

# On the Relationship Between Challenges of Critical Information Systems and System Requirements: Case Apotti EHR System

Leena Hellman\*, Petri Ihantola, Tommi Mikkonen and Niko Mäkitalo

Faculty of Information Technology, University of Jyväskylä, Finland

## Abstract

Critical information systems such as Electronic Health Record (EHR) systems are an important part of our society. The procurement and implementation of such systems involve many stages and different stakeholders with a variety of expectations. An example of this kind of procurement in the public sector is the Apotti EHR system, which has been in public discussion, especially due to unsatisfied users. Our objective is to better understand the concept of the original system requirements and the operational challenges. Thus, we have conducted a case study on Apotti to identify challenges and negative experiences from the gray literature. Identified challenges were mapped to challenge domains from the literature, non-functional requirement categories, and specific requirements from Apotti's documentation. The preliminary results show that patient safety is the biggest concern among challenges. Usability problems are also present in many challenges. The main finding of our study is that we were unable to trace the original system requirements for many identified challenges. This may indicate that some collective expectations and many challenges related to public and critical information systems are difficult to capture within system requirements. However, more research is needed to determine whether these findings can be generalized to other critical systems.

## Keywords

Critical information systems, Electronic Health Record Systems, Requirements engineering

## 1. Introduction

Critical information systems play a vital role in our society. These systems keep people safe, operate the necessary infrastructures, and, for example, manage health records. The acquisition of such systems is often highly costly and involves complex procurement and implementation processes, typically involving multiple stakeholders from both the public and private sectors.

To successfully deliver a software product, the project team must have a deeper understanding of the application area and the relevant technologies. In addition, experience in the requirement engineering process and early consultation with stakeholders are essential to increase and strengthen the team's knowledge base [1]. Hoffmann and Lehner [1] concluded that inadequate requirements are one of the primary reasons software development projects fail.

Over the years, much research has been conducted on requirements engineering (RE) and its different phases [1], [2], [3], [4]. Requirements engineering is the first step in the development of software systems, in which informal ideas of a system become a specification [5]. Pohl [5] continues that the requirement specification gathers and documents both the functional and non-functional requirements of the system and also the criteria for measurement of the degree of their fulfillment.

The procurement of public information systems is another topic that has been studied before in various application areas, such as [6], [7], [8], and [9], for example. However, little attention has been paid to what extent the challenges that arise during the operation of a critical IT system align with the original system requirements and what kinds of gaps might exist.

*TKTP 2025: Annual Doctoral Symposium of Computer Science, 2.–3.6.2025 Helsinki, Finland*

\*Corresponding author.

✉ leena.m.hellman@jyu.fi (L. Hellman); petri.j.ihantola@jyu.fi (P. Ihantola); tommy.j.mikkonen@jyu.fi (T. Mikkonen); niko.k.makitalo@jyu.fi (N. Mäkitalo)

🆔 0009-0009-2174-8548 (L. Hellman); 0000-0003-1197-7266 (P. Ihantola); 0000-0002-8540-9918 (T. Mikkonen); 0000-0002-7994-3700 (N. Mäkitalo)



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The objective of this study is to develop a better understanding of the misalignment between the original system requirements and the operational challenges. That is why we have conducted a case study where we first identify operational challenges and negative experiences related to Apotti – a Finnish Electronic Health Record (EHR) system – and then analyze how these identified challenges can be mapped to Apotti’s original system requirements. In general, EHR systems manage patient data in digital form, store and exchange data securely, and allow access to multiple authorized users [10], [11]. EHR systems can be defined as one of the mission-critical systems for society, and hence provide an interesting angle to understand the collective expectations [12] for such public and critical information systems and their related procurement and development processes.

In contrast to historical paper-based patient charts [13], the motivation and collective expectations for digitalizing patient records are clear: EHR systems are expected to improve the quality of care, reduce medical errors, provide better financial performance, and conduct research to achieve improved population health [14].

An EHR system such as Apotti provides an interesting case study, as the system needs to support multiple health care professionals in their work in several different ways. According to [11], five functional parts of the EHR system are an integrated view of all relevant patient data (with complex data types), clinician order entry (point where physician takes actions and makes decisions), clinical decision support, access to knowledge resources, and integrated communication with other organizations and reporting support.

From a technical perspective, EHR systems are also complex to implement. Typically, an EHR system consists of different databases, data repositories, directory services, knowledge services with terminological systems, patient care paths, workflows, user interfaces, reporting modules, security, and respective hardware and network components [15]. EHR system is not a single product, but rather an on-site configuration of various applications, computers, and networks [15].

The remainder of the paper is structured as follows. Section 2 introduces the case study and the related literature. Section 3 describes the methodology and phases of our research. In section 4, the results are presented. Section 5 discusses and analyzes the results, and finally, section 6 summarizes the main results and future prospects.

## **2. Background and related work**

### **2.1. Apotti EHR system**

The Finnish Apotti software for Electronic Health Record Systems – or Apotti for short – is a social and health care information and operational control system that combines social and health care information into one system [16]. There was a need to improve social and health care services in Helsinki and Uusimaa district, so Helsinki, Vantaa, Kirkkonummi, Kerava, Kauniainen – all cities or municipalities in the region – and HUS, the Helsinki Metropolitan Area Hospitals, joined to start a project in 2012 to unify the existing systems [17]. Before Apotti, the hospital district HUS had several different electronic patient and customer record systems. The first implementation of Apotti was introduced in November 2018 in Peijas Hospital Vantaa, and was gradually implemented in other parts of the hospital district by 2022 [18]. The total costs of Apotti from 2016 to 2021 were 626 million euros [19]. In addition, Tivi magazine reported in 2022 that costs are rising above 800 million euros [20]. In 2022, more than 47,000 people were using Apotti [18].

The vision of the Apotti project was to become the world’s first joint information and operations management system for social and health care [18]. The procurement was done with a negotiated procedure, and the suppliers submitted their applications for participation [21]. The selection of the new system was based on a scoring system, determined on qualitative characteristics, such as usability, functionality, scope, transparency, and maintainability of the solution, as well as the provider’s deployment capability [21]. The selected system was Epic, which was considered the best with its functional quality [18]. Epic is founded in the USA and is used in most of the top-ranked hospitals in the USA [22]. The goal with implementing Apotti was to improve and unify social and health care

maintenance services and operating methods to save costs in Helsinki and in the Uusimaa region [18]. The developers of Apotti organized workshops where 200 professionals from different fields were gathered, 600 pages of user stories were collected, and regulatory requirements and factors related to social and health care integration were investigated [21]. After the definition work, six main goals were concluded for the transformation [21]:

1. Customer-oriented operations
2. Unified operating methods
3. Cost-effective and high-quality operation
4. Knowledge management and information utilization
5. Satisfied users
6. New innovative operating modes.

## 2.2. Related work

There are relatively few scientific articles about Apotti and its implementation. Hertzum et al. [23] studied the experiences of Epic implementations in Denmark and Finland. They conducted a documentary analysis and reviewed an open data set from the Finnish Institute for Health and Welfare. This dataset covered responses from nationwide surveys of physicians, nurses, and social workers regarding their experiences with the EHR they used. The researchers concluded that both physicians and nurses experienced inferior usability and reduced work support after the implementation of Apotti.

Another study was conducted by Kyytsönen et al. [24] who performed a questionnaire for nurses in 2020. The aim was to find out how well different EHR systems used in Finland support the work of nurses in specific work environments. The study revealed that only 11% of the nurses using Apotti thought that the patient records were easy to read, and only 10% agreed that completing routine tasks is straightforward with Apotti. Similar results were presented in Vehko et al. [25] study, in which the experiences from practical nurses working with different EHR systems in Finland were collected through a questionnaire. The survey showed that 79% of the practical nurses working in public health care agreed that EHR takes too much time away from working with patients. In addition, only 26% thought that Apotti's user interface has a logical layout.

Lindén-Lahti et al. [26] studied the effect of Apotti's implementation on reported medication errors. Apotti has a feature of a closed-loop electronic medication management system (EMM). The study showed that the implementation phases increased temporary medication errors. In addition, administration and dispensing errors decreased, but medication reconciliation, ordering, and prescribing errors increased after implementation. The researchers stated that most medication errors were related to user skills and technical usability.

Grön[12] conducted a case study on Apotti with a special interest in the common good in public health care. The key actors of the Apotti project were interviewed, and analysis was conducted based on these interviews and other documents. The study revealed that common interests justify a new information system, and this is based on multiple perceptions of common interest, which may conflict with each other.

## 3. Research questions and methods

### 3.1. Research questions

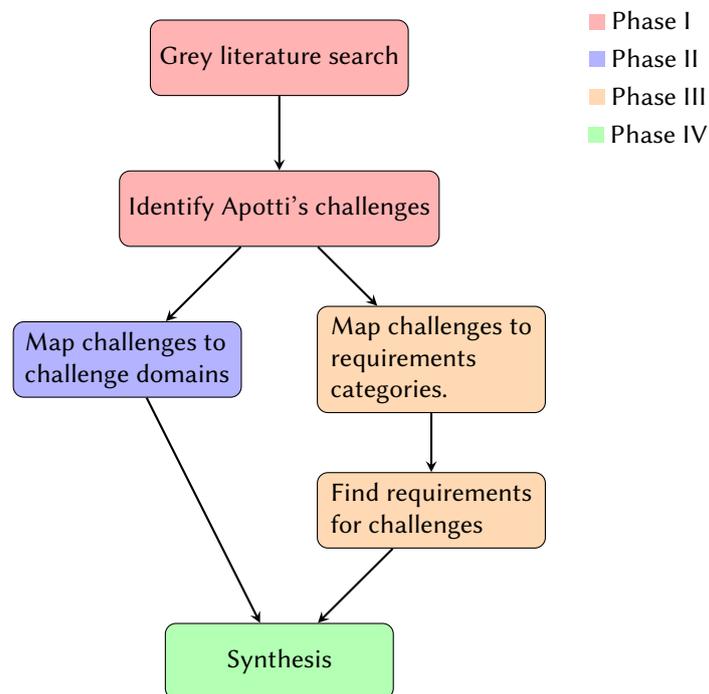
In this study, the aim is to better understand the misalignment between the original system requirements and the operational challenges in the case of Apotti. The following research questions are formulated to achieve this goal:

**RQ1** What system challenges can be identified in the public discussion related to the Apotti EHR system?

**RQ2** How do the Apotti EHR system challenges map to the related requirements?

### 3.2. Research methods

We used content analysis [27] to identify challenges in Apotti from the gray literature and categorize these challenges. The course of the research is presented in Figure 1. The first phase was to find newspaper articles, opinion pieces, reports, and other gray literature that report challenges with Apotti. We used a master's thesis list of articles related to Apotti [28] as a basis for our search and selected articles that were published in *Helsingin Sanomat*, *Tivi*, *Yle*, and *Iltasanomat* and which had comments or reports on problems or challenges in Apotti. An additional search was conducted with Google to find more articles reporting the challenges of Apotti. We used the terms "Apotti" and "Apotti potilastietojärjestelmä". All selected articles were read and analyzed to find challenges. In total, 14 articles or papers were selected. These articles are listed in Appendix 6. The criteria were that the text described experiences from Apotti's users or reported difficulties with Apotti to get the most realistic picture of the challenges. The focus was on technical problems and challenges related to software engineering.



**Figure 1:** Research phases.

The second phase of the research was to understand the challenges and put the challenges to a certain category. Huang et al. [29] performed a literature review and categorized the existing challenge domains in Electronic Health Record System transitions. They studied 70 articles that described transitions from one EHR system to another and mapped challenges into 10 different domains, which are briefly presented here:

- Financial considerations: costs from software, hardware, devices, consultants, etc.
- Human infrastructure: the existing and new IT staff and other associated personnel involved in the transition.
- Technical considerations: network connections, database integrity, data conversions, backup, data integrity, and other issues concerning the technical part of the transition.
- Data migration: things related to data conversion securely and maintaining the integrity and confidentiality of data. This is a crucial part of the transition.

**Table 1**

Non-functional requirements according to Apotti requirements [30].

Requirement category	Appendix
General functionality	B8
Usage requirement	B8
Usability	B8
Efficiency of use	B8, PS2.1
Legislation	B8
User documentation	B8
Data security	B8, B9
Data privacy	B8, B10
Scalability	B8, PS2.1
Maintainability	B8, PS2.1
Maintenance documentation	B8
Platform requirements	B8
Architecture	B8
Integrations	B8, TS2.3, B12, B13, B14, B15
Compatibility	B8

- Patient safety: data migration and transition processes can affect patient safety. In addition, usability issues, lost or distorted data, and difficulty in finding data are major issues that can threaten patient safety.
- Provider expectations: physicians' expectations, prior experience, and adaptation to the new system, adequate initial training
- Patient expectations: consists mainly of the satisfaction with providers and the efficiency of the work.
- Training and support: Appropriate training and support for staff during and after the transition is crucial.
- Cybersecurity during and after transition
- Chief medical informatics officer responsibilities: selection, analysis, configuration, and migration to the new EHR system.

After mapping the challenges to the challenge domains, we studied Apotti's documentation and tried to find a relevant categorization for requirements. Apotti presents a categorization of non-functional requirements [30] in their documentation. These categories outline the system conditions that must be met to successfully implement the functional requirements. There are 15 categories for non-functional requirements, which are presented in Table 1. Each category has an appendix that describes the requirements more thoroughly. The categories and their appendix are presented in the document [31]. In Table 1, you can find a link to the corresponding appendix. Some of the attachments mentioned in the document were not found. Requirements have a unique code and a description. The requirements connected to a certain challenge based on our analysis are found in Table 2 with a short description.

## 4. Results

In this section, we present the results of each phase. Table 3 summarizes all collected data, categorizations, and requirements. Table 4 presents the challenge domain categorization, table 5 the non-functional categorization, and table 6 gathers results from tables 4 and 5 into cross-tabulation.

**Table 2**

Non-functional requirements [31] that could be identified with challenges. Id-coding is made for this study by the authors, code means the coding in the original source.

id	Code	Description
r1	ETV_0047	Data confidentiality and encryption of communications.
r2	ETV_0083	The system must support multiple geographically separated locations and enable smooth connections between different locations.
r3	ETV_0102	Data integrity between version updates.
r4	ETV_0164	The system has to be integrated with other systems and services defined elsewhere.
r5	ETV_0183	New updates must not lose information about patient records or limit their presentation.
r6	ETV_0194-5	Success in medication management tasks e.g. recording, modifying, and prescribing.
r7	ETV_0196	Success in tasks like retrieving relevant patient records, medication, getting an overall picture of a patient's history and current status.
r8	ETV_0203-4	Correctness in medication management tasks e.g. recording, modifying, and prescribing.
r9	ETV_0205	Correctness in tasks like retrieving relevant patient records, medication, getting an overall picture of a patient's history and current status.
r10	ETV_0211-24	Efficiency in tasks like booking appointments, inspecting and prescribing medication, writing an epicrisis, recording status. It is assessed on time spent or the number of execution path steps.
r11	ETV_0241	Learnability in tasks like scheduling an appointment, medication modification, retrieving essential patient records, and getting an overall picture of a patient's history and current status.
r12	ETV_0242	Subjective learnability as assessed by the user.
r13	ETV_0247	Satisfaction with the performance of work tasks. Assessed with a usability survey.
r14	ETV_0250	The user interface should be as simple as possible and present only the information the user needs as accurately as possible.
r15	ETV_0256	The user interface should not require memorization.
r16	ETV_0259	The user interface should be consistent in its usage logic and appearance. It should follow familiar conventions.

#### 4.1. Phase I

Phase I consisted of data gathering. Altogether, 14 articles were selected for further review. The articles are listed in Appendix 6. These articles come from Finnish newspapers, and a few papers are from the Finnish health care field. The identified challenges are presented in the second column of Table 3. We found 27 different comments or statements that described a challenge. Some of these challenges were found in multiple papers. Challenges are something that a person using Apotti has experienced and has told in an interview or something that a person has written. Some challenges are not anyone's opinion or experience, but a system challenge, for example, a connection problem or a problem with data security. The most featured challenges were that Apotti is slow to use and that the user interface is difficult and confusing to use. Both of these challenges were presented in six different articles. In addition, learning to use Apotti was difficult and time-consuming according to three articles.

#### 4.2. Phase II

The second phase was to analyze one challenge at a time and map the challenge to a certain challenge domain that Huang et al. [29] presents. The results of this categorization can be seen in Table 4. Each identified challenge could be put into a challenge domain. Patient safety is the biggest group with 37% of challenges, although provider expectations have almost the same number of challenges with 33%. Technical considerations came third with 15% of challenges. Training and support present 11% of the challenges.

**Table 3**  
Challenges collected from newspapers and magazines.

id	Phase I Challenge	Phase I Reference	Phase II Challenge domain	Phase III Requirement category	Phase III Requirement in Table 2
1	Apotti is slow to use	[35], [36], [37], [38], [39], [40]	Provider Expectations	Usability	r10
2	The user interface is confusing and difficult to use	[36], [41], [37], [39], [42], [40]	Provider expectations	Usability	r7, r9, r13
3	The user has to know and learn things in advance	[41]	Training and support	Usability	r15
4	Learning to use Apotti takes long time	[43], [40], [38]	Training and support	Usability	r11, r12
5	It is difficult to find relevant information about the patient's condition	[36], [42]	Provider expectations	Usability	r7, r9
6	Medication system is slow	[36], [40]	Provider expectations	Usability	r10
7	It is hard to get up-to-date picture of a patient's medication	[40]	Provider expectations	Usability	r7, r9
8	Apotti suggested wrong medication and the patient got severe reaction from the medicine	[43]	Patient safety	-	-
9	Medication errors have increased	[43]	Patient safety	-	-
10	Compromises the patient's right to receive the best possible care or exposes the patient to dangerous situations.	[35]	Patient safety	-	-
11	Problems in data transmission because Apotti does not work with systems not using Apotti	[44]	Technical considerations	Compatibility	r4
12	Transfer report has unclear layout, and it is difficult to obtain important information from it	[45]	Provider expectations	-	-
13	It takes a long time to open the system and patient records	[37]	Provider expectations	-	-
14	Apotti verifies patient's medication, and this can increase the risk of medication errors	[37]	Patient safety	-	-
15	It is difficult to find relevant information to treat the patient	[37]	Patient safety	Usability	r7, r14, r16
16	You can not find old, canceled prescriptions, and this increases the risk of drug abuse.	[37]	Patient safety	-	-
17	The training does not reflect real situations, and three days of training is not enough	[37]	Training and support	-	-
18	Nurses' personal IDs were leaked into patient records	[39]	Data migration	Data privacy	r1
19	Instructions for patient care were not received	[46], [37]	Technical considerations	Compatibility	r4
20	The treatment has gone wrong and the patient's health is in danger	[46]	Patient safety	-	-
21	Bad and dangerous system	[47]	Patient safety	-	-
22	Communication problem with HUS and Apotti. Patient records could not be retrieved.	[47]	Technical considerations	Scalability	r2
23	Five patients were recorded wrong medication because of an update in Apotti.	[48]	Technical considerations	Maintainability	r3, r53
24	A patient died because the transfer report was confusing, and the hospital staff did not get the relevant information.	[36]	Patient safety	-	-
25	Working in different roles in Apotti is time-consuming and difficult	[40], [41]	Provider expectations	-	-
26	Technical aspects take too much attention from the patient and risk the patient's safety	[38]	Patient safety	Usability	r15, r16
27	The structured recording makes it hard to get an overall picture of the patient's situation.	[38]	Provider Expectations	Usability	r7

**Table 4**

Overview of the found challenges in challenges domains.

Domain	Number	Percentage
Patient safety	10	37%
Provider expectations	9	33%
Technical considerations	4	15%
Training and support	3	11%
Data migration	1	4%
Total	27	100%

**Table 5**

Overview of the found challenges in requirement categories.

Category	Number	Percentage
Usability	10	37%
Compatibility	2	7%
Data privacy	1	4%
Maintainability	1	4%
Scalability	1	4%
Undefined	12	44%
Total	27	100%

### 4.3. Phase III

The third phase was to find a particular non-functional requirement category for a challenge. After finding a suitable category, the corresponding appendix for the category was reviewed and explored. The idea was to find one or several requirements that might describe the challenge.

Table 5 presents the number and percentage of challenges found per requirement category. Usability was mapped to 37% of the challenges. Most of the challenges (44%) were left unidentified. Unidentified means the challenge could not be put in any of the existing categories for the non-functional requirements. These challenges were mainly issues that concerned patient safety. For example, in [35] two physicians claimed that Apotti compromises the patient's right to receive the best possible care or exposes the patient to dangerous situations. This kind of argument is difficult to put into any category because the requirement categories do not seem to have the aspect of patient safety. Another argument was that Apotti is a bad and dangerous system [47]. There was no explanation of what this argument was based on, for example, a technical aspect or usability. The assumption could be that the dangerous part means that Apotti endangers patient safety. In addition, in [46] it is claimed that when using Apotti, treatment has gone wrong and the patient's health is compromised.

When looking at specific requirements, many of the challenges could be identified with one or several requirements. Some challenges could be identified with a certain requirement category, but we did not find a particular requirement for the challenge. For example, some medication related challenges could mean that it is a usability problem, but no specific requirement was found to explain these. These challenges, without identified requirements, were left without a category and classified as Unidentified. In addition, challenges not identified with a requirement category were classified as Unidentified. Almost all challenges categorized as usability could be identified with a requirement. For example, the most common challenge was that Apotti is confusing and difficult to use, having three different requirements. These requirements describe, for example, how the user interface should be simple and the overall picture of a patient's condition should be retrieved.

#### 4.4. Phase IV

Table 6 collects results from phases II and III in one cross-tabulation table. From the table, you can see how requirement categories and challenge domains are related to each other. There were 10 challenges in the patient safety domain, and of these challenges, 2 were related to usability and 8 were left unidentified. The provider expectations had 9 challenges, and 6 of these were defined as usability issues, and 3 were left without a category. There were 3 challenges in training and support; 2 of these were classified as usability requirements, and one was unidentified. You can look at the table from the perspective of requirement categories. The usability category had 10 challenges, and 2 of them concerned patient safety, 6 provider expectations, and 2 training and support. There were 12 challenges without a category and of these, 8 were related to patient safety, 3 provider expectations, and 1 training and support.

**Table 6**

Cross-tabulation of the results presented in tables 4 and 5.

	Usability	Compatibility	Data privacy	Maintainability	Scalability	Undefined	Total
Patient safety	2	0	0	0	0	8	10
Provider expectations	6	0	0	0	0	3	9
Technical considerations	0	2	0	1	1	0	4
Training and support	2	0	0	0	0	1	3
Data migration	0	0	1	0	0	0	1
<b>Total</b>	<b>10</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>12</b>	<b>27</b>

## 5. Discussion

In this study, we have been investigating the relationship between the challenges of critical information systems and system requirements. We selected the Apotti EHR system as a specific case study because it provides several motivations. Firstly, the Apotti EHR system is a good example of a complex and large-scale system that is critical for the Finnish society. Secondly, there are obvious collective expectations for digitalizing patient health records, and more specifically, for the Apotti EHR system, which has been developed for the most population-rich area in Finland. Thirdly, the Apotti EHR system has been under a lot of public discussion and debate in the media. Finally, the public nature of the procurement and development processes of the Apotti EHR system provides a lot of material for research.

To understand the collective expectations and challenges, we set our first research question as follows:

**RQ1** What system challenges can be identified in the public discussion related to the Apotti EHR system?

The search in the gray literature produced 27 different challenges. The main focus on these challenges was the users' dissatisfaction with the usability of Apotti. There were also complaints about the learnability of using Apotti, medication errors, and technical issues. These findings are consistent with previous studies on usability: a systematic review [32] stated that the most used qualities to describe usability in different models and standards were learnability, efficiency, satisfaction, and effectiveness. Heiskari et al. [33] discovered that usability is often seen just as a part of the user interface development rather than as a process that involves other aspects of the software process. This can be misleading since [33] suggests that usability specialists should be part of requirement engineering from the beginning. Usability and user satisfaction must be studied more in the context of critical information systems.

Identified challenges were categorized using the Huang et al. [29] categorization of challenge domains. This categorization suited well, and all identified challenges were placed in a category. The largest group was the patient safety domain with 37% challenges, and the second domain was the provider expectations with 33% challenges. These findings are in line with the study by Hertzum et al. [23] who

stated that the physicians and nurses who worked with Apotti experienced poor usability and poor quality of care.

In addition, Grön has proposed a classification [12] that divides the objectives behind Apotti for 1) Promoting public health and individual well-being, 2) Providing support and management for health care professionals, 3) Changing health care information system markets, 4) Providing new possibilities for research and business, and 5) Making the Finnish health care system and society more visible. While we did not apply this categorization in our study, Grön's objective categories may imply how health care professionals use the system, and may also indicate why most of the challenges discussed in the media relate to only one specific objective behind the system.

We continued our study to better understand how the identified challenges relate to Apotti's original system requirements, which are available due to the public procurement process. Hence, the second research question was:

## **RQ2** How do the Apotti EHR system challenges map to the related requirements?

Table 6 summarizes our analysis and mapping from the identified challenges to the non-functional system requirements. The largest group of identified challenges, 10 (37%), fell under the usability non-functional requirements category. From these, 6 were provider expectations challenges, 2 were training and support issues, and 2 were patient safety challenges. Previously, similar results have also been reported by Kyytsönen et al. [24] who found out that only 10% of nurses using Apotti thought that it was straightforward completing routine tasks with Apotti.

Our main finding was that we were only partially able to map the identified challenges to Apotti's non-functional requirements [30]: from the 27 identified challenges, we were not able to find suitable requirements for 12 challenges, and hence these were left in the Unidentified category. However, with the categorization by Huang et al., we were also able to categorize 8 of these challenges under patient safety, 3 under provider expectations, and one under training and support.

Especially challenges dealing with patient safety were left without system requirements and their category. Since patient safety situations are often complex, we reasoned that it can be difficult to capture these into user stories or non-functional system requirements. In addition, it may be difficult or even impossible to test such requirements concerning patient safety. Nevertheless, patient safety is crucial, and it should not be passed lightly.

However, it must be noted that the public discussion may be concentrating on patient safety to get attention, and considering the large scale of the system, the problem may not be as severe as the discussion might suggest. On the other hand, however, it may be that some patient safety-related requirements are indeed missing. At least, in Apotti's five main goals [21], patient safety is not directly mentioned.

More generally speaking, the challenges in EHR to EHR transitions are known, and Huang et al. [29] state that enough resources should be directed to human infrastructure, technical challenges, security gaps, unrealistic provider expectations, workflow changes, and training and support. According to Apotti [21], health care specialists from different fields were gathered to workshops and user stories were collected to get a better understanding and to prepare the requirements. Still, despite the comprehensive groundwork, the users experienced Apotti as confusing, slow, and difficult to use. The study [34] concluded that two main reasons for failed EHR projects are technical and managerial.

Our study showed that many challenges in the public discussion surrounding Apotti can be mapped to patient safety and usability. However, a major part of the challenges (44%) cannot be directly traced to any of the original system requirements. This indicates that at least these kinds of challenges are complex and hard to capture into non-functional requirements. In addition, challenges that did not map into any specific requirements were predominantly related to patient safety (67%). Whether this is related to the fact that those kinds of features are different from others or simply from the selection bias where patient safety has been used as an easy-to-understand argument in public discussion is an open question. Moreover, it should be noted that our research concentrated on one system and only provides preliminary results. For this reason, the findings do not apply directly to other critical information

systems. To generalize the results, more research is needed to better understand how well operational system challenges can be mapped to system requirements in critical systems in other application areas.

## 6. Conclusion

In this paper, we examine the relationship between operational challenges and original system requirements in the case study of the Apotti EHR system. We first used the content analysis method to analyze public discussion in Finnish media to find challenges and negative experiences related to Apotti. Eventually, we were able to identify 27 different challenges. We mapped the identified challenges with Huang et al.'s challenge domains in EHR transitions and then tried to find the corresponding original system requirements from Apotti's public specifications. Based on our analysis, two main groups of challenge domains were patient safety with 37% and provider expectations with 33%. The identified challenges mainly (37%) fell under usability in Apotti's non-functional requirements categorization. Our main finding is that while we were able to trace the original system requirements for many challenges, 44% of the challenges could not be linked to any documented requirement. While these preliminary results indicate that many challenges are hard to represent through user stories or capture within non-functional system requirements, further research is needed to determine whether these findings can be generalized to other critical information systems.

## Acknowledgment

This work has been supported by the Software Engineering Doctoral Pilot, funded by the Ministry of Education and Culture, Finland.

## Declaration of Generative AI

The authors have not employed any Generative AI tools.

## References

- [1] H. Hofmann, F. Lehner, Requirements engineering as a success factor in software projects, *IEEE Software* 18 (2001) 58–66. doi:10.1109/MS.2001.936219.
- [2] J. Klier, M. Klier, S. Muschter, How to manage IS requirements in complex public sector structures: toward an action design research approach, *Requirements Engineering* 22 (2017) 419–432.
- [3] J. Verner, K. Cox, S. Bleistein, N. Cerpa, et al., Requirements engineering and software project success: an industrial survey in Australia and the US, *Australasian Journal of information systems* 13 (2005).
- [4] R. K. Sandhu, H. R. Weistroffer, A review of fundamental tasks in requirements elicitation, *EuroSymposium on Systems Analysis and Design* (2018) 31–44.
- [5] K. Pohl, *Requirements engineering: An overview*, Citeseer, 1996.
- [6] A. S. Patrucco, D. Luzzini, S. Ronchi, M. Essig, M. Amann, A. H. Glas, Designing a public procurement strategy: lessons from local governments, *Public Money & Management* 37 (2017) 269–276.
- [7] A. Koski, T. Mikkonen, What we say we want and what we really need: experiences on the barriers to communicate information system needs, *Requirements Engineering for Service and Cloud Computing* (2017) 3–21.
- [8] C. E. Moe, Research on public procurement of information systems: the need for a process approach, *Communications of the Association for Information Systems* 34 (2014) 78.
- [9] M. Fazekas, J. R. Blum, Improving public procurement outcomes, *Policy research working paper* 2 (2021) 2–3.

- [10] K. Häyrinen, K. Saranto, P. Nykänen, Definition, structure, content, use and impacts of electronic health records: a review of the research literature, *International journal of medical informatics* 77 (2008) 291–304.
- [11] C. J. McDonald, P. C. Tang, G. Hripcsak, Electronic health record systems, in: *Biomedical informatics: computer applications in health care and biomedicine*, Springer, 2013, pp. 391–421.
- [12] K. Grön, Common good in the era of data-intensive healthcare, *Humanities and Social Sciences Communications* 8 (2021) 1–10.
- [13] T. Seymour, D. Frantsvog, T. Graeber, Electronic health records (EHR), *American Journal of Health Sciences* 3 (2012) 201.
- [14] N. Menachemi, T. H. Collum, Benefits and drawbacks of electronic health record systems, *Risk management and healthcare policy* (2011) 47–55.
- [15] A. Winter, K. Takabayashi, F. Jahn, E. Kimura, R. Engelbrecht, R. Haux, M. Honda, U. H. Hübner, S. Inoue, C. D. Kohl, et al., Quality requirements for electronic health record systems, *Methods of Information in Medicine* 56 (2017) e92–e104.
- [16] Apotti, Toiminnanohjausjärjestelmä - Apotti, 2025. URL: <https://www.apotti.fi/>, (accessed Jan 31, 2025).
- [17] Apotti, Apotti hankkeen lyhyt kuvaus, 2016. URL: <https://www.apotti.fi/wp-content/uploads/2016/02/Hankekuvaus.pdf>, (accessed March 28, 2025).
- [18] Apotti, Apotti-hankkeen loppuraportti, 2023. URL: <https://www.apotti.fi/wp-content/uploads/2023/11/Apotin-hankevaiheen-loppuraportti-11.2023.pdf>, (accessed Jan 31 2025).
- [19] H. Välimäki, Tietojärjestelmien kustannuksia voidaan laskea monella tavalla, 24.9.2021. URL: <https://www.apotti.fi/tietojarjestelmien-kustannuksia-voidaan-laskea-monella-tavalla/>, (accessed Feb 1, 2025).
- [20] Tivi, Apotti-hankkeen hinta karkasi käsistä: yli 800 miljoonaa euroa, 7.11.2022. URL: <https://www.tivi.fi/uutiset/apotti-hankkeen-hinta-karkasi-kasista-yli-800-miljoonaa-euroa/df5fcbca-b3f3-41ec-92e1-4d4f0184873a>, (accessed Feb 1 2025).
- [21] Apotti, Hankkeesta yritykseksi, 2025. URL: <https://www.apotti.fi/apotti/apotti-yrityksena/apotti-hankkeen-vaiheet/>, (accessed Jan 31 2025).
- [22] Epic, Epic health system community, 2025. URL: <https://www.epic.com/community/>, (accessed Feb 1 2025).
- [23] M. Hertzum, G. Ellingsen, Å. Cajander, Implementing large-scale electronic health records: experiences from implementations of Epic in Denmark and Finland, *International journal of medical informatics* 167 (2022) 104868.
- [24] M. Kyytsönen, H. Hyppönen, S. Koponen, U.-M. Kinnunen, K. Saranto, E. Kivekäs, J. Kaipio, T. Lääveri, T. Heponiemi, T. Vehko, Tietojärjestelmät sairaanhoitajien työn tukena eri toimintaympäristöissä: kokemuksia tuotemerkeittäin, *Finnish Journal of eHealth and eWelfare* (2020).
- [25] T. Vehko, J. Ikonen, M. Kyytsönen, S. Koponen, U.-M. Kinnunen, K. Saranto, Tietojärjestelmät lähihoitajien työn tukena eri toimintaympäristöissä: kokemuksia tuotemerkeittäin 2022, *Finnish Journal of eHealth and eWelfare* 15 (2023) 199–218.
- [26] C. Lindén-Lahti, S.-M. Kivivuori, L. Lehtonen, L. Schepel, Implementing a new electronic health record system in a university hospital: the effect on reported medication errors, in: *Healthcare*, volume 10, MDPI, 2022, p. 1020.
- [27] T. G. Harwood, T. Garry, An overview of content analysis, *The marketing review* 3 (2003) 479–498.
- [28] L. Lampi, Sosiaali- ja terveystieteiden muutos – Apotti: Miten media käsitteli Apottia vuosina 2020–2022?, Master’s thesis, Helsingin yliopisto, 2023. URL: <http://hdl.handle.net/10138/359377>.
- [29] C. Huang, R. Koppel, J. D. McGreevey III, C. K. Craven, R. Schreiber, Transitions from one electronic health record to another: challenges, pitfalls, and recommendations, *Applied clinical informatics* 11 (2020) 742–754.
- [30] Apotti, Liite 32. B1 Järjestelmän vaatimusmäärittely (päädokumentti), 2015. URL: <https://www.apotti.fi/wp-content/uploads/2016/02/Liite-32.pdf>, (accessed March 12, 2025).
- [31] Apotti, Liite 39-40. B8 Ei toiminnalliset vaatimukset (Yhdistetty Käytettävyys), 2015. URL: <https://www.apotti.fi/wp-content/uploads/2016/02/Liite-39-40-1.xlsx>, (accessed March 12, 2025).

- [32] K. Sagar, A. Saha, A systematic review of software usability studies, *International Journal of Information Technology* (2017) 1–24.
- [33] J. Heiskari, M. Kauppinen, M. Runonen, T. Mannisto, Bridging the Gap Between Usability and Requirements Engineering, in: 2009 17th IEEE International Requirements Engineering Conference, 2009, pp. 303–308. doi:10.1109/RE.2009.37.
- [34] S. A. Ebad, Healthcare software design and implementation—A project failure case, *Software: Practice and Experience* 50 (2020) 1258–1276.

## Appendix: Original articles

- [35] L. Lyly and K. Vaaramo, “Apotti on epäonnistunut potilastietojärjestelmä,” *Helsingin Sanomat*, 15.12.2021. Last accessed 12 March 2025.
- [36] M. Aalto and K. Kuokkanen, “Syvä huoli Apotista,” *Helsingin sanomat*, 30.1.2020. Last accessed 12 March 2025.
- [37] I. Hallikainen, “Hidas, monimutkainen, jopa vaarallinen Apotti,” *Iltasanomat*, 21.10.2021. Last accessed 12 March 2025.
- [38] T. Peets, “Apotti on yhä painajainen,” *Lääkärilehti*, 2021. Last accessed 12 March 2025.
- [39] I. Hallikainen, “Emeritusprofessori lyttää Apotti-potilastietojärjestelmän KL:ssä:,” *Iltasanomat*, 5.10.2021. Last accessed 12 March 2025.
- [40] R. Hankonen, “Apotti tuli taloon – tehyläiset kertovat, mitä mieltä he ovat uudesta massiivisesta työvälineestään,” *Tehy-lehti*, 5.5.2023. Last accessed 12 March 2025.
- [41] A. Lahjajarvi, “”Apotti on pääosin epäintuitiivinen” – potilastietojärjestelmässä on potentiaalia, vaikka se koetaan hankalaksi käyttää,” *Tivi*, 14.01.2021. Last accessed 12 March 2025.
- [42] V. Ekholm, “Myrskyn silmässä,” *Lääkärilehti*, 9.12.2022. Last accessed 12 March 2025.
- [43] V.-P. Hämäläinen, “Potilas joutui hengenvaaraan väärän syöpälääkkeen takia – lääkärit kertovat Ylelle, miten Apotin erilaisia ongelmia on peitelty,” *YLE* 6.8.2022. Last accessed 12 March 2025.
- [44] J. Laakso, “Apotti aiheutti vakavia murheita – päädyttiin palaamaan entiseen järjestelmään,” *Tivi*, 09.06.2021. Last accessed 12 March 2025.
- [45] S. Savonen, “Apotti syytön potilaan kuolemaan? – Mtv: Husin johtajaylilääkärin mukaan ”tapaukseen liittyy paljon muitakin tekijöitä”, *Tivi*, 04.02.2020. Last accessed 12 March 2025.
- [46] R. Lehtokari and V. Marttinen, “Yli 200 lääkäriä tekee surullisenkuuluisasta potilastietojärjestelmä Apotista kantelun – sen mukaan järjestelmä vaarantaa potilasturvallisuuden,” *YLE* 26.07.2022. Last accessed 12 March 2025.
- [47] V. Helpinen, “Potilastietojärjestelmä Apotti toimii taas – järjestelmä kaatui aamulla HUSissa,” *YLE* 5.5.2022. Last accessed 12 March 2025.
- [48] V. Marttinen, “Kalkkitabletti vaihtui psykykenlääkkeeksi: Viidelle potilaalle väärää lääkettä Apotti-järjestelmään liittyneen virheen vuoksi,” *YLE* 23.8.2022. Last accessed 12 March 2025.