensible as possible. Additionally, the catalogue was temporarily locked to prevent any inadvertent data manipulation during the review process.

The sample of professionals remained consistent with the first stage of this study, and qualitative research methods were once again employed, mirroring the approach used in prior stages.

Data collection and analysis

The interviews took place from February 8, 2023, to March 6, 2023. The process of the interview was the same although a new questionnaire was developed for the interview process. The primary objective of this questionnaire was twofold: to validate the work accomplished in the prototype and to gain a deeper understanding of what aspects needed further refinement within the method.

The questionnaire commenced with detailed instructions on how to utilise the prototype preview, complete with visual aids and guidance for following an illustrative example to acclimate interviewees to the Notion platform. To streamline the interview process, interviewees were also provided with instructions to familiarise themselves with the prototype platform's operation, ensuring their ability to navigate it effectively for the purposes of the study. The questionnaire was divided into 10 sections, with the first two sections dedicated to instructions and an introduction to the platform. Subsequent to these introductory sections, six sections focused on the validation of functionalities within a single system. The final two sections pertained to data tables (Resources) and a comprehensive review of the model presented. A detailed breakdown of the questionnaire's structure, along with descriptions, is provided in Appendix 3**.**

Following the development of the questionnaire, the author reached out to the same interviewees who participated in the second stage of the study. They were invited to complete the questionnaire individually or to arrange a video interview with the author. These video interviews were allotted a duration of 60 minutes, before which the interviewees were encouraged to preview the catalogue to familiarise themselves with its basic features.

Subsequently, the collected results were coded, subjected to thematic analysis, and consolidated. Conclusions were drawn based on the analysis. The inductive data analysis method was used as in the first stage of the study. If a section was functionally validated by the interviewees with minor recommendations for improvement, it was considered a functionally valid section ready for implementation within the method. Furthermore, the metamodel architecture was developed based on the final results.

While qualitative research often involves a limited sample size, the methods employed in this study were designed to achieve data saturation. Data saturation is reached when no further data can be obtained or, more broadly, when incoming data does not contribute additional information to address the research inquiries [24].

The qualitative analysis also formed a part of the design research method for prototype validation. Subsequent to the validation and data gathering, further requirement engineering was conducted. While design research typically involves multiple iterations of prototyping and validation, this study employed only one complete iteration of the cyclic process, encompassing research, prototyping, and evaluation.

Lastly, the outcomes of the study led to the creation of a resource of requirements in the form of a table. The resource compiled all the essential requirements for a mapping, which had been discussed in multiple stages of the study, along with descriptions. This resource defines elements and constructs to be used to ensure consistency and logical integrity within the mappings.

4 Results

This chapter presents the results obtained throughout the entire study. As the study process was divided into four stages, the findings are correspondingly presented in three subchapters, each representing any discoveries made during the respective stages. The second stage primarily focused on the prototype's design, yielding no additional findings.

Each subchapter has numerous appendices which are collectively represented in the following Table 2.

Table 2. Table of appendices with findings

Appendix	Item	Description
Appendix 5	Requirements for prototype development	11 categories of 56 preliminary requirements with descriptions and amounts mentioned
Appendix 6	Use cases for the e-health systems mapping	Four categories of 22 use cases
Prototype visual representation examples		Attributes of every section can be viewed in Figure 2
Appendix 7	Gallery view of e-health systems	Visual gallery of systems for quick overview and navigation
Appendices 8-14	All system data sections and single functionality window (Appendix 11)	(Categorisation data), Descriptions, Contacts, Functionalities, Integrations and Interoperability, Security and Regulations, Sources + view of a single functionality
Appendix 15	Visual example of three sections together	To show how the layout of multiple sections looks like
Appendices 16-19	All resource tables	Functionalities, Software categories, Security and regulations, Contacts
Appendix 20	Most assigned HL7 functionalities	Hl7 functionalities assigned to 10 systems or above. From a total of 849 instances of assignments to 60 systems
Appendix 21	Validation table of prototype review	21 proposed changes and additions with descriptions
Appendix 22	Final resource of requirements of an optimal e-health systems mapping	11 categories and 85 requirements with descriptions and comments
Appendix 23	Final simplified architecture of the optimal mapping	Supplementary architecture for the requirements
Appendix 24	Modified metamodel of the mapping	Metamodel with additional elements and attributes

4.1 Results from the first interview

The first questionnaire and interviews involving 12 e-health or healthcare professionals resulted in two main outcomes. First the initial design requirements for the potentially optimal model on which the catalogue architecture was based on. They were essential for building a prototype for the design research process and user review later in the study. The second outcome was the insight into the sustainability of the catalogue.

Table 3 presents an overview of the background information of the interviewees. Notably, the sample included several project managers, although it must be said that each interviewee represented a distinct organisation. Within the table, individuals classified as senior managers held positions of significant importance within their respective organisations. The sample composition comprised 5 individuals from the private sector and 7 from the public sector.

Table 3. Background information of the interviewees

Current position	Experience in the healthcare field (years)	Current sector
Senior manager	21	Private
Product Owner	21	Private
Senior manager	18	Public
Entrepreneur	17	Private
Senior Analyst	16	Public
Project Manager	15	Public
Senior Manager	15	Public
Project Manager	15	Public
Project Manager	7	Public
Entrepreneur	5	Private
Healthcare professional	5	Public
IT Project Manager	2	Private

4.1.1 Initial requirements for the mapping

After coding and analysing all the responses, a total of 56 distinct requirements were identified. These were categorised and further allocated among 12 overarching topics. While specific requirements mirrored the unique needs and preferences of professionals, it was noteworthy that all professionals gravitated toward certain general requirements for a model. Table 4 illustrates the most frequently mentioned requirements, supplemented with additional descriptions for clarity. The complete table of requirements from the first stage can be found in Appendix 5.

Table 4. Most requested requirements for an optimal mapping model with descriptions. Weight is the number of mentions (12 max).

Topic	Requirements	Weight	Description
Integrations	List of services and systems the system is integrated with	12	List of services used by the system and services that are using the system with descriptions of how the system is integrated
Functionalities	List of functionalities of the system	12	A standardised list of functionalities of what the system is capable of
Technical information	Documentation of technology stack	7	A list of tools and technologies that make up the system
Business Information	Information about accessing the system	6	Details regarding the business model, licensing fees, and related aspects should be provided.
	Information about important or specific contacts	5	Specialised contacts in case of business or integration opportunities
Regulations, certificates and security	System accordance with the medical device regulation	5	Defining if the system is a medical device under the EU medical device directive
Platform design	Optimised user experience and user interface	5	The platform must have an intuitive interface, easy access to necessary functions and data
Platform review system	Platform user feedback to the system	5	Feedback and review system implementation for the system
Platform management	Verification of data accuracy	5	All of the information about the systems must be validated and verified by the manager of the system or system providers
	Information updating	5	Information of systems must be periodically updated and the last update time mentioned for potential users to understand how adequate is the information

Among all the requirements, a notable common interest among everyone interviewed was the necessity for the model to include a list of functionalities and integrations specific to an e-health system. While the need for a list of functionalities was widespread, comprehending all the systems' integrations received not only a similar amount of mentions but appeared to be the primary focus. The main interest lies in understanding the connections between systems and how these integrations function. Several interviewees expressed their desire to visualise the entire network of connections and sought insights into potential connections for their own systems.

The interest in knowing the technological stack (documentation of technologies a system uses) was seen mostly by the representatives of private companies. There was a need to understand how other systems are built to create systems which can integrate with them or find systems to which they can connect to.

Regarding business information, interviewees wanted to see all of their options in one place. The details on the business model of a system to consider various services were sought for. To make their decision processes more efficient and find all possible variations of the services they need on the market. Knowing the technological stack would also make the decisions easier as the most preferred services are the ones that have the same technologies used.

The last three topics in Table 3 were related to the functionalities of the catalogue platform itself. User experience and interface emerged as a crucial aspect, particularly for interviewees who had unfavourable encounters with other platforms that, despite seeming exceptional theoretically, did not cater to the end user's needs and perspective. The subsequent requirement highlighted was the inclusion of a review system in the catalogue, enabling users to provide feedback or assessments of specific systems. This feature would offer additional insights into the services provided by the systems, aiding decision-makers in their evaluations. Furthermore, it would allow system owners to identify necessary changes, thereby revealing prevailing issues within the e-health landscape.

While the topic of platform management was not raised in every interview, those who discussed it deemed it vital. Selecting the right manager for the catalogue platform significantly impacts its sustainability. Neglecting to keep the platform updated both technologically and in terms of data renewal could render the catalogue ineffective.

3.1.2 Sustainability of the mapping

The sustainability of the mapping determines whether the catalogue can withstand the evolving conditions of the digital landscape. Therefore, understanding the intended uses of the catalogue (use cases) and identifying who will maintain the data is crucial when developing the catalogue. The following findings refer to questions 5 and 6 in Appendix 1.

The results for these use cases were compiled and appended to a table in Appendix 6. The use cases discussed by the interviewees were categorised into four distinct topics. An overview of each topic is presented in the following paragraphs.

Creating new services - One of the use cases for this mapping would be for understanding what e-Health systems already exist on the market, and what kind of functionalities they have, to create new solutions that either improve the exciting ones or create new important services that do not exist yet. On a governmental level, the catalogue's role could be shaping procurement and planning regulations, where it aids in creating precise requirements. It also would be vital in developing new private and public systems, offering key insights for system design. By identifying gaps in crucial services, the catalogue would facilitate the introduction of needed solutions, preventing market oversaturation with duplicate offerings. Furthermore, it would serve as a platform for connecting system users with providers, fostering partnerships and enhancing service delivery.

Research purposes - The availability of detailed information about all of the systems and their connectivity with each other allows the creation of more research on e-health systems. The catalogue would be used as a key academic resource that can be used in introducing the landscape. Additionally, the catalogue would aid in analysing existing systems to enhance their efficiency, guiding improvements by comparing their structures and functionalities. The catalogue could be a central hub for system references, support comparative sectoral analysis, and keep users updated on new solutions and startups. Additionally, it's instrumental in mapping various systems for government use.

Communication - The catalogue could serve as an E-health publication centre, providing a centralised platform for disseminating healthcare information and updates. As a database, it could facilitate connections by offering valid contact details of system owners and providers, improving communication channels. The catalogue would be valuable in elevating awareness of the Estonian healthcare landscape, both locally and internationally, by providing detailed insights into the system. Furthermore, it would be used for creating collaboration opportunities among system providers, enabling them to engage and cooperate effectively, thereby enhancing the efficiency and reach of healthcare services.

Integration with services - One of the main use cases would be finding insights into existing registries and their integration processes, enabling connections between different e-health systems. The catalogue would be used as a repository of detailed information on technical standards and conditions for potential integrations, including those with international systems. Additionally, it would aid governmental entities in identifying and integrating with suitable private services, enhancing public-private healthcare collaboration.

Each professional interviewed represented the organisation they worked for, and they were asked about their willingness to contribute information to the catalogue. It is noteworthy that 11 out of the 12 organisations represented by the interviewees were managed, owned, or developed e-health systems.

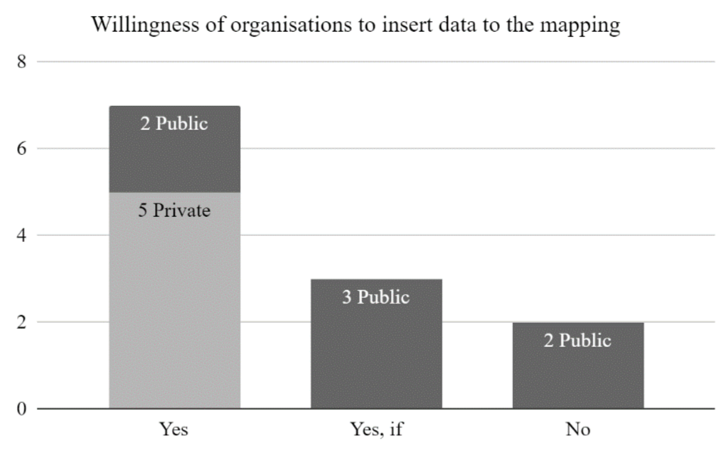

Figure 3. Willingness of organisations to insert data to the mapping based on the interviewed professionals.

Based on the responses, most of the organisations (7 in total) expressed willingness to input and maintain their data in the catalogue. Their primary motivation was either to ensure an accurate representation of their systems or a belief in the catalogue's necessity as a tool for representation. This group included all private sector representatives and two from the public sector. Additionally, three public organisations agreed to contribute data, but only under one specific condition: data entry must be mandated at the leadership or governmental level. The remaining two public organisations were not inclined to add data themselves but suggested implementing automatic data entry and collection, citing a lack of resources to manage the data manually. The findings indicate a disparity in willingness between the sectors, with only two out of seven public sector representatives agreeing to data entry, in contrast to all five representatives from the private sector.

During the discussions about sustainability, several critical issues were emphasised. The longevity of the mapping depends on three main factors: the management entity of the platform, the renewal of its data, and its attractiveness. A consensus emerged that a dependable entity, such as a government institution, should oversee the platform to guarantee its ongoing availability to all users. Additionally, the data on the platform requires regular updates, and incentives should be established to encourage these updates. Without such measures, the platform is at risk of becoming outdated and underused. Lastly, it's crucial to ensure the inclusion of all systems pertinent to the e-health landscape on the platform. A partial listing would not offer a complete view of the landscape, thereby undermining the platform's intended purpose.

4.2 Results from mapping prototype development

As the second stage of the study, which focused on the design of the mapping prototype, primarily served as preparation for the third stage, its sole outcome was the creation of a prototype (Figure 2) using Notion. In the third stage, this prototype was populated with data, and the screenshots, along with explanations of the developed prototype, are presented in Appendices 7-19.

The main subjects of this stage of the study were the data entry team members who had an assignment to populate the prototype with data about systems. The data entry team consisted of 30 students from the Digital Health curricula subject IHT1050 Healthcare Data Systems and Analysis. After data entry, multiple questions were asked from the students. The results of this stage are separated into 4 sections for easier consumption.

4.2.1 Viability of Notion as a platform for building the mapping

Notion was the chosen platform for building the prototype in this study. The data entry team worked with Notion for a 4-5 week period and filled the catalogue with data. The results from the first section of the questionnaire showing the viability of Notion being a potential platform to build this model are in the following Table 5**.**

Table 5. Data entry team average evaluation scores for Notion as a platform for entering the data.

Item	Average rating (1-5)
Data entry team skill level rating for Notion before starting the project	1.14
Data entry team skill level rating for Notion after finishing the project	2.71
Rating if the data entry team will use Notion for their future projects	2.76
Viability rating of Notion as a platform for creating the prototype	3.29
Difficulty rating of entering data to the platform by the data entry team	3.00

The results indicate that the students initially had a low skill level and knowledge of the platform, with an average rating of 1.14 out of 5.00 before starting to use it. In terms of viability, the average rating for Notion as a platform for building the prototype was 3.29 out of 5.00, slightly higher than the median rating of 3.00. This positions Notion as an average platform for prototype creation, highlighting certain areas where the platform falls short.

Furthermore, to understand why Notion was perceived as either effective or lacking, an open-ended question was posed. The responses received were coded and generalised into various topics, which are summarised in the subsequent Table 6.

Table 6. All mentioned issues regarding Notion as a platform for data entry.

Topic	Weight
Accidental data manipulation	11
Lack of functionalities	7
Issues with UX/UI	5
Missing knowledge of the platform	4

The analysis of open-ended responses revealed four main topics. The most frequently mentioned issue was accidental data manipulation, where students easily altered filters, data tables, and information entered by others. Crucially, major changes often occurred without confirmation prompts, and restoring altered elements was challenging for inexperienced students, usually requiring the author's intervention. Although this could be categorised as a UX/UI issue, its significant impact on the project warranted separate consideration.

Another key finding was that students perceived Notion as lacking in certain functionalities which could have streamlined the data entry process. The most notable was the need for a more efficient method to enter HL7 functionalities for a system, as the current approach was considered time-consuming and cumbersome. To mitigate accidental data manipulation, a data locking system was proposed, along with other suggestions like an offline data entry mode and a schematic to visualise linked systems.

From a user experience and interface perspective, Notion was described as non-intuitive for use and navigation. Issues such as additional pop-up windows, extra steps for data addition or formatting, and difficulty in locating specific platform functionalities were highlighted as major concerns.

Lastly, the lack of platform knowledge was explicitly mentioned in four cases. However, this was a general theme, as evidenced by the low skill level rating (1.14 out of 5.0) of the students prior to using the platform.

4.2.2 Viability of data entry to the model by a third party

In this study, the data entry for the prototype was entirely conducted by a third party, referred to as the data entry team or students. A few students had the benefit of direct access to specific e-health systems or previous interactions with them, providing them with more information. However, the majority of the students had no access to most systems. The results presented here pertain to 42 systems entered into the catalogue. Each student was responsible for 2 systems in the prototype and was required to answer questions about both systems. These results were compiled from questions 8 to 10 in Appendix 2.

The average rating for the difficulty of finding documentation for the 42 systems was 2.86 out of 5. The scores assigned were distributed across the scale and did not consistently align with the closest average rating option (3), indicating that the difficulty of sourcing information varied significantly for each system.

Table 7. Issues regarding finding the necessary information for data entry. Max weight 42.

Topic	**Weight**
Lack of publicly available documentation about the system	27
Difficulties matching HL7 functionalities to available information	4
Obscurity of available information	4

Students were prompted to identify specific issues they encountered, and their responses were categorised into three main topics, as detailed in Table 7. The most significant challenge was accessing documentation for the systems. While some systems had publicly accessible information online, the majority lacked any publicly available documentation. The students attempted to contact system owners via email, but responses were rare, and most contacts were reluctant to share information, with a few exceptions. However, this study did not focus on collecting data on these interactions. In cases where information was available, another issue emerged: matching the provided information with the HL7 functionalities proved to be too challenging. This aspect will be explored further in the subsequent part of the results section.

Finally, students mentioned that while they had access to information about the systems, they encountered challenges understanding it in certain cases. This difficulty arose from the technical nature of the documentation, which was geared towards specialists. Consequently, students either had to conduct additional research on specialised topics or possess prior knowledge in the field. Most instances pertained to the students' familiarity with information and communications technologies and their related aspects.

4.2.3 Viability of HL7 standard functionalities

At this stage of the study, the initial validation of the HL7 standards for e-Health systems functionalities took place. The data entry team, tasked with assigning these functionalities, engaged with them in great detail. In total, the students assigned 925 instances of functionalities across the 60 e-Health systems featured in the prototype catalogue. Out of these, 849 instances conformed to the HL7 standard, while the data entry team identified and added 76 instances of functionalities not covered by the HL7 standard. In total, there were 456 unique HL7 functionalities and an additional 32 custom functionalities added.

There were eight distinct groups of HL7 functionalities, and Table 8 illustrates the distribution of functionalities assigned to systems.

Table 8. Statistics on assigned HL7 standard functionalities.

Functionality code	Functionality group name	Total functionalities assigned to systems	Percentage of assigned functionalities from total
PH	Personal Health	283	33.33%
POP	Population Health Support	17	2.00%
CPS	Care Provision Support	43	5.06%
CP	Care Provision	53	6.24%
AS	Administrator Support	15	1.77%
TI	Trust Infrastructure	279	32.86%
S	Personal Health Support	71	8.36%
RI	Record Infrastructure	88	10.37%

The findings indicate that the most frequently utilised functionalities fell into two categories: trust infrastructure and personal health. Functionalities related to personal health are concerned with how individuals can manage their healthcare information, while trust infrastructure functionalities focus on system operations, security, efficiency, and interoperability with other systems. A table detailing the most commonly assigned functionalities (associated with 10 or more systems) along with their descriptions can be found in Appendix 20.

Additionally, the study gathered data on the data entry team's perspectives regarding the viability of the HL7 functionalities for the catalogue model. Their ratings and opinions are presented in the subsequent Table 9.

Table 9. Viability of HL7 standard functionalities based on rating. For the first two diffictulty ratings lower rating means that it was more difficult.

Item	**Average rating (1-5)**
Difficulty rating on using the list of functionalities	2.43
Difficulty rating on finding the functions connected to a system	2.14
Suitability rating for the list of functionalities for the catalogue	3.33

The table illustrates that assigning and connecting the list of functionalities to the systems was challenging, with ratings falling below 3.00. However, the overall viability rating for using this list of functionalities appears to be higher than the median value (3.00). To gain a deeper understanding of these ratings, additional open-ended questions were posed, asking about factors that either facilitated or complicated the process of assigning functionalities. The majority of responses highlighted difficulties encountered, and these are summarised in the following table (Table 10). The results were categorised into two primary themes: unfamiliarity with the systems and the clarity of functionalities. The latter theme includes four subtopics detailing specific issues faced by the data entry team.

Table 10. Issues with the assigning functionalities to e-Health systems.

Topic		**Weight**
Unfamiliarity with the system		10
Clarity of HL7 standard functionalities		15
	Abundance of functionalities	8
	Similarity of functionalities	6
	Abundance of details for functionalities	4
	Understanding of functionalities	4

The findings reveal that for approximately half of the students (10 in total), the most challenging aspect of assigning functionalities was their unfamiliarity with the systems they were working on. This was either due to a lack of substantial documentation on the systems or complete unawareness of these systems owing to their limited public accessibility. Consequently, this lack of knowledge made it more difficult to accurately assign functionalities to systems they were not well-acquainted with.

Most students (15 out of the total) indicated that the primary challenge they faced was related to the clarity of HL7 functionalities. They found that the extensive range of available functionalities, each requiring significant effort to understand and validate, was overwhelming. Additionally, many functionalities within the same category were defined in similar terms, making it difficult to distinguish between them. This similarity often led to confusion about whether they were assigning the correct functionality. The lack of comprehensive system documentation further compounded these difficulties.

Another issue highlighted was the lengthiness of the descriptions for each functionality. With almost every functionality accompanied almost by half a page of text and assignment criteria (as shown in Figure 1), comprehending such a large volume of information in one sitting was challenging, especially considering the total of 456 functionalities.

Lastly, the technical language used in the descriptions or the specialised nature of some functionalities presented barriers. Students lacking specific knowledge in certain areas found it impossible to accurately assign these functionalities. The prospect of researching and understanding each functionality, especially without prior knowledge, was deemed impractical by the students.

The responses concerning the beneficial utility of HL7 functionalities were limited in quantity, although still yielded insightful observations. An advantage identified by the students was the convenience offered by standardised lists of functionalities. This feature alleviated the need for students to independently devise or seek out documentation for these functionalities. The ease of selecting options from a pre-defined list, complete with instructions, was contrasted with the more demanding task of each student having to formulate their own functionality definitions.

Furthermore, they were asked what could have been different to make the assignment of functionalities easier in their opinion to understand more of why they were hard to use or what is it possible to do in the next iterations.

The most frequently suggested change was related to the extensive number of functionalities and the detailed nature of these functionalities. The data entry team proposed having a more concise list, with functionalities defined more narrowly to facilitate quicker understanding. They also recommended removing functionalities that appeared unnecessary, either by reducing the overall number or the number of similar functionalities. Further suggestions from the data entry team included improved training or preparatory work. This could involve learning more about the technical aspects of the Notion platform, workshops on more efficient assignment of functionalities, or gaining specialised knowledge about certain complex functionalities to ensure their more effective and efficient assignment. Other recommendations included implementing a more straightforward method for entering functionalities into the system, as the current method was deemed too cumbersome, gaining access to documentation before starting data entry, and categorising functionalities more clearly.

As noted earlier, not all functionalities assigned were from the HL7 standard. During the assignment process, students were instructed to add functionalities with justification if an e-Health system possessed a clear functionality not represented in the HL7 list. These additional functionalities were double-checked by the author to ensure no overlap with the HL7 list. In total, 32 new functionalities were added: 10 similar to HL7 functionalities, 12 related to system integrations, and 10 specific to a system. These extra functionalities were used 76 times out of a total of 925. The HL7 standard, derived from electronic health record systems, might not align with every type of system.

4.3 Results from prototype review

The final stage of the study involved a prototype review with e-health professionals. The results presented here validate the functionalities of the developed prototype and expand upon the requirements identified in the initial interviews.

During the interview process, all existing functionalities in the prototype were confirmed as necessary for the catalogue. However, certain sections required changes and additions for further optimisation. For the e-health system sections, all new requirements, complete with descriptions, were combined and compiled into a table (Appendix 21). The following paragraphs summarise these results.

The first navigational section of the prototype, presenting systems in a gallery view (Appendix 7), did not prompt specific functional changes. This gallery consisted of 60 cards featuring an image, name, software category, related stakeholders, and a brief description. The feedback mainly focused on the need for more data on the cards and the issue of descriptions being not fully visible.

The next section, the description section, appears after selecting a system from the gallery view. It contains the same elements as the gallery, along with a more detailed description and a screenshot of the interface (Appendix 8). Professionals suggested adding more information such as links, references, and a healthcare system classification to this section.

The next section for validation was the contacts section (Appendix 9), where only a few changes were proposed. These changes included the addition of more concrete business contacts for customer support, integration, or further information about the system. Additionally, interviewees expressed a desire for the contact information to be automatically updated when changes occur. This addresses a common issue in third-party information repositories, where contact information can become outdated due to a lack of ongoing oversight after the initial data entry.

The functionalities section comprised two elements: the functionality name and code, along with an explanation or rationale for assigning the functionality to the system (Appendix 10). These functionalities were clickable, revealing all systems linked to a given functionality and providing further details (Appendix 11). This section was one of the most extensively developed in the study and emerged as a major requirement for the catalogue. The primary modifications suggested by professionals focused on (1) improving the clarity and visualisation of functionalities, (2) connecting functionalities with other sections, (3) adding a filtering function to the section, and (4) expanding the range of functionalities.

For some interviewees, the HL7 functionalities were overly technical and challenging to comprehend for everyday healthcare professionals, thereby reducing their practical value. However, the use of a standardised approach was highly valued. An issue raised was the visualisation of functionalities; it was suggested that they should be categorised or visually distinguished for improved readability. When more than 10 functionalities were assigned to a system, readability became an issue, necessitating some form of classification within that section. Additionally, a filtering option to view specific functionalities was requested. There was also interest in exploring the connections between the functionalities of systems and other sections. For instance, a link could be made between a functionality that indicates the security of information in a system and the security certificate displayed in the "Security and Regulations" section.

The interoperability and integrations section (Appendix 12) consisted of two parts, similar to the functionalities section. It included the title of the interoperability or integration and a description of its implementation. This section was tailored to each system, as they all had different methods of integration with various systems. The main additional requirements identified for this section were: (1) adding more specialised integrations and detailed descriptions, (2) standardising this section within the catalogue, and (3) including information about the documentation of these integrations. The integrations displayed, sourced from publicly accessible repositories, were quite broad. Specialists expressed a desire for more specific integrations, such as the type of API systems are connected to, with more technical descriptions of the data transfer involved. The current representation of integrations and interoperabilities varied in function and description. For example, technological connections like connectivity with X-road (a data exchange service between environments and organisations [55]) were listed alongside mentions of the Estonian Health Insurance Fund, explaining its role in covering healthcare service costs. Due to the broad range of topics covered, professionals recommended standardising this section to ensure information is categorised and described according to specific criteria. The final suggestion was to add references and access to documentation on how integrations are implemented, allowing other systems to access manuals for connecting with the same platforms.

The subsequent section, security and regulations (Appendix 13), comprised of four elements: the name of the implemented security feature or the title of the regulation linked to the system, its description, the reference source, and other systems sharing similar security features or regulations. While this section was largely validated, the primary concern raised was the need to separate security elements and regulations into distinct lists due to their differing natures.

Among some interviewees, there was uncertainty about the necessity of displaying a list of regulations or whether this constituted an essential functionality. In terms of the content within this section, professionals expressed a desire for more detailed information regarding specific certifications, such as the E-ITS (Estonian Information Security Standard) audit [65] and other similar credentials.

The final section, the sources section (Appendix 14), although not initially listed among the requirements, was essential for academic purposes and served as a reference point for sourcing information about the system. This section comprised a list of source names along with links to these sources. As this section was a component of the prototype, reviewers affirmed its necessity, validating it as crucial for providing references for further research. They also expressed a preference for including references to case studies within this section.

In addition to the sections specific to each system, the interviews also examined the resources section of the prototype, where global lists of items are stored (depicted as blue cylinders in Figure 1). These resource lists, vital for creating links in the Notion platform, encompassed items used across systems in the catalogue, such as functionalities, security and regulations, contacts, and software categories. Each of the other sections contained unique, system-specific items. The resource lists were highlighted as essential for filtering specific search items and identifying systems with particular functionalities, belonging to the same software category, having similar security certificates or regulations, or sharing the same contacts. These resources were deemed crucial, as a mapping focused solely on systems would lack the capacity to display all possible functionalities or other items of interest. Exemplary visualisations of each resource list with descriptions are available in Appendices 16-19.

Regarding the validation of the resources section, the most frequently mentioned issue concerned the visualisation of the functionalities resource. The user interface aspect of the Notion platform was considered suboptimal, particularly in terms of navigation and quickly understanding the most used functionalities or the systems to which they are assigned. Another significant suggestion involved the descriptions of HL7 functionalities, which were initially too broad, prompting a call for more specific and detailed descriptions and names. This feedback mirrored issues raised during the data entry phase of the study. Additionally, it was suggested that the resource lists should include explanations of their purpose and what users can expect from them.

Regarding the overall prototype, it was affirmed as suitable for demonstrating the possibilities within the scope of the project. The general consensus on the functionalities was positive, and despite the issues highlighted earlier, the catalogue was considered readable and functional. The feature enabling the visibility of connected systems, particularly the linking of functionalities (Appendix 11), was highly valued as a key aspect. Across all sections, the quality of the data emerged as a recurring concern, emphasising the need for accurate, verified data that is tailored to the end users of the catalogue. Furthermore, comprehensive coverage of systems in the e-health field was identified as a crucial requirement. With a vast array of systems, there was a call for more specific categorisation, such as differentiating between public and private systems or filtering by service owners. Another important consideration was defining the purpose and target audience of the mapping platform to ensure it attracts the most relevant users.

The use of Notion as a platform was recognised as a commendable initiative and a good starting point for this type of mapping. However, challenges were identified in terms of its intuitive navigation. Users found it difficult to navigate effectively, often unsure where to click to achieve the desired outcome, leading to a less than satisfactory navigation experience. Additionally, the platform was noted for its lack of a filtering option in its preview configuration, which interviewees considered an essential feature. They suggested that a tutorial would be necessary for effective use of the platform, thereby enhancing the overall user experience.

4.4 Repository of requirements and the metamodel

Throughout the study, including the data entry stage, all identified requirements were analysed, revised, and consolidated into a comprehensive table repository, as detailed in Appendix 22. This resource encompasses all identified aspects of the mapping, with a significant focus on detailed information about individual systems. Additionally, it addresses the design and management of the platform and the back-end aspects of data entry, which are crucial components of effective mapping. This repository represents one of the key outcomes of the study, compiling all essential information required to construct what could potentially be the most optimal mapping for the e-health systems landscape. The simplified architecture of the mapping is represented in Appendix 23, to visually represent connections and elements of the requirements.

Drawing from the dimensions and criteria identified in the e-health landscape mapping, a simplified metamodel was developed (see Appendix 24), based on the concepts of the TOGAF content metamodel [61]. This metamodel indicates the main connections among key concepts (in green). Furthermore, attached to these concepts are lists of elements (in blue) which define potential models for these concepts.

5 Discussion

In this chapter, a detailed analysis of the study's results and their wider significance is presented. Due to the limited research in this field, the discussion is supplemented by insights from the author, who brings five years of experience in software development and design. The goal is to comprehensively address the research questions initially outlined at the beginning of this study.

5.1 Essential dimentions and requirements when creating an e-health systems mapping.

In this study, a comprehensive repository of requirements for e-health systems mapping was established (see Appendix 22). This resource outlines all potential functionalities and aspects necessary for optimal mapping. While most requirements pertain to specific system information, others relate to the mapping platform and data entry. The repository incorporates needs from both public and private sector professionals, covering a broad range of functionalities, not all of which are applicable to both sectors. The inclusion of a comments column in the repository further enriches the discussion.

The most frequently mentioned requirements aligned with the author's expectations, though two unexpected findings emerged from the initial interviews. Contrary to the assumption that system functionalities would be the primary focus, there was considerable interest in mapping the interactions between systems and connected services, including integration, interoperability, technical documentation, and key contacts. This underscores a gap in understanding the connectivity within the e-health landscape. Developing a mapping is expected to enhance system interactions, contributing to a more integrated e-health landscape.

Another highlighted finding to the author was the interest in seeing user reviews of systems, highlighting the absence of a comprehensive review system for e-health systems. While mobile applications can be assessed using ratings in app stores, most e-health systems, especially those not featured on commercial platforms, lack a formal rating or review mechanism. There is a clear need for such a system, as it plays a crucial role in assessing product quality and managing user relationships [59]. Introducing a review or assessment module within the mapping platform would enable the collection of user feedback for all systems from a single platform. This would be advantageous both for research purposes and for platform owners, who could use user assessments or reviews to identify and address issues within their systems [60].

The study also emphasised the critical importance of usability design (UX/UI) in developing a mapping. Insights from the data entry team, the author's experiences, and final interviews revealed that Notion is unsuitable as a mapping platform and highlighted the significance of intuitive design in such platforms. Effective design caters to the specific needs of end-users, enhancing the platform's utility for both general users and specialists.

Public system owners' reluctance to participate in data entry, identified as a potential sustainability issue, suggests that governmental institutions could be ideal managers, ensuring the inclusion and regular updating of public systems. Past challenges with government-managed systems, such as infrequent updates and project abandonment, highlight the need for commitment and funding from the overseeing governmental entity. The identification of benefits a mapping would bring in this study could motivate the government to assume this responsibility effectively.

Building upon the identified requirements, there is an opportunity to develop a mapping that not only identifies existing services but also highlights gaps in the landscape. Such a mapping would foster collaborations between public and private systems and aid government decision-makers in efficiently allocating resources. Furthermore, the extensive information and visualisation capabilities of the platform are crucial for showcasing the Estonian e-health landscape, serving both educational and international purposes. Comparing healthcare landscapes can assist other countries in their development efforts and potentially lead to a global mapping platform, encouraging international collaboration and enhancing the e-health landscape worldwide.

Another area where mapping can be beneficial is in countries experiencing a lack of cooperation between the public health sector, private businesses, and research [48]. For the full potential of e-health to be realised, it is essential to develop clear policies at both national and international levels. These policies should clarify the collaboration among various stakeholders and the implementation of health services [43]. Effective policy-making requires extensive data analysis, and with a repository that provides an overview of the current landscape, policies can be tailored to benefit all parties involved.

In conclusion, the dimensions of e-health landscape mapping discussed in this chapter and found in the study hold significant potential for positively disrupting the e-health landscape. The resources developed through this study could play a crucial role in catalysing this disruption. However, it is important to acknowledge that a single study, no matter how useful, is insufficient to address every necessary aspect. Therefore, all ideas gathered here require further development and exploration.

5.2 Method for creating the most optimal e-health systems mapping

The process of creating the prototype in this study can be considered as a valid example of the method of creating an e-health systems mapping, but it certainly is not the most optimal.

This study reveals that the method of creating the mapping involves more than just the development of the mapping platform and the addition of data. Several crucial factors influence the longevity of the mapping: the ownership of the platform, the comprehensiveness of system coverage, and the regular updating of data. It is essential to construct a sustainable mapping system rather than creating another platform that may not provide long-term value to the industry.

The study identifies one of the key components of e-health systems mapping as the selection of an appropriate manager. The manager should be a reliable and secure entity capable of managing and regularly updating the mapping. As a single entity, the government emerges as a suitable manager, meeting most criteria and possessing the ability to encourage publicly owned e-health system owners to contribute data. An academic institution, such as a university, is another viable option, especially when the mapping is conducted for research purposes and maintained by the institution itself. These options are preferable to ensure that the mapping remains publicly accessible. Private entities are ideally positioned to maintain and develop this solution due to their specialised development knowledge. However, they are often reluctant to create large-scale solutions freely accessible to all, as it may not be financially beneficial for a company to sustain such an extensive and detailed mapping. A viable approach, as evidenced in other contexts, is a collaborative effort involving academic, governmental, and private entities [62]. In this model, the platform is initiated by a government structure, managed by a private company, and standardised and researched by an academic institution.

Before populating the catalogue with data, selecting an appropriate platform for mapping is essential. In this study, Notion was utilised as the platform for the prototype mapping. However, as revealed throughout the study, it lacks in user interface and experience. The findings indicate that Notion's average viability rating for constructing the prototype is 3.29, marginally higher than the median of 3. This suggests that while Notion has potential, it may not be the most optimal solution for mapping, particularly from data entry and usability perspectives. Additionally, specific functionalities and requirements, such as filtering and visualisation of linked systems, cannot be implemented on the Notion platform.

The ideal solution would be to develop custom software specifically for mapping. While this is not the simplest approach, such a solution would inherently incorporate all necessary standards and requirements, making it suitable for global use. This implies that the managing entity must undertake the development process.

Alternatively, a different platform with the requisite functionalities could be identified. During the study's development, Obsidian was also considered as a potential alternative to Notion. Obsidian is a more customisable platform than Notion and could potentially meet all the requirements for optimal mapping. However, Obsidian is not the simplest system to use; thus, the person inputting the data must be specialised in basic programming [70], or another user-friendly interface must be developed by the mapping manager to facilitate easier data entry. In essence, either a suitable platform must be developed or an existing one found that can meet all the specified requirements (Appendix 22).

There is a significant question regarding which entities will want to include their system in the catalogue, and more importantly, how the data will be entered into the mapping. The best source for the data is typically the owner or developer of the system, which implies that the catalogue must be appealing for system providers to input information about their systems.

This study indicates that while private organisations are willing to independently enter data about their systems, not all public companies share this enthusiasm. Consequently, not every e-health system may be represented in the catalogue, potentially diminishing its completeness and, therefore, reducing the interest and impact it has in encouraging others to contribute data.

However, if data entry is to be undertaken by e-health system owners and managers, the process must be straightforward. Support for data entry is essential, along with well-defined instructions for the entities inputting the data. The more challenging the data entry process, the less likely organisations will participate, diminishing the mapping's effectiveness.

Data entry by a third party or the manager is another possibility, but this requires close communication with the system owners and developers to ensure data accuracy. Furthermore, professionals who understand all aspects of the platform and are knowledgeable about the used standards must perform the data entry. Alternatively, developing an automated system could also be considered.

Automation, although beneficial, has its limitations in terms of interoperability, and not all processes are suitable or feasible for automation. Essential data such as basic information, functionalities, certifications, and integrations are typically not updated frequently – often not daily or even monthly. In most cases for catalogues, data should be entered once and perhaps updated biannually. Automation is not practical for primary data entry, and automating complex elements like functionalities and integration information would require development on both the e-health system and the mapping platform. Creating a database in the e-health system with the specific information required for mapping may not be the most effective solution. However, simpler information like user count, which the system provider already has, could potentially be automated via an API, developed by the mapping platform.

In the context of Estonia, some level of automation is feasible at the governmental level through X-road, but this mostly covers basic information. Developing a service for automating standardised data transfer for mapping could benefit not only the healthcare sector but other sectors as well.

In conclusion, several considerations determine the most optimal method for creating e-health systems mapping. This study proposes the following approach:
1. **Assigning a reliable manager:** The mapping platform should be managed by a reliable entity, with a governmental institution being the preferable choice. This ensures stability and integrity in the management of the platform.

2. **Platform development:** A suitable platform for the mapping should be identified or developed. Developing a custom platform is recommended for tailored functionality; however, utilising an existing platform created by another entity is a viable alternative if it meets the necessary criteria.

3. **Platform construction based on requirements:** The development of the platform should adhere to the specific requirements outlined in the resource provided in Appendix 22 and 23. This ensures that the platform is fit for purpose and meets the needs of its users.

4. **Standardisation and user-friendly data entry:** It is crucial that the data is standardised as per the outlined requirements, and that the process of data entry is streamlined for ease of use. Simplifying the data entry process encourages regular and accurate updates from contributors.

5. **Data entry management:** Establishing a dedicated data entry team is one approach, but ideally, e-health system owners should directly enter data into the system. This direct involvement ensures accuracy and ownership of the data provided.

6. **Ongoing maintenance and updates:** Continuous updating and maintenance of the platform are essential. This includes keeping the standards current and ensuring that the system owners regularly update their data. Where possible, automation should be implemented to facilitate these updates, enhancing efficiency and accuracy.

5.3 Validation of HL7 standard functionalities for e-health systems mapping

In this study, the HL7 functional model for electronic and personal health records [19], [20], [36] was adopted as the standard for functionalities in the prototype. A total of 456 functionalities were formatted and entered into the Notion platform by the author (see Appendix 16), and the validation of this standard occurred during the data entry and review stages of the study.

The data entry team, comprising students, spent a significant amount of time working with the list of functionalities. They found the HL7 standard functionalities challenging due to unfamiliarity and the technical nature of some descriptions, requiring specialised knowledge. If the mapping is intended for general use, then simplification of the functionalities is necessary. However, for more technical professionals, the complexity of functionalities might not pose an issue. It's crucial to discern which aspects can be more technical, such as system technical documentation, and which can be less so, like basic system information. Hence, a certain level of complexity in functionalities is acceptable, provided they are understandable to the person responsible for data entry.

Additionally, the students observed that many functionalities were similar and the overall list was too extensive to fully comprehend. This could suggest that the list is overly detailed and should be revised to remove superfluous functionalities. The similarities might also stem from a lack of specialised knowledge to distinguish between functionalities. On the other hand, the breadth of functionalities could mean they cover all possible options for system functionalities.

While the functionalities were intended for electronic and personal health records and covered these well, the students still added additional functionalities to the system. Of these, 10 were similar to existing HL7 functionalities, 12 were integrations rather than functionalities and thus not critical, but 10 specific to the X-road service [reference] were not included in the HL7 list. The inclusion of X-road, a closely related support system, raises the question of whether the HL7 list is comprehensive enough.

The findings also indicated that mainly two types of functionalities were used, which could be due to inadequate system documentation. These functionalities pertained to managing individual health information and security features and were easier to define with limited documentation.

In the review stage, professionals echoed the students' challenges, finding some functionalities too broad. They preferred more specific and concisely presented functionalities. As the list included main functionalities with several sub-layers, some appeared too general. Hence, a review and selection of specific functionalities are necessary. The use of the HL7 standard was well-received by some students and most prototype reviewers, who recognised the benefits of standardisation. The HL7 list includes criteria for determining system functionalities (see Figure 1), which are advantageous for the selection process and generally validated.

In conclusion, the HL7 standard's list of functionalities was a valuable addition to the prototype. However, it is not entirely suitable for the optimal e-health system mapping, as it does not encompass all potential systems in the mapping. The HL7 list should be reviewed for conciseness, removing redundant functionalities and ensuring clear presentation for data entry specialists.

5.4 Main contribution

This study and its resources could be instrumental in developing an e-health landscape mapping, which has the potential to significantly benefit the e-health sector. The mapping is crucial as it fosters greater interaction and collaboration between the public and private sectors, potentially leading to innovative solutions. A functional mapping could positively disrupt the e-health landscape, creating new connections and collaborations across and within sectors, and sparking innovative developments.

Prior to developing a mapping platform, several key challenges need addressing. Firstly, a capable manager with adequate resources must be identified to oversee the platform. Secondly, incentives should be established to encourage both public and private e-health systems owners to input and regularly update their data. Once these prerequisites are met, the platform can be developed, incorporating international standards for functionalities and ensuring the intuitive design of the platform.

Furthermore, the necessity of standardised software catalogues is not only seen in the field of healthcare but for example in research as well [46]. The mapping developed here can be easily extended to other fields, as most requirements are not unique to the e-health landscape. The primary healthcare-specific element is the functionality standard, but additional standards can be incorporated into the platform. Since this mapping aims to be standardised and optimised across various fields, it holds significant global potential in facilitating international collaboration and interoperability.

5.5 Limitations

Design research is a standard method for requirement engineering, characterised by its iterative nature, involving stages of research, prototyping, and evaluation. However, in this study, only one complete iteration was conducted, meaning the method wasn't fully utilised. Despite this and the limitations of the Notion platform, the study achieved considerable results with the features implemented in the prototype. Efficiency could have been improved by conducting more iterations. The process could be divided into 3 or 4 iterations by categorising interviewees into groups, ensuring a diverse representation of sectors (public or private) and skill sets in each group.

The length of the interviews might have affected the identification of requirements. A longer duration could have yielded a higher mention rate for additional requirements. The prominence of certain requirements in the initial responses of professionals indicates their importance, but this could also be due to chance. The study should have included specialists from non-healthcare fields experienced in mappings, as they could have offered valuable insights.

Another limitation was the lengthy questionnaire, particularly in the review phase. Some interviewees chose to respond in writing, as reviewing the questionnaire and participating in an interview was time-consuming. This variation in response format meant that it was not always possible to ask for further explanations or information about an answer.

The limitations of the Notion platform meant that not all requirements were implemented; only the most critical ones were validated, leaving many potential features untested. The intended design of the functionalities section as a table, like other sections, was hindered by the platform's limitations, resulting in unmanageable tables.

Furthermore, academic value was considered. Implementing all 56 requirements during prototype development wasn't seen as appropriate for academic purposes, as it would have required the student data entry team to input much more information. However, a significant number of important functionalities were covered and eventually validated. The absence of prior research presented challenges in the study process, as it increased the likelihood of overlooking important elements crucial for developing large-scale standardised mappings. However, this thesis now contributes to the body of research on the topic.

5.6 Further research

This study provides a valuable foundation for further research into the most effective method, metamodel, and requirements for mappings. While the resources presented are comprehensive, they have not undergone extensive validation, as only one complete iteration of the design research was conducted. Despite the possibility that the final version may not differ significantly from the current one, full validation and exploration of additional optimisation angles of the method and requirements remain crucial.

Standardisation is a key aspect of this study, and the HL7 standard functionalities have been tested. However, they are not suitable to standardise all data elements in the mapping comprehensively, the implementation and validation of additional international standards is necessary. Alternatively, other standardisation options might be considered and research on creating a unique standard or combination of standards must be considered.

Furthermore, exploring regulatory, technological, security, and data exchange requirements is essential for integrating the mapping with Estonia's digital landscape and services like X-road [55]. Ensuring seamless integration of the developed platform will facilitate its adoption by governmental institutions. Collaborating with Accelerate Estonia [57] during the study could help address any regulatory or trust issues within the government.

Another area for research is defining what constitutes an e-health system and determining which systems should be included in the mapping. There is ambiguity regarding other services and systems integral to e-health systems, such as hospital inventory management, patient registration and scheduling systems, or data transfer services between e-health platforms. These systems, which provide crucial support structures, need to be considered for inclusion in the catalogue. The aim is to extend the proposed standardised mapping to encompass all relevant systems while discerning what to categorise within the e-health landscape. Consequently, some requirements and functionality standards for other system types not covered in this study should also be identified.

Although Notion was not the most optimal platform, it was suitable for this study's purpose of facilitating student data entry, offering an intuitive interface with a minimal learning curve. The author's familiarity with Notion also aided in supporting students during accidental manipulations or the data entry process. Identifying or developing a more suitable platform would be a significant advancement. Future studies should include more extensive UX and UI design optimisation, as platform usability significantly influences the sustainability of the mapping. An ideal approach would be to review existing mapping designs, validate them with designers and users, and then develop the most effective design, ultimately incorporating it into the software for the catalogue platform.

5.7 Final conclusions

The following conclusions emerge from the findings of this study:

1. There is a clear need to create a mapping of the e-health landscape. Professionals are particularly interested in understanding the landscape's intricacies, especially in terms of integrations, interoperability, and functionalities of various e-health systems. This mapping has numerous potential systems (see Appendix 6), highlighting the diverse uses of the mapping platform. An e-health system landscape mapping serves as a foundational resource for mapping studies, offering a comprehensive view of the field's scope and aiding in the identification of research gaps and trends [51].

2. The incorporation of international standards is crucial for the sustainability of the e-health systems mapping. For optimal mapping, standardised content is essential, and the HL7 standard functional model [36] effectively addresses most functionalities needed for e-health systems. However, it may not encompass all functionalities present in the systems included in the mapping. Therefore, the integration of another standard separately or alongside the HL7 standard must be considered.

3. Developing a sustainable mapping involves more than just functional requirements. The longevity of the mapping significantly depends on the reliability of the manager of the mapping platform, the ease and willingness of data entry, and the regular updating of information. Additionally, to ensure other sustainability factors, the usability design of the platform must be optimised for effective use.

4. Due to the scarcity of research on the topic of creating system and software mappings, this study has laid a decent foundation for further investigation, or for serving as a repository of valuable information in the development of e-health systems landscape mapping. The potential method and metamodel proposed in this research provide a basis for further exploration into various topics related to the creation and sustainability of mappings. These findings can be utilised as resources for implementing methods on both national and global scales.

5. The author suggests that the current TalTech Digital Health study programme would benefit from incorporating more courses on information and communication technologies (ICT), embedding this knowledge in students before they encounter projects requiring its application. Understanding the software design, and challenges and requirements of digitisation is crucial, and as all systems are moving towards digital integration, addressing this topic now is imperative.

6 Summary

The objective of this thesis was to formulate an optimal method and a metamodel, while also identifying the various challenges and dimensions involved in constructing a mapping for the e-health systems landscape. The author developed a prototype for this mapping, enlisted students for data entry and validation, and conducted two sets of interviews focusing on requirement engineering and prototype validation.

Firstly, the requirements identified reveal that specialists in the e-health field have a keen interest in numerous aspects, particularly in understanding their options and how to integrate with other systems. The mapping serves as a crucial tool to facilitate this understanding, thereby speeding up processes and enhancing collaboration.

Secondly, the development of a mapping extends beyond merely constructing a catalogue based on specified requirements. Significant sustainability challenges must be addressed for the mapping to be truly beneficial. Key among these are identifying a dependable manager for the catalogue and ensuring comprehensive coverage of data and its currency from both public and private systems.

Thirdly, the employment of international standards and standardised content enhances the interoperability of the mapping on a broader scale and ensures that information is concretely defined for all users. However, standards such as the HL7 EHR functional model appear to be either overly technical for universal comprehension or too broad to encompass specific functionalities, failing to cover all aspects. Given that the mapping is intended for both technical specialists and general healthcare professionals, it is imperative that the implemented standards are clear and concise.

In conclusion, developing an e-health systems landscape mapping can greatly benefit the e-health landscape by providing a centralised resource to easily compare and select appropriate digital tools, facilitating interoperability between different systems, encouraging innovation through visibility of existing solutions, and aiding in the identification of gaps in e-health that need to be addressed. Further elaboration on this topic is needed, and the dimensions of an optimal method and metamodel can accelerate the process. In time, the established mapping standard could be seamlessly integrated into other fields of interest on a global scale.

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Appendix 1. Interview questions with comments and reasoning for questions.

Question	Purpose	Comments
1. What is your current role in the healthcare landscape? And how long have you been in the healthcare industry?	Validation for a variety of professionals, seniority and sector	A variety of positions and a variety of years of experience in the healthcare field and the sector (public or private) was considered to accommodate all of the potential users of the catalogue.
2. Have you used similar catalogues in your work or research, such as RIHA (LINK), the Danish Telemedicine Map (LINK), or the Capterra application catalogue (LINK)? Please specify the catalogues you have used.	Validation of previous experience with catalogues and gathering more materials for additional research.	The question had hyperlinks to the mentioned catalogues. These were some of the catalogue references to give examples for interviewees of more clarity on what is an application catalogue, what kind of catalogues exist.
3. Do you have a need for a catalogue that contains a mapping of all e-health solutions?	Validation of the necessity of a catalogue.	This question was an integral part of validating the further need for this study.
4. What functionalities would you like to see in this catalogue?	Inquiry of the requirements of an optimal catalogue	The question provided the necessary data for creating a metamodel of the catalogue
5. In what situations would you use such a catalogue, and when do you believe such a catalogue would be most useful?	Validation of broader use of the catalogue and information about specific use cases	Understanding in which instances the catalogue is needed helps to improve the setting of the metamodel and helps to create use cases for further research.

6. Would you be willing to add information to the catalogue if something is missing for any entry (or if there is missing information about your own platform and/or application)?	Validation of data entry by the professionals, their team or organisations to keep the catalogue updated.	Many catalogues and databases suffer from the phenomenon of a lack of updated information. This renders catalogues inactive and is the demise of every system. Therefore it is important to understand who is going to keep the data updated.
7. Would you be willing to provide feedback on the catalogue prototype?	Confirmation for review interviews for the last stage of the study process	Part of the methodology, is not shown in the results
8. Do you know anyone else I could contact who might have a need for such a catalogue?	Inquiry of additional professionals if more interviews are necessary.	Part of the methodology is not shown in the results
9. Do you have any questions on this topic or would you like to add anything else?	Generic question to understand the interest in the topic, and elaborate on any previous answers.	The idea of this model is a universal catalogue, which would be used by the same professionals. Therefore it is important to hear what comments they have about the model

Appendix 2. Questionnaire for the data entry team

Question	Type	Validation
What was your skill level for Notion before starting the project?	Scale 1-5	Understanding the base skill level prior to using the platform
What do you consider your skill level to be now?	Scale 1-5	
How likely would you use Notion again for future projects?	Scale 1-5	Longevity question for valuing Notion as a platform
Please rate Notion as a platform for creating this type of catalogue.	Scale 1-5	Defining whether the Notion platform is viable for building the prototype
How difficult was it to enter data into Notion?	Scale 1-5	
What is Notion lacking or what is great about Notion as a platform for this type of project?	Open-ended	
Comments about Notion as a platform for creating the catalogue.	Open-ended	
Choose your application	Selection	Defining how viable is a third party to enter data into the model. To understand if it is possible for a third party to participate in data entry. These questions were separate for each application.
How difficult was it to find information for your applications?	Scale 1-5	
What were the most difficult parts of finding the information for your	Open-ended	

applications?		
How necessary do you consider this catalogue as a tool?	Scale 1-5	Defining the longevity and usefulness of the prototype for the data entry team. Adding more information to understanding the viability of this format for the catalogue.
How usable do you consider this catalogue as a tool?	Scale 1-5	
How likely would you use this catalogue as a tool in the future?	Scale 1-5	
What sections are missing from the catalogue or what do you think this catalogue should contain to be a more efficient catalogue?	Open-ended	
Any comments or suggestions for the catalogue?	Open-ended	
How difficult was it to use this list of functionalities?	Scale 1-5	Defining the viability of using the HL7 functionalities standard in the specific format and viability of using the HL7 standard overall.
How difficult was it to find the functions related to the platform?	Scale 1-5	
How suitable would you consider this list of functionalities for the current project?	Scale 1-5	
What was the hardest/easiest part of using these lists of functions?	Open-ended	
What could have been different regarding the list of functions and what could have made entry of these functions easier?	Open-ended	
Comments regarding HL7 standard functionalities list for health records.	Open-ended	

Appendix 3. Structure of the review questionnaire

Question	Purpose	Description
1. Which features in the BLANK section meet the requirements of optimal mapping?	These open-ended questions confirmed the validity and shortcomings of every section implemented for the application.	Every set of questions was accompanied by an introduction and visualisation of the section. This provided extra clarity for the interviewees to focus on the right section
2. What are the shortcomings of the BLANK section?		
3. Please write overall feedback and comments to the BLANK section.	Redundancy question which was meant to improve feedback if something was. The majority of replies were divided across the first two questions	
4. Which features in the BLANK data table meet the needs of optimal mapping?	These open-ended questions confirmed the validity and shortcomings of every resource data table and the resources section.	Every set of questions was accompanied by a short introduction and visualisation of the resource. This provided extra clarity for the interviewees to focus on the right data table
5. What are the shortcomings of the BLANK data table?		
6. Please write general feedback and comments to the resources section.		
7. What are the main shortcomings of this catalogue and the data tables, or what parts need modifications?	Question to understand the general consensus on the prototype as a whole.	A short introduction and visuals of the section were provided

8. Please provide your feedback on Notion as the platform for managing this catalogue and displaying data.	Question to define the viability of Notion as a potential platform for the model	Now that the interviewees have experienced the Notion platform, they can validate the viability of the platform for building the prototype based on their brief interaction.

Appendix 4. List of e-Health systems added to the mapping prototype

Registries of Health Board	Lab Services Registry	Health Insurance Registry
State Information System Management System (RIHA)	minudoc	Hospital Information System Liisa
Watson	Migrevention	Genome Center Database
School Nurse Information System	National Health Care Decision Support	HOIA
Registries of Agency of Medicines	Medicum Information System	Estonian PACS
Qvalitas Digikliinik	Medical Birth Registry and Estonian Abortion Registry	EHIS E-Ambulance
VaccineGuard	MediReg	Digital Identity Certificates Service
Verekeskuse infosüsteem (EVI)	Minu Synlab	Dental Clinic software - Dentas
Small Clinics Medical Records EKliinik	MediKeep	EHIS Doctor Portal
X-Road	Laboratory Information System - Ester 3	A-veeb
Prescription Centre	Health Statistics and Health Research Database	Business Registry
Triumf Health	Geneto	Database of Agency of Statistics
Viveo Health	Synbase	Cancer Registry
Pharmacy Information System - HansaSoft	EHIS Patient Portal	Communicable Diseases Information System
Population Registry	Hospital Information System HEDA	EHIS Data Viewer (Andmevaatur)
Medipost	Information System of Genetic data (GAIS)	DocuMental
Perearst 2 / 3, Family Doctor EMR	Hospital Information System eHL	e-perearstikeskus - e-PAK
Myocardial Infarction Register	Kõneravi.ee	E-doonor
MyAntegenes	EHIS Health Information System - EHR	Dental Clinic software - Hammas
Laboratory Information System - GLIMS	Hospital Information System - PERH (ESTER 2, Lab)	Dermtest

Appendix 5. Table of requirements for prototype development. Full list.

Topics	Requirements	Weight	Description
System functionalities	List of functionalities of the system	12	A standardised list of functionalities describing all of the features of a system
	Description of each functionality	12	Every functionality should be described in a short format for clarity
	Linked systems	4	List of all of the systems on the catalogue which have the same functionality
System integrations	Integrated systems	12	List of services and other systems that are integrated or used by the system in view
	Integration to systems	12	List of services and systems that are using the system in view
	Governmental systems	4	Details if the system is connected with governmental information systems or services like consent service [56]
System technical information	Documentation of technology stack	7	Details on the tools and technologies that make up the system
	Standards used	4	List of standards implemented in the system (SNOMED, HL7, etc)
	Manuals for integration	4	References of technical manuals to help with the integration process but also to see if it is even possible to integrate with the system
	Data exchange standard	3	Details on data exchange standards used by the system
	API availability	3	Details of existing application programming interfaces and how to use them
	Customisability	3	Details on the possibility of tailoring the system to the needs of the client
	Info on the data model	2	Technical details on how information is stored in the system
	Data sets	2	Details about data sets within the system
System basic	Evidence-based information	5	All of the details and information of the system in the mapping must be based on facts and

information			not marketing info
	Basic contact	4	Contact information for support and additional information
	Description	4	Each system should include a description detailing its purpose and features
	Languages of the system	3	Details of the national languages the system can be used in
	Manuals for the system	3	References to user manuals, integration manuals and tutorials
	List of services	2	List of the services the system provides for the end-user
System categorisation	System type	4	Details on the general function of the system (database, information system, application etc.)
	End-users	4	Details on who are the main users of this system by category (doctors, technicians, nurses, patients etc.)
	System sector	3	Details on whether the system is managed by the public or private sector
	System domain within the healthcare sector	3	Details of the domain of the system within the healthcare sector (telehealth, disease management, prevention, health record, symptom checker)
System business information	Business model	5	Details regarding the business model, licensing fees, and related aspects should be provided.
	Important contacts	5	Specialised contacts in case of business or integration opportunities
	International clients	4	List of organisations using the system
	Governmental clients	4	List of governments using the system
	Activity and user base	4	Details on the number of users using the system, the number of requests the system is getting within a timeframe
	Age of the system	4	Information on how long has the system been on the market

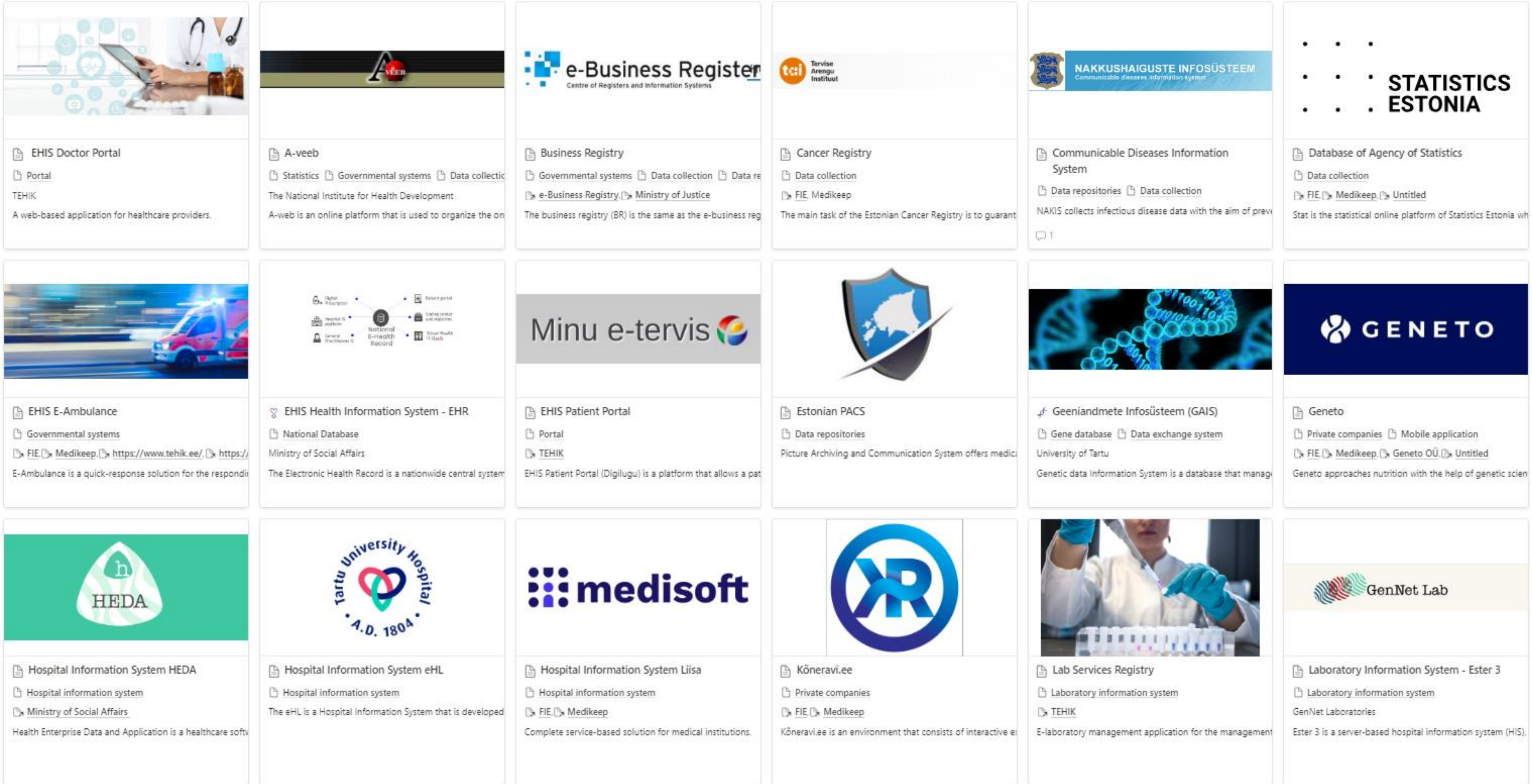
	System manager info	3	Details on the owner and the developer of the system
	Provider support availability	3	Details on technical support availability by the system owner
	Availability of custom solutions	3	Details of the possibility of providing customised solutions for the client
	Integration costs and requirements	2	Details of the possible costs and necessary requirements to integrate with the system
	System funding sources	2	Details on the funding of public systems
System-related regulations and certificates	In accordance with the medical device regulation	5	Details whether the system is a medical device under the EU medical device directive
	Accordance with GDPR	4	Details on the systems in accordance with GDPR policies
	Certifications from regulatory entities	4	Details of received certifications from validated entities
System security	Security certificates	4	Validated security certifications (e.g. E-ITS [65])
	Developer or client-side data security	2	Information on who is responsible for the system and data security
	Localisation of the system	2	Storage location of the data (cloud-based, internal, external etc.)
Review system	User review and feedback	5	Mapping must have a feedback and review system for the users of the e-health system
	Integration with the system appraisal system	4	The platform must be integrated with a standardised appraisal system
	Clinical research	4	The systems must have clinical research references where available
	References to case studies and reviews	3	The systems must have references to case studies and reviews if available
Platform design	Optimised UX and UI	5	The platform must have an intuitive interface, easy access to necessary functions and data
	Usage of validated standards for functionalities	4	The mapping platform must use international standards where possible
	Visual schematic of lined systems	4	The platform must have a visual figure of all systems and connections between them

	Filtering systems	4	The platform must have capabilities to filter systems and lists
	Linking systems	4	The platform must have capabilities to link systems with each other
	Made for all users	3	The platform must be designed to be accessible and understandable by the public and specialists alike
	Usage of standards for all sections	3	All of the information in the mapping must be visualised in a similar fashion
Platform management	Verification of data accuracy	5	The accuracy of all of the information in the mapping must be verified
	Information updating	5	All of the information in the mapping must be kept updated periodically
	Publicly available	4	The platform must be available for public use
	Universal data host	3	The platform must have a single and reliable host for the data in the mapping

Appendix 6. Table of use cases for the e-Health systems mapping

Topic	Use cases
Creating new services	Creating requirements for procurements and requirements for planning regulations
	Creating new private and public systems
	Filling a market gap of crucial services that don't exist based on the catalogue
	Avoid creating duplicate solutions
	Connecting with system providers to offer them services
Research purposes	Using as material for academic teaching and researching
	Analysing systems to improve other systems
	Searching for a specific type of system with the necessary requirements
	Accessing specific system sources and references
	Business analysis of existing systems
	Comparing systems between sectors
	Find information about the newest solutions and startups
	Mapping (not only healthcare) systems landscape for government
Communication	Using the model as an E-health publication centre
	Using as a database of valid contacts to connect with the system owners and providers
	Using the model to raise the knowledge of the Estonian healthcare landscape (locally and internationally)
	Creating collaboration opportunities between system providers
Integration with services	Learn about existing registries and how to integrate with them
	Integration with other systems
	Learning about technical conditions and alignment of standards of other systems for integration opportunities
	Integrating with international systems in case they are added to the catalogue
	Governmental entities integrating with suitable private services

Appendix 7. Prototype visual representation. Gallery view of e-Health systems



Appendix 8. Prototype visual representation. Description section.

DocuMental

Short Description: Secure, web-based decision support tool, designed for staff of mental health services.

Category: Decision support system

Contact: Documental

Data Controller: Documental

3 more properties

Add a comment...

10 Functionalities   6 Security and regulations

https://documental.ee/

Description

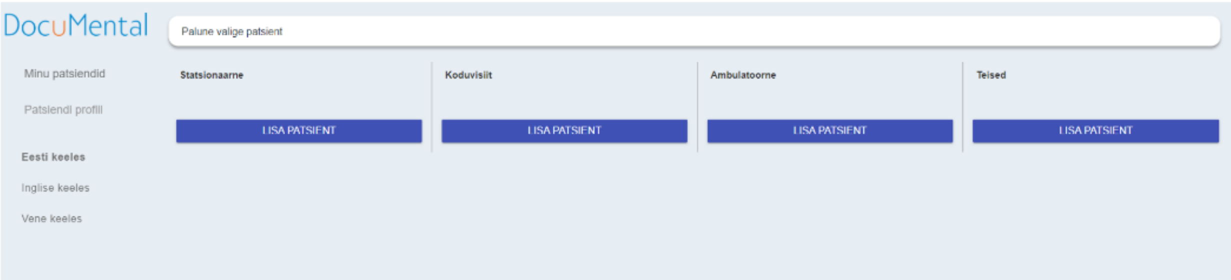
DocuMental is a clinical decision support system.

The system is designed to diagnose, treat and manage mental disorders, providing a platform for digitized mental health workflows. DocuMental is a web-based software tool for mental health professionals, including physicians, nurses, psychologists, social workers, care coordinators, and health care managers. DocuMental's principle of delivering immediate results. Each step forward is related to the results (automatic documentation, greater time efficiency, review of process and progress, accuracy, error prevention, reliability, evidence-based data, etc.).

DocuMental is the only clinical DSS with digitized and structured ICD-10 diagnostic criteria for all mental disorders. It also provides a clinical presentation to the treatment registry, monitoring drug choices and managing care plans in a standard manner.

A pilot project is planned for 2022, in cooperation with a psychiatric clinic and family doctors.

Screenshot



Appendix 9. Prototype visual representation. Contacts section.

Contacts (list)

Table List

Contacts

Aa Organisation	Email	Webpage	Contact Name	Phone	Related to eHealth Catal...
Tartu Ülikooli Kliinikum	kliinikum@kliinikum.ee	Esileht - Tartu Ülikooli Kliinikum		731 8131	Myocardial Infarction Regi

+ New

Appendix 10. Prototype visual representation. Functionalities section.

Functionalities (list)

Functionality	Description (explanation)
PH.0 - Personal Health	The personal health record (PHR) may be represented via multiple approaches including a personally-maintained paper.
PH.1.1 - Identify and Maintain a PHR Account Holder Record	Account holders log in via ID card, Smart ID or Mobile ID, they can be confident that the system is reliable, uniquely identify them, and provide access to their health record.
PH.1.2 - Manage PHR Account Holder Demographic Information	The system maintains the current demographic data set that defines the PHR Account Holder including personal attributes and contact information (including emergency contact, next-of-kin information, and insurance information sufficient to meet the information needs required to provide health care services, and if applicable, facilitate the need to locate family members in the event of an emergency or to expedite next-of-kin notification).
PH.2 - Manage Historical Clinical Data and Current State Data	Providers can enter historical information directly or import at least part of this data from outside electronic data sources
PH.2.1 - Manage PHR Account Holder Originated Data	PHR data, including personal observations and most specific data elements (such as allergies and intolerances or problems), may be entered directly by the medical personnel.
PH.2.2 - Manage Data from External Administrative Sources	Healthcare provider can manage patient information from administrative data sources such as insurance plans and pharmacy.
PH.2.3 - Manage Data and Documentation from External Clinical Sources	Healthcare professional is able to capture and manage historical clinical information.
PH.2.4 - Produce and Present Ad Hoc	The system may provide the ability to create customised views of summarised information based on sort and filter controls for custom or other parameters
PH.2.5 - Manage Historical and Current State D	The current state data set is a data model of the PHR Account Holder that is useful to the PHR Account Holder, but is particularly useful to any healthcare provider who is asked by the PHR Account Holder for help. These data characterize the PHR Account Holder in current time and is useful in the evaluation of new conditions and predictive of how they might respond to treatments and/or therapies.

Appendix 11. Prototype visual representation. Single functionality window.

PH.1.1 - Identify and Maintain a PHR Account Holder Record

Explanation of Ge...	Empty
Component	Kõneravi.ee Medicum Information System Perearst 2 / 3, Family Doctor EMR
Statement	Unambiguously identify the PHR Account Holder; correctly link the information with the PHR Account Holder and vice-versa.
Description	The PHR Account Holder must be confident that the system can reliably and uniquely identify them and provide access
Type	HL7 PH

+ Add a property

Linked to this page

- EHIS Doctor Portal eHealth Landscape / ... / eHealth Catalogue
- Minu Synlab eHealth Landscape / ... / eHealth Catalogue
- Kõneravi.ee eHealth Landscape / ... / eHealth Catalogue
- Medicum Information System eHealth Landscape / ... / eHealth Catalogue
- Migrevention eHealth Landscape / ... / eHealth Catalogue
- minudoc eHealth Landscape / ... / eHealth Catalogue
- Qvalitas Digikliinik eHealth Landscape / ... / eHealth Catalogue
- Registries of Health Board eHealth Landscape / ... / eHealth Catalogue
- e-perearstikeskus - e-PAK eHealth Landscape / ... / eHealth Catalogue
- E-doonor eHealth Landscape / ... / eHealth Catalogue

··· 4 more

Appendix 12. Prototype visual representation. Interoperability and integrations section.

Interoperability and integrations

Interoperability or integration	Description
X-road	Gathers data from the platform and exchanges it with the patient portal, personal healthcare provider, ambulance and the hospital.
TEHIK	The Health and Welfare Information Systems Center is an information and communication technology competence center in the health, social and work fields.
EHIS Patient Portal	The Patient Portal allows to view medical data, submit statements of intention, appoint representative(s), and act on behalf of the persons who have appointed as a representative.
EHIS Data Viewer (Andmevaatur)	Allows data to be visualized in a way that significantly simplifies access to the data. The user can move dynamically from one view to another, set filters to narrow / expand the composition of the displayed data, display graphs for specific data to illustrate the dynamics of the data, and more.
Estonian PACS	Foundation of Estonian PACS - Pildipank. Purpose: to develope and manage the common environment for transmission, archiving and usage of medical images for all Estonian healtcare institutions in equal conditions. Pildipank PACS system is capable to receive DICOM images from most of modern imaging modalities (CR,CT,MR,US,ES,NM, etc).
Estonian Health Insurance Fund	Covers the cost of healthcare services.

Appendix 13. Prototype visual representation. Security and regulations section.

Security and regulations

Name	Description	Source	Application
National Health Information System Regulation	The health information system processes data related to the fi	https://www.riigiteataja.ee/akt/106122016011?leiaKehtiv	EHIS Health Information System - EHR, EHIS Doctor Portal
Health Services Organisation Act	(1) This Act provides the organisation of and the requirements	https://www.riigiteataja.ee/en/eli/508012018001/consolide	Qvalitas Digikliinik, Viveo Health, EHIS Health Information System - EH
GDPR	1. Lawfulness, fairness and transparency — Processing must	https://gdpr.eu/what-is-gdpr/	Geeniandmete Infosüsteem (GAIS), DocuMental, Health Insurance Regi
Personal Data Protection Act	The Data Protection Inspectorate shall review the compliance	https://www.riigiteataja.ee/akt/104072014007	Geeniandmete Infosüsteem (GAIS), Health Insurance Registry, Triumf H

Appendix 14. Prototype visual representation. Sources section.

Sources

Aa Name of the sourcce	Link or medium	+
Manual for EHIS Doctor Portal users	https://pub.e-tervis.ee/manuals/Juhend%20Arstiportaali%20kasutajale/1/Juhend_TIS_Arstiportaali_kasutajale.pdf	
TEHIK	https://www.tehik.ee/tervise-infosusteem	
Nation-wide PACS system in Estonia	http://mug.ee/ehealth/presentations/Andrus_Paats.pdf	

Appendix 15. Prototype visual representation. Three sections together.

Table

Interoperability and integrations

Interoperability or integration	Description
X-road	Gathers data from the platform and exchanges it with the patient portal, personal healthcare provider, ambulance and the hospital.
TEHIK	The Health and Welfare Information Systems Center is an information and communication technology competence center in the health, social and work fields.
EHIS Patient Portal	The Patient Portal allows to view medical data, submit statements of intention, appoint representative(s), and act on behalf of the persons who have appointed as a representative.
EHIS Data Viewer (Andmevaatur)	Allows data to be visualized in a way that significantly simplifies access to the data. The user can move dynamically from one view to another, set filters to narrow / expand the composition of the displayed data, display graphs for specific data to illustrate the dynamics of the data, and more.
Estonian PACS	Foundation of Estonian PACS - Pildipank. Purpose: to develope and manage the common environment for transmission, archiving and usage of medical images for all Estonian healtcare institutions in equal conditions. Pildipank PACS system is capable to receive DICOM images from most of modern imaging modalities (CR,CT,MR,US,ES,NM, etc).
Estonian Health Insurance Fund	Covers the cost of healthcare services.

+ New

Table

Security and regulations

Name	Description	Source	Application
National Health Information System F OPEN	The health information system processes data related to the fi	https://www.riigiteataja.ee/akt/106122016011?leiaKehtiv	EHIS Health Information System - EHR EHIS Doctor Portal
Health Services Organisation Act	(1) This Act provides the organisation of and the requirements	https://www.riigiteataja.ee/en/eli/508012018001/consolide	Qvalitas Digikliinik Viveo Health EHIS Health Information System - EH
GDPR	1. Lawfulness, fairness and transparency — Processing must	https://gdpr.eu/what-is-gdpr/	Geeniandmete Infosüsteem (GAIS) DocuMental Health Insurance Regi
Personal Data Protection Act	The Data Protection Inspectorate shall review the compliance	https://www.riigiteataja.ee/akt/104072014007	Geeniandmete Infosüsteem (GAIS) Health Insurance Registry Triumf H

+ New

Table

Sources

Name of the sourcce	Link or medium
Manual for EHIS Doctor Portal users	https://pub.e-tervis.ee/manuals/Juhend%20Arstiportaali%20kasutajale/1/Juhend_TIS_Arstiportaali_kasutajale.pdf
TEHIK	https://www.tehik.ee/tervise-infosusteem
Nation-wide PACS system in Estonia	http://mug.ee/ehealth/presentations/Andrus_Paats.pdf

+ New

Appendix 16. Prototype visual representation. Functionalities list in resources.

Code	Type	Statement	Description	Component
		the Personal Health Record.		
PH.2.5 - Manage Histori OPEN Current State D	HL7 PH	Maintain the summary lists depicting the PHR Account Holder's current medical state and history.	The current state data set is a data model of the PHR Account Holder that is useful to the PHR Account Holder, but	Viveo Health, EHIS Patient Portal, Migrevention, Hospital Information System Liisa, e-perearstikeskus - e-PAK, Dermtest, Hospital Information System eHL
PH.2.5.1 - Manage Problem Lists	HL7 PH	Manage the PHR Account Holder's health problem list and provide the ability to manage the problem list over time in accordance with organizational policy and/or jurisdictional law.	Problems are a core feature of the patient record that provides structure and direct management. Problems may include	Dental Clinic software - Hammas, DocuMental, Hospital Information System Liisa, School Nurse Information System, Hospital Information System eHL, VaccineGuard, Perearst 2 / 3, Family Doctor EMR
PH.2.5.10 - Manage Social History	HL7 PH	Manage the PHR Account Holder's social history including, health related habits and risk factors.	The social history provides a profile with a number of characteristics that help define the PHR Account Holder's background	EHIS Patient Portal, Hospital Information System Liisa, Hospital Information System eHL, Medicum Information System
PH.2.5.11 - Nutrition and Diet Information	HL7 PH	Manage the PHR Account Holder's nutrition and diet-related information.	Nutrition is related to health and wellness as well as chronic diseases. People want to record and monitor their food	Geneto, EHIS Patient Portal, Migrevention, Hospital Information System Liisa, Triumf Health, Hospital Information System HEDA, School Nurse Information System, Hospital Information System eHL
PH.2.5.2 - Manage Medication List	HL7 PH	Manage the PHR Account Holder's medication list.	Medication lists are managed over time, whether over the course of a visit or stay, or the lifetime of a patient. All pertinent	Dental Clinic software - Hammas, Hospital Information System HEDA, EHIS Patient Portal, MediKeep, e-perearstikeskus - e-PAK, School Nurse Information System, Perearst 2 / 3, Family Doctor EMR
PH.2.5.3 - Manage Test Results	HL7 PH	Manage results of diagnostic tests including inpatient, ambulatory and home monitoring tests.	Recent diagnostic studies further define the PHR Account Holder's current state. The system should capture, display, and	Laboratory Information System - GLIMS, Dental Clinic software - Hammas, Laboratory Information System - Ester 3, EHIS Patient Portal, MyAntegenes, DocuMental, Hospital Information System Liisa, Medipost, Dermtest, Hospital Information System HEDA + 3
PH.2.5.4 - Manage Allergy, Intolerance, and Adverse Reaction List	HL7 PH	Manage the PHR Account Holder's list of known allergens and adverse reactions with all pertinent information.	Allergies, intolerances, sensitivities, and adverse reactions must be reviewed with every new prescription to avoid an	Laboratory Information System - GLIMS, Hospital Information System HEDA, EHIS Patient Portal, MediKeep, Dermtest, School Nurse Information System, Medicum Information System, Perearst 2 / 3, Family Doctor EMR
PH.2.5.5 - Manage Immunization List	HL7 PH	Manage the Account Holder's immunization data and associated capabilities including reminders, alerts, compliance, and administration.	Immunization records can be maintained in the PHR-S. The list of immunizations can be associated with the health	Hospital Information System HEDA, Hospital Information System Liisa, Watson, School Nurse Information System, Hospital Information System eHL, VaccineGuard, Perearst 2 / 3, Family Doctor EMR
PH.2.5.7 - Manage Surgical History	HL7 PH	Manage the PHR Account Holder's history of surgical procedures.	The list of past procedures is a useful summary of what has been done in the past and anatomic changes have occurred that	Hospital Information System HEDA, Hospital Information System Liisa, Dermtest, Hospital Information System eHL
PH.2.5.6 - Manage Medical History	HL7 PH	Manage the PHR Account Holder's medical history.	Significant or serious past medical illnesses and hospitalizations can be referenced in this list with a brief description	Viveo Health, Hospital Information System HEDA, e-perearstikeskus - e-PAK, Minu Synlab, Hospital Information System eHL

Appendix 17. Prototype visual representation. Software categories list in resources.

Software Categories

Table +

Aa Name	Application
Hospital information system	Hospital Information System HEDA, Hospital Information System - PERH (ESTER 2, Lab), Hospital Information System Liisa, Small Clinics Medical Records EKliinik, Hospital Information System eHL
Dental practice	Dental Clinic software - Hammas
GP practice	Medicum Information System, e-perearstikeskus - e-PAK, MediReg, Perearst 2 / 3, Family Doctor EMR
Laboratory information system	Laboratory Information System - GLIMS, Lab Services Registry, Laboratory Information System - Ester 3
Health related game	
Private companies	Viveo Health, Qvalitas Digikliinik, Geneto, Triumf Health, Migrevention, minudoc, Medicum Information System, Minu Synlab, Dermtest, VaccineGuard + 1
Gene database	Genome Center Database, Geeniandmete Infosüsteem (GAIS)
Statistics	Medical Birth Registry and Estonian Abortion Registry, Health Statistics and Health Research Database, A-veeb
Data repositories	Myocardial Infarction Register, Medical Birth Registry and Estonian Abortion Registry, Registries of Agency of Medicines, Registries of Health Board, Communicable Diseases Information System, Estonian PACS, Business Registry
Data exchange system	Population Registry, X-Road, Geeniandmete Infosüsteem (GAIS)
Interoperability enablers	Population Registry, X-Road, Prescription Centre, Synbase
Mobile application	Viveo Health, Geneto, Triumf Health, HOIA, Migrevention, Dermtest
Governmental systems	Population Registry, X-Road, EHIS E-Ambulance, State Information System Management System (RIHA), Business Registry, A-veeb, Digital Identity Certificates Service

Appendix 18. Prototype visual representation. Security and regulations list in resources.

Security and regulations

Table

↑ Name | Add filter

Filter | Sort | Reset | Save for everyone | New

Name	Description	Source	Application
Health Services Organisation Act	(1) This Act provides the organisation of and the requirements for the provision of health services, and the procedure for the management, financing and supervision of health care.	https://www.riigiteataja.ee/en/eli/508012018001/consolide	Kõneravi.ee
Public key infrastructure	PKI or the public key infrastructure enables secure digital authentication and signing. The infrastructure also allows forwarding data by using an encrypting key pair: a public encryption key and a private decryption key. In Estonia, this technology is used in relation with electronic identity (ID card, mobile ID, digital ID). All members of X-Road are using Digital seal certificates for signing messages. Citizens and officials are using electronic identity tokens.	https://www.ria.ee/en/state-information-system/electronic-identity-eid.html	EHIS Health Information System - EHR EHIS Data Viewer (Andmevaatur)
RIA	RIHA serves as a catalogue for the state's information system. At the same time RIHA is a procedural and administrative environment via which the comprehensive and balanced development of the state's information system has ensured. RIHA guarantees the transparency of the administration of the state's information system and helps to plan the state's information management.	https://www.ria.ee/en/state-information-system/administration-system-riha.html	EHIS Health Information System - EHR EHIS Data Viewer (Andmevaatur)
X-road	Secure data exchange layer X-Road is used for gathering data from different registers. X-Road is a technological and organizational environment enabling a secure Internet-based data exchange between information systems. All registers and Statistics Estonia must be a member of X-Road	https://www.ria.ee/en/state-information-system/x-tee.html	EHIS Health Information System - EHR EHIS Data Viewer (Andmevaatur)
Access control	flexible and granular access control policies to define access rights for single users (or groups of users) to patient records or specific encounters.		DocuMental, Laboratory Information System - Ester 3 A-veeb
Activities of a nurse providing school health care and requirements for the time, volume, availability and location of nursing activities	The regulation establishes the school health care provided to a student acquiring basic and general secondary education in full-time education, which includes the activities of a nurse in a basic school, upper secondary school or vocational school, and the requirements for the time, volume, availability and location of activities.	https://www.riigiteataja.ee/akt/13349448?leiaKehtiv	School Nurse Information System
Audit trail	includes a legally valid immutable logging system. Tracking of who accesses data, when it was accessed, and from where. Logs contain enough information in case of legal disputes, without violating users' privacy.		DocuMental
Citizen of the European Union Act	This Act governs the principal aspects of entry to and residence in Estonia of citizens of the European Union and their family members and provides the grounds for imposing the obligation to leave Estonia and the prohibition of entry to Estonia on citizens of the European Union and their family members.	https://www.riigiteataja.ee/en/eli/ee/517122020002/consolide/current	Population Registry
Data sets of documents transmitted to the Health Information System and conditions and procedure for their submission	The Regulation establishes the data sets of documents transmitted to the Health Information System and the conditions and procedure for their submission.	https://www.riigiteataja.ee/akt/13349775?leiaKehtiv	EHIS Health Information System - EHR

Appendix 19. Prototype visual representation. Contacts list in resources.

Contacts

Table +

Filter Sort

Organisation	Email	Webpage	Phone	Contact Name	Role of the team	Application Component (Do not delete)	Related to eHealth Catal...
Synbase OU		https://synbase.eu/					
Eesti Haigekassa	info@haigekassa.ee	https://www.haigekassa.ee/				Health Insurance Registry	Health Insurance Registry
MIPS Regional Headquarter	info@mips.be	https://www.clinisysgroup.com/in/en/contact/				Laboratory Information System - GLIMS	Laboratory Information System - GLIMS
Synlab	synlab@synlab.ee	https://synlab.ee/	+372 640 8210	SYNLAB Eesti OÜ		Laboratory Information System - GLIMS	Laboratory Information System - GLIMS
Qvalitas Digital Clinic	[redacted]	https://qvalitas.ee/?lang=en		[redacted]			
Qvalitas Digital Clinic	digikliinik@qvalitas.ee	https://qvalitas.ee/?lang=en					
Viveo Health	info@viveohealth.com	https://viveohealth.com/	+372 631 1900				
IT and Development Centre of the Ministry of the Interior	abi@rahvastikuregister.ee	https://www.smit.ee/et/valdkonnad/rahvastikuregister	+372 612 4444	IT and Development Centre of the Ministry of the Interior	data processor	Population Registry	Population Registry
Ministry of the Interior	abi@rahvastikuregister.ee	https://www.siseministeerium.ee/tegevusvaldkonnad/rahvastikutoimingud/rahvastikuregister	+372 612 4444	Ministry of the Interior	data controller	Population Registry	Population Registry
Documental	[redacted]	www.documental.ee		[redacted]	Founder and CEO	DocuMental	DocuMental
Documental	[redacted]	www.documental.ee		[redacted]	Chief Technology Officer		
Hospital Information System HEDA	ester@gennet.ee	https://www.gennet.ee/home/#heda					
Tervise Arengu Instituut	tai@tai.ee	www.tai.ee/et					
Estonian Myocardial Infarction Register	emir@infarkt.ee	www.kliinikum.ee/infarkt/en	626 9301				
https://www.tehik.ee/							
Nordic Institute for Interoperability Solutions	info@niis.org	https://www.niis.org	+372 7130 800			X-Road	X-Road
Dental Clinic software - Hammas	info@innovaatik.ee, [redacted]	https://www.innovaatik.ee/	+372 740 2288	[redacted]	Data Protection Specialist	Dental Clinic software - Hammas	Dental Clinic software - Hammas

Appendix 20. Most assigned HL7 standard functionalities

Functionality name	Functionality description	Amount of systems
TI.1.6 - Secure Data Exchange	Secure all modes of PHR data exchange.	26
TI.1 - Security	Manage PHR-S security.	23
TI.1.11 - Trusted Information Exchange Environment	Maintain a Trusted Information Exchange environment to enable common security measures among participants in the health information exchange.	20
TI.1.8 - Patient Privacy and Confidentiality	Enable the enforcement of the applicable jurisdictional and organisational patient privacy rules as they apply to various parts of a PHR-S through the implementation of security mechanisms.	16
TI.4 - Standard Terminology and Terminology Services	Support semantic interoperability through the use of standard terminologies, standard terminology models and standard terminology services.	16
PH.2 - Manage Historical Clinical Data and Current State Data	Historical health information as well as current health status should be captured and maintained in the health record.	15
PH.2.5.3 - Manage Test Results	Manage results of diagnostic tests including inpatient, ambulatory and home monitoring tests.	14
TI.8 - Database Backup and Recovery	Provide for the ability to back up and recover the PHR system.	14
PH.0 - Personal Health	Manage information and functions related to self-care and provider-based care over time.	13
PH.1.5 - Manage Consents and Authorizations	Enable the PHR Account Holder to manage consent directives and authorisations.	11
TI.1.1 - Entity Authentication	Authenticate PHR-S users, and/or entities before allowing access.	11
TI.1.3 - Entity Access Control	Manage access to PHR-S resources.	11

TI.3 Registry and Directory Services	Enable the use of registry services and directories to uniquely identify, locate and supply links for retrieval of information related to: - patients and providers for healthcare purposes; - payers, health plans, sponsors, and employers for administrative and financial purposes; - public health agencies for healthcare purposes, and- healthcare resources and devices for resource management purposes.	11
TI.1.2 Entity Authorization	Manage set(s) of EHR-S access control permissions.	11
PH.6.4 - Data and Documentation from External Clinical Sources	The system should capture, index, and store documentation related to the encounter.	10
TI.4.1 - Standard Terminology and Terminology Models	Employ approved standard terminologies to ensure data correctness and to enable semantic interoperability (both within an enterprise and externally). Support a formal standard terminology model.	10
TI.5.1.2 - Structured-Document Interchange Standards	Support the management of structured documents.	10

Appendix 21. Table of validation and changes for the prototype in review stage of the study

Section	Description	Validation	Proposed changes	Description of changes
Description	Section where one can find a short description of the system and visuals to understand the basics of the system in view. The visual example of this section is in the **Appendix 8**	Validated section for basic information, although the section should have more functionalities not only the description, but general information as well	Information verification	Important for any part of the model. The basic information must be valid and correct
			Information quality	The information in this section regarding the description must be tailored to the user and must be more evidence-based not biased sales and marketing information
			Software category	Software category must be stated in the description or basic information section, to ascertain what is the system in view (e.g. information system, registry, mobile application etc.)
			Classification of healthcare application	Different from the software category, the applications must have assigned classifications from a standardised list for example (https://www.who.int/publications/i/item/9789240081949)
			Adding more general information	The description section must have more basic information about the system like links and references and owner and developer information.
Contacts	Section for all contact details necessary to connect with someone regarding the system in view. The visual example of this section is in the **Appendix 9**	Validated as a necessary element which had all of the necessary information users would expect. Although some quality-of-life changes can be	Specific contacts for specific inquiries	Adding more contacts who can support with different issues regarding the system

		made.		
Functionalities	A list of the functionalities the system has based on the HL7 standard functionalities list. The visual example of this section is in the **Appendix 10**	Validated the necessity of this section as well as the use of standardised functionalities, coding and descriptors of functionalities for clarity	Clarity of functionalities	HL7 standard is too technical for business users or any user who is not aware of the functionalities. Therefore there should be easier descriptions for the functions.
			More functionalities	Not all of the possible functionalities are represented in the HL7 standard as the standard is meant for health records. Different kinds of systems need additional functionalities to assign
			Connecting functionalities with other sections	Functionalities and other sections like integrations are related to each other and therefore connecting them is valuable to see the system as a whole and connecting sections will give more accurate information on how a functionality is implemented. (Technical information, security, interoperability)
			Clarity of classifications	Some of the functionalities are abstract and more concise solutions would be preferred for clarity
			Visualisation of functionalities	Although the functionalities are categorised by code the categories should be more evident for users
			Filtering function	For finding specific or similar functionalities in a more efficient manner in case of an abundance of functionalities
Interoperability and	A list of system integrations with other systems and	The current solution is validated and gives a high	Quality of descriptions	The descriptions must be more detailed on how the integrations are implemented to understand them fully.

integrations	descriptions of the specific integrations. The visual example of this section is in **Appendix 12**	level of overview if all integrations would be listed	Technological descriptions	Integrations must have details of how they function, what protocols are used and what technology is used.
			Information verification	The integrations and descriptions must be verified to make sure the information is correct.
			Standardisation	Standardise the list of interoperabilities and integrations to find similar solutions and how different systems have implemented them
			Instruction manuals for integration	Manuals and references to requirements on how to integrate a system with another system
Security and regulations	A list of security and regulations with references/sources and descriptions. The visual example of this section is in the **Appendix 13**	Section validated, although security and regulations must be separated	Separating security and regulations	The sections are too distinct to keep them together and must be separated into security features and regulations.
			Clarity of information	The information must be presented in a standardised manner
			Information verification	The information presented in these sections must be verified to make sure it is correct.
Sources	A list of sources where the information about the system was collected. The visual example of this section is in the **Appendix 14**	Validated as sources are always necessary, although the necessity of sources depends on the entity entering the data into the system	Addition of case studies	Sources should also include references for the case studies made about the systems

Appendix 22. Resource of requirements for an optimal e-health systems mapping

Topic	Requirement	Description	Author comments
General system information section	Description	Description of the system	The length should be limited and purpose of the system should be stated as well
	System managers	Details on the owner, the developer, and other stakeholders of the system	There can be multiple stakeholders to the system, all of them should be represented with their respective function
	System type	Classification of the software into categories such as diagnostic tools, treatment management, health record systems, or administrative tools.	The classification should be standardised if possible and all of categories defined
	System sector	Details on whether the system is managed by the public or private sector	For understanding the connectivity with and within the sectors
	Healthcare domain	Classification of the software based on its specific application in healthcare, such as electronic health records (EHR), telemedicine, health information management, patient engagement tools, or wellness and fitness apps.	This classification should also be implemented from an international standard or repository [71]
	Cost and licensing	Details on pricing, subscription models, and licensing terms, including any free or open-source options.	Helping to compare pricing of solutions between providers with similar features
	Target user group	Identification of the primary users of the software, such as healthcare professionals, patients, health administrators etc.	Important for decision-makers to find the systems tailored to the necessary group
	Usage metrics	Data on how frequently the software is downloaded, installed, or used, can be crucial for understanding its popularity and user base.	Information on how popular is the software for decision-making
	Basic contact	Contact information for general information	Repository of contacts in one place gives more value to the catalogue and implores collaboration
	Important contacts	Direct contacts of the specialists managing aspects of the system (integration, sales, helpdesk etc.)	Contacts for ease of access in case of various needs for business, integration, or other opportunities, and user support
	Visual of the system	Screenshots of the system	Visuals of the system to analyse their design or to get a subjective opinion on the system
	Clients	Details on clients of the system (Local, International, Governments)	List of clients defines the capability of the developer or of the system
	Language support	List of the national languages supported by the system	For potential international clients or services to understand if the system is available in their local language
	List of services	List of the services the system is providing for the end-user	For redundancy as not all services can be represented in functionalities
	Provider support	Details on technical support availability	Important in case of issues with integration

	availability		
	System funding sources	Details on the system funding	Functionality applies mostly only to public systems that can reveal their governing entitites.
	Age	The current number of years the system has been live	Another factor for evaluation
Technical information section	Technology stack	Details about the underlying technologies used in the system, such as programming languages, frameworks, and databases.	Most of these elements are related to the technological documentation to mainly understand the capability to integrate with one system or another. The information must use as many standards as possible although they most probably are already implemented to the documentation.
	Integration features	Specifics on APIs, data exchange formats, and other integration capabilities that enable the software to work in conjunction with other systems.	
	System architecture	Description of the software's architecture, such as client-server, cloud-based, or standalone, which can be important for understanding deployment and integration capabilities.	
	Customisation and scalability	Information on how easily the software can be customised to fit specific needs and its scalability to accommodate different user loads or data volumes.	
	Data exchange standards	Details about the specific standards the software uses and supports, such as HL7, SNOMED, DICOM for medical imaging, or ICD-10 for coding.	
	Data model	Details on how information is stored in the system	
	Platform compatibility	Information about which operating systems (Windows, macOS, Linux) or devices (smartphones, tablets, PCs) the software is compatible with.	
	Dependencies and requirements	This element describes what each software needs to function correctly, such as specific hardware, operating systems, or other software dependencies.	
	Data sets	Details about data sets within the system	What kind of data sets are offered within the system for integration with specific data
Functionalities section	List of functionalities	A standardised list of functionalities describing all of the features of a system	One of the main components of the mapping
	Clear description	Every functionality should be described in a short format for clarity. They must be understood by everyone	Descriptions that are understandable by every stakeholder
	Categorisation of functionalities	Each category of functionalities must be described and made clear of its purpose	Categories must be marked and explained for clarity
	Linked systems	List of all of the systems on the catalogue which have the same functionality	Important for overview
	International standard	The functionalities should be based on a standard and the standard must be indicated	Using one or multiple international standards to define all of the features of the system

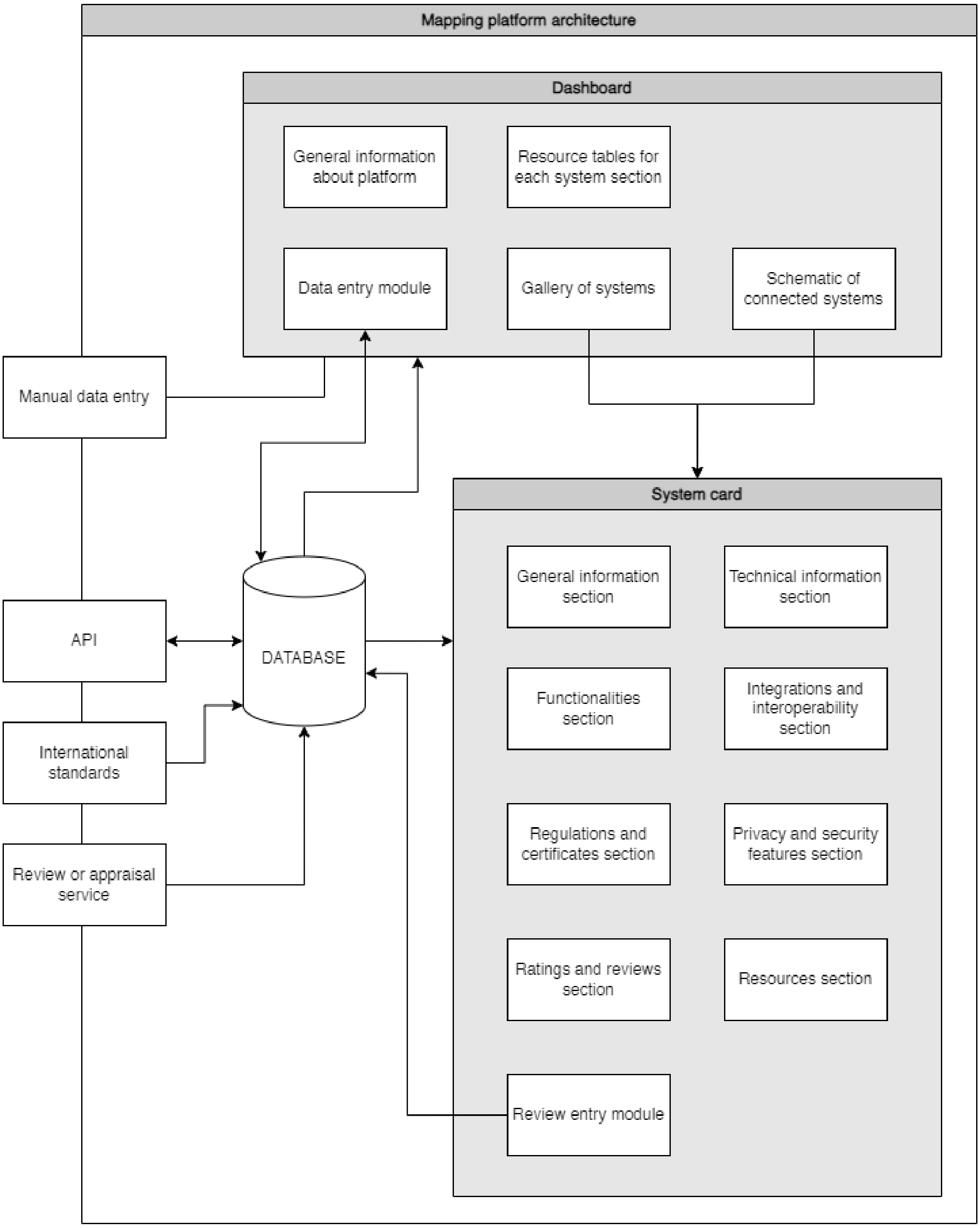
	Module details	Breakdown of the system into its constituent modules or components, describing the specific functionality of each.	Systems may have multiple modules therefore there is a case to be made that they should be diferentiated as well with their own functionalities
The integrations and interoperability section	Information on interoperability	Information on how the system interfaces with other e-Health systems or data standards, is crucial for integrated healthcare delivery.	Essential information to understand what the systems are providing and making sure that integration is necessary and evaluating the comprehensiveness of the scale of a system. Also opportunity to find integrations beyond e-health field.
	Connectivity with governmental systems	Details if the system is connected with governmental information systems or services like consent service [56]	
	Connectivity with external databases	List of the databases that are connected to the system	
	Third-party Integration capabilities	Details on how the system integrates with third-party applications or services, such as payment gateways, scheduling tools, or laboratory information systems.	
	Integrated systems	List of services and other systems that are integrated or used by the system in view	
	Integration to systems	List of services and systems that are using the system in view	
	Description of integration	Details on how the integration is implemented and what features and integrated	
Regulations and certificates section	Certifications	Information on any certifications a system has received from recognised bodies or consortiums.	Necessary for evaluation and for other systems to see what kind of certifications can be implemented and what is possible overall
	Regulatory compliance	Information regarding compliance with specific healthcare regulations, and standards (like FDA approval for medical devices, or EMA regulations in Europe).	Necessary for evaluation and for policymakers to understand where are the gaps in the system
	Description	Description of the regulation or certificate	Additionally the date of receiving a certificate
	Source	Reference to the regulation or certificate	Easy access to documentation of regulations or certificates
	Linked systems	Visualisation of connected systems that have the same regulations and certificates	Important for overview
Privacy and security features section	Security feature	Detailed information about data protection measures, privacy policies, and security features, such as encryption and compliance with health data regulations like HIPAA or GDPR.	This information is for making sure that the systems are secure and also to understand what kind of security standards are necessary to create similar systems or integrate with them.
	Security certificates	Details on validated security certifications (e.g. ISKE, HCISPP, CISSP etc.)	
	Data storage and management	Details on how the software handles data storage, including whether it uses local, cloud-based, or hybrid storage solutions.	

	System data manager	Details on who is responsible for the system and data security (client or the service provider)	
	Reference to the certificates and features	Reference of documentation for every feature and certificate	
	Linked systems	Visualisation of connected systems that have the same features or certificates	Important for overview
Ratings and reviews section	User ratings and reviews	List of user reviews and ratings	
	Integration with appraisal platforms	The platform should be integrated with a standardised appraisal platform	An option is to develop a platform but an already validated platform or standard would benefit the most.
	Review entry module	Module where users can enter reviews and ratings for the system	As with every good review module, it must have a verification option from the platform manager side, to remove spam reviews, although the manager must be unbiased
Resources section	Case studies	References to case studies	References improve the value of stated information and research on the systems. Having references to user and integration manuals in one place raises the value of the platform for every stakeholder as a single repository where necessary information is found.
	Manuals for integration	References of technical manuals to help with the integration process or understand integration availability	
	User manuals and tutorials	References to user manuals, tutorials, forums or other helpful information	
	Clinical research	References to clinical research	
Platform design and dashboard	Optimised usability design	The user interface and user experience of the platform must be intuitive and easy to use	Platforms made for everyone must take into account that concise and clear information visualisation, tooltips, minimisation of moving elements, highlighting and guiding in design must be considered
	Standardised data presentation	Data in every section must be presented in a standardised format, which is indicated in the data entry	
	Made for public	The platform must be designed to be accessible and understandable by the public and specialists alike	
	Schematic of systems	Visual and interactive schematic of all of the systems and what are they connected to	Better visualisation helps to get a clearer overview of which systems of the landscape are connected
	General information section	General information about the platform and copyright information	This should include contact details, the description of the platform, the purpose of the platform, and any information that the platform host deems necessary
	Instructions and materials	Repository of instructions and manuals using and navigating the platform	These materials are necessary as not all of the functionalities and features will be understandable to everyone

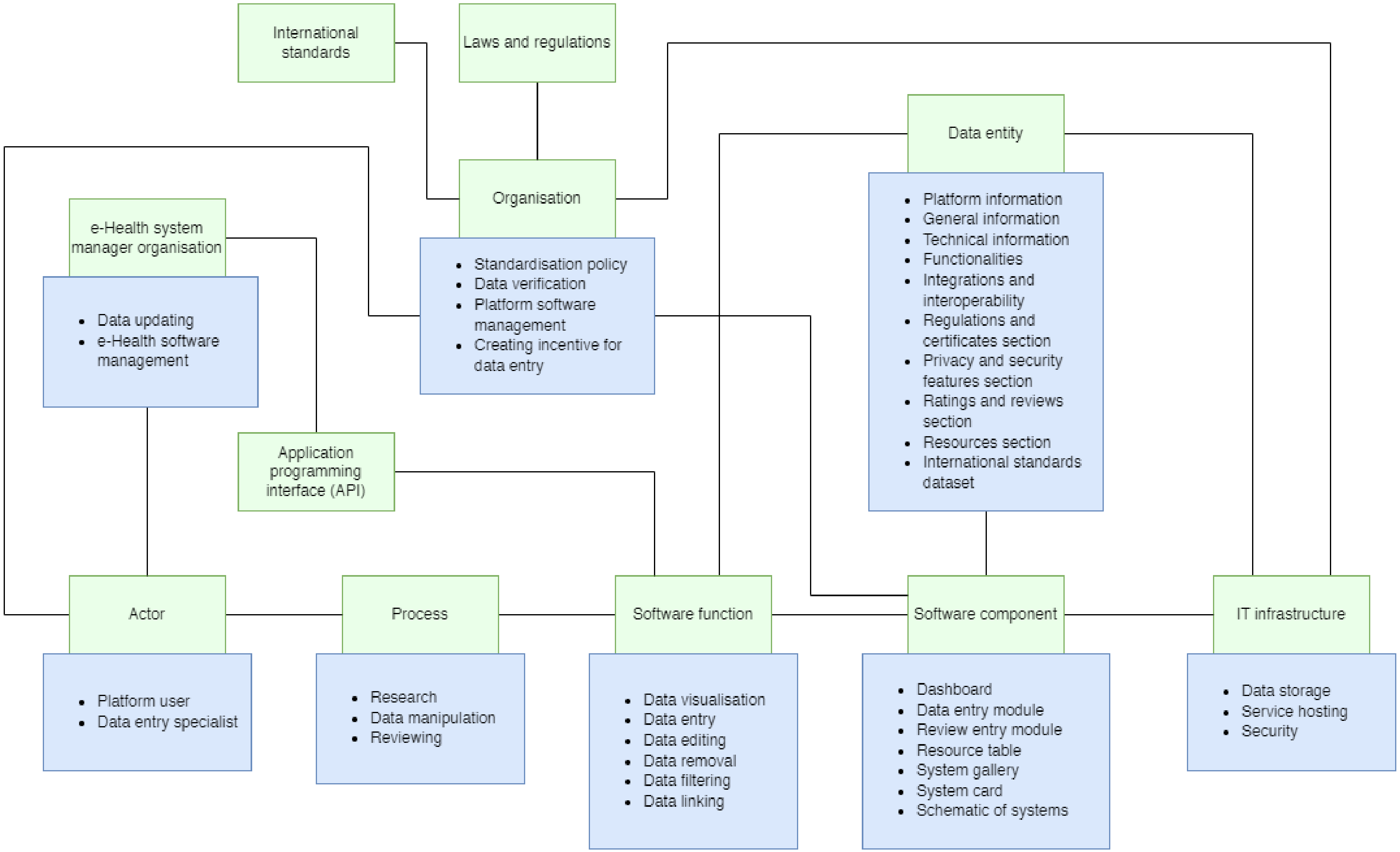
	Sources of standards	References to the origin of international standards and currently used version	Necessary validation of the standards used and source of documentation if must be researched
	System update date	The latest renewal of data by the system should be indicated	Providing users with a clear indication of the information's currency.
	Gallery of systems	Section where all of the systems are represented in a gallery	The attributes of this section should include a short description, icon, owner, selection of info from "general information" section and review info. Could look something like DiGA [41]
	Resource tables	Every section where data is entered must have tables where all of the assigned items and connections are visualised	Resource tables also must have descriptions of their purpose and instructions for filtering
Platform management and features	Data verification	The platform must confirm the accuracy and integrity of data to ensure its reliability and correctness.	While it may not be feasible to verify all the data, at the very least, the basic information should be accurate
	Evidence-based information	The entered data to the platform must be factually correct	The attributes of this section should include a short description, icon, owner, info from the "categorisation" section and review info
	Universal data host	The data must be stored in a location owned by the platform manager	Data must be stored and managed by the same entity for security and ownership reasons.
	Public accessibility	The platform must ensure that is easily and readily available to all members of the public	To e-health specialists and any other interested party alike, other industries should also collaborate with the e-health landscape
	Information updating	The platform manager must ensure that the information contained within the mapping is regularly and periodically updated.	An automated service could be established to periodically prompt data entry specialists to confirm the accuracy of their system's information. Since most of the data does not require frequent updates, this verification could be scheduled biannually.
	Automation API	An API for automation must be developed	Although this may not be the first feature that needs to be developed for the platform, it is certainly beneficial to create an API that can periodically receive specific data, such as the number of users on the platform, contact info etc.
	Platform updating	The platform and the features of the platform must be kept updated	Including updates for new revisions of standards, the addition of new functionalities, or the installation of security updates etc.
	Filtering feature	The platform must have capabilities to filter systems and tables	An essential feature to find something specific especially when the amount of data is high
	Automatic linking feature	The platform must have capabilities to link or connect systems with each other	Understanding connections with systems with same attributes is crucial to getting an overview of the landscape
Mapping platform data entry module (requirements for the back-end of the	User restrictions	Users must be restricted so that they can only edit the systems and elements of the platform for which they have permission.	Acts as a protection from accidental and malicious editing
	Functionalities selection criteria	Functionalities must be defined with clear selection criteria to ensure a proper understanding of which functionalities are applicable.	Similarly to the HL7 selection criteria shown in the study (figure 1), the feature helps to make sure if added functionality is correct

platform for data entry)	Premade functionalities	The user is limited to selecting functionalities exclusively from the standardised list provided on the platform.	The built-in lists by the platform make sure that data is entered within the constraints. The functionality suggestion feature can be implemented if other systems have assigned similar functionalities
	Helpdesk for data entry	The platform manager is required to offer a contact option for resolving any issues related to data entry on the platform.	It is imperative that data entry is simple, then in case of any issues or for example prompt help should be available
	Instructional material	The manager must provide instructional materials and documentation on how to use the platform and enter data.	The material has to be easy to consume as well, videos would be the best to explain data entry
	Clear descriptions	Functionalities and other items must be described clearly and concisely.	In some cases, the system could define keywords that may be too technical
	Premade lists of items	The manager must provide lists of linkable items from other sections (e.g. interoperabilities, certificates, security features, categories etc.)	Some of these lists can be premade like the categories, but they have to be based on an international standard. Other systems will also populate some of the lists like interoperabilities, but they have to be verified. Every item that can be assigned must be presented.
	Intuitive user interface	The data entry process should be streamlined and user-friendly, ensuring that the usability design is optimised for efficient and effective data entry.	The interface must be validated and tested by the potential data entry specialists before it is launched
	Proposal of functionalities	Data entry specialists must have the capability to suggest additional functionalities for the platform.	The existing standards may not always have the functionalities that are implemented in systems, therefore there has to be a way to either modify or add specific functionalities. They must be verified by the system manager.

Appendix 23. Final simplified architecture of the optimal mapping



Appendix 24. Modified metamodel of e-health systems landscape mapping



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