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Designing a digital service for cervical screening participants

Visualizing cervical cancer registry data

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Master thesis in informatics

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Abstract. Screening programs for cervical cancer are performed to diagnose the early stage of cancer and prevent its development. Historically, the screening test was taken every three years, but it gradually varied due to continuous changes in technology, guidelines, and a new type of test. These changes made the screening participants uncertain and worried about understanding and interpreting the meaning of various test results and frequent follow-ups. These test results are manual and time-consuming to date. The participants seek it as digital, allowing easy and fast access to information. The primary research challenge of the proposed study is to present simple and complex test history data to the participants in an easily understandable way. The proposed research helped to design an artifact (prototype) that can be utilized to develop a digital service that does not cause any uncertain worry for the participants in understanding the complex test history results. For this, the proposed thesis study used state-of-the-art visualization techniques following the guidelines of design science research.

Keywords: cervical cancer, screening program, visualization of healthcare data, design science research, and digital service.

1 Introduction

Cervical cancer is the fourth most common cancer in women, with an estimated 604,000 cases and 342,000 death cases (Sung et al., 2021). Human Papilloma Virus (HPV) is the leading cause of this disease (Cogliano et al., 2005). It consists of a total of 197 subtypes, of which most are harmless, and some of them are high-risk. Type 16 and 18 are found at high-risk, and around seventy percent of women are found to have cervical cancer due to type 16 and 18 (Klonteig et al., 2023). Women having Human Immunodeficiency Virus (HIV) are most likely to develop this disease compared to women with no HIV (Dryden-Peterson et al., 2016). Both viruses spread from one person to another during sex, and it is a primary reason for cervical cancer death in the East, west, middle, and South African continents, with the highest number of 6.5 percent of women developing this disease in Eswatini (Arbyn et al., 2020). China and India contributed one-third globally, with 106,000 and 97,000 cases and 48,000 and 60,000 death cases, respectively (Arbyn et al., 2020).

A screening program for cervical cancer includes a mass examination of women participants having no symptoms. This program aims to detect the cancer stage early before it spreads and prevent precancers from developing. Historically, a screening test was taken every three years following the "one size fits all" principle (Nygård & Nygård, 2023). However, the context of screening programs has changed due to continuous changes in guidelines, recent technological advancements, and new types of tests. These emerging changes make the screening participants and primary care doctors uncertain and worried about understanding the meaning of test results and how to follow up for the next procedure.

Screening participants are often found unable to understand the exact meaning of test results as they do not receive the test results in an appropriate way. It causes uncertain worry for the participant may be due to misinterpretation or misunderstanding of the test results. For example, a participant attempts a cervical screening test, and if its result is positive, it does not mean the participant has cervical cancer. For instance, if a participant has attempted for HPV test and received her test result as positive, it may not mean she has cervical cancer because there are further multiple types of HPV that can lead to other diseases apart from cervical cancer. In contrast, the participant becomes worried about the test result. In this situation, if she tries to find the particular HPV type over the internet, there are multiple chances of misunderstanding the test type while interpreting. It may be due to an unauthentic source of information over the internet. It is all because the cancer registry routines are manual and time-consuming to date. At the same time, the participants seek digital that allows fast and authentic access to information about screening tests in an easily understandable way.

The test result also needs to be more understood by the screening participants as there are multiple test types, each having a unique code. Each test type does not result in the same way. For example, some test results as positive-negative, some as normal-abnormal, and some as detected, not detected. Some participants may need to understand these different types of test results, and some may need clarification and guidance about understanding the exact meaning of test results. So, the test result must be delivered to the participants with precise information about each medical code and term (if utilized so far in the test result) in an easily understandable way that avoids uncertain worry and any misunderstanding.

Additionally, it is tough to understand the suitable time for the next test, whether the result is positive or negative. The current system of intimating the participant about their test result could be

more efficient, providing them with precise and clear information, the number of follow-ups for the following tests, and the suitable dates. Historically, the pap smear test is taken every three years, and HPV after every five years. This time duration varies depending on one's test result severeness, but the participant remains unaware of the test date, like when to do the next test. Due to a manual cancer registry, they do not receive proper intimation of the next test.

Another research problem is that the screening participant record needs to be centralized. For example, if a participant migrates from one city to another, the primary care doctor does not find her test history due to a manual cancer registry.

To sum up all the problems like participant test results, test history, an appropriate number of follow-ups, precise information about medical terminologies, and making all the data centralized in one place. One more research challenge arises about how to present all this information to the participant in an easily understandable way. In this regard, various visualization techniques are available in the literature that helps how different types of data can be visualized with the help of multiple visualization techniques. A variety of visualization techniques are cited in the literature review chapter.

1.1 Research aim and question

This thesis study proposes how the digital service can be designed for screening participants to solve the research challenges. In this regard, it is crucial to know the current possibilities from the literature that help in developing the solution in an efficient, accessible, and understandable way. The overall aim of this thesis study is organized in a research question as follows:

- How can the digital service be designed to visualize the cancer registry data for the screening participants in an easily understandable way?

Using cancer registry data to benefit screening participants is a tremendous and active research challenge. The proposed thesis study carried out these research challenges by utilizing state-of-the-art visualization techniques and following design science research guidelines (DSR) guidelines, briefly described in the next chapter of the literature review and method chapter, respectively.

The rest of the document is structured as follows: chapter two is about the literature review. Chapter three discusses the material and method used to conduct the proposed research. Chapter four consists of a brief description of how the artifact is designed. Chapter Five demonstrates the designed artifact as a proper user context for the evaluation. Chapter six is the discussion section, which discusses and highlights the research contribution. Chapter Seven concludes the essential findings of the proposed thesis study. This structure is inspired by (Gregor & Hevner, 2013) as they shared this as a publication schema for a DSR.

2 Literature review

This section briefly overviews the literature on participant awareness of cervical screening and test types. It has literature on various kinds of data in healthcare, which helped in knowing the multiple types of healthcare data. It also includes literature on data visualization techniques that have been reviewed, which results in understanding which visualization techniques would be more suitable to design digital services for the proposed research challenges.

2.1 Participants' awareness of cervical screening and test types

Research has repeatedly found that increasing knowledge of HPV tests in women is decreasing stress and anxiety level among women (Markovic-Denic et al., 2018; Papa et al., 2009). It also increases the willingness of women to participate in the screening program. Many kinds of literature (Ciavattini et al., 2021; Szwarc et al., 2021; Verhoeven et al., 2010) have also highlighted that it remains a big problem for women to get appropriate information from the personnel and lead them to search the answers online. If a woman has positive HPV or an abnormal Pap smear test, there remains a large gap between the information a participant desired and received. Specifically, the participants need more detailed information about the explanation of test results, impact of developments, disease progression, follow-ups procedure, risk of cervical cancer, and sexual transmission of the disease. Similar findings were also found in another survey paper from France, Spain, and Portugal. Eighty percent of the women asked for more information. Specifically, its emotional impact on the participant's personal life, family life, and partner relations (Monsonego et al., 2011).

(Marlow et al., 2020) has also reported that women need various information, whether the test result is positive or negative. For example, the women with positive HPV were found to know when they got infected, why they got infected, what they need to do now with the current infection, and how to prevent future infections. On the other hand, the women with negative HPV were found to know the purpose and procedure of the test, and more specifically difference between HPV and Pap smear tests. A survey of 153 women reported that 71.4% felt confused when diagnosed with HPV and its consequences of high-risk and low-risk HPV types (Daley et al., 2010). (McBride et al., 2020) has reported that many women found confused like why they got HPV test and what does is it; many others also found who did not know that positive means good or bad. Some participants found themselves familiar with the normal result of the Pap test, but they have not known the exact meaning of the term due to a lack of knowledge about test results (Head et al., 2017).

2.2 Healthcare data

Healthcare is a vast domain that consists of a massive amount of raw data, and it is vital to understand its significant types. In this regard, (Goodfellow et al., 2018) proposed three essential types of healthcare data. First, clinical data collected by patient treatment includes Electronic Health Records (EHR) consisting of laboratory tests and radiological images. Second, sensor data collected through sensors involve time series and an ordered data sequence. Third, omics data is a collection of massive, complex, and high dimensional data, which is further divided into genomic data (array of gene expression, sequence number, and DNA data) used in bioinformatics, transcriptomic data (collection of multiple mRNA transcripts data), and proteomics data (array of proteins data that expressed in the form of tissues, cells, or organisms).

Healthcare data is rapidly increasing due to the emerging variety of laboratory tests (Mindemark & Larsson, 2011), and physicians receive thousands of tests results every week (Poon et al., 2003). The cancer registry (Kreftregisteret) has a tremendous amount of cervical cancer data in healthcare, which belongs to the first type of data is clinical data. Unfortunately, it is used manually, which may cause primary care doctors to misinterpret the test results. This tremendous amount of cancer registry data must be presented in a suitable way that would be understandable for the screening participants. In this regard, getting better insights into the current problems, information needs, and

user requirements is mandatory. Such data can be collected using one of the twelve different data collection sources described by (Goldkuhl, 2019).

Once the data is being collected, including current problems of the existing system, information needs, and user requirements. The next step is to analyze, understand, and visualize the data is the next major challenge. There exists a variety of visualization techniques to present simple or complex data. Let us have a look at its various techniques from state-of-the-art literature.

2.3 Data visualization techniques

Visualization of healthcare data is a challenging task to integrate a variety of text information and other health attributes. Various visualization techniques exist; the most widely used is the flowchart algorithm, which is referred to as clinical algorithm maps (Woolf et al., 1996). It is a standard proposed by the Committee on Standardization of Clinical Algorithms of the Society for Medical Decision Making. Gant charts and Timelines are the best method (comparatively flowchart algorithm) to represent interval data. (Plaisant et al., 1998) Proposed Lifelines, the extension of Timelines that uses horizontal bars to visualize the data elements and temporal location. They were used to visualize the patient records and personal history. (Sharma et al., 2015) have presented public healthcare data using scatter plots and line graphs (where appropriate) as data visualization techniques.

Other techniques like Paint Strips (Chittaro & Combi, 2003) were developed to visualize queries on medical databases. Temporal Objects (Combi et al., 1999) was designed to depict temporal data. Time Annotation Glyph (Kosara, 2001) and an interactive 2-D technique, the SOPO view (Messner et al., 2000), were developed to utilize for the graphical propagation of temporal data but not for making complex notions of time.

It is crucial in healthcare to visualize the data so that it becomes easily understandable for healthcare professionals and optimizes the quality of decision-making. In developed countries, busy doctors want to spend a short duration of consultancy time on their patients without compromising the quality of service (Hossain & Ahmed, 2021). They require the patient's medical history quickly through visualization without the involvement of the patient because they can give inaccurate details to the doctors due to their less knowledge and understanding about a disease. In this regard, (Hossain & Ahmed, 2021) proposed that Gant Chart is the best way to visualize a patient's medical history, as shown in **Figure 1**. They have established a patient's age and year-wise history for each test in any age duration. One can easily read this Gant chart and understand when a specific test was taken.

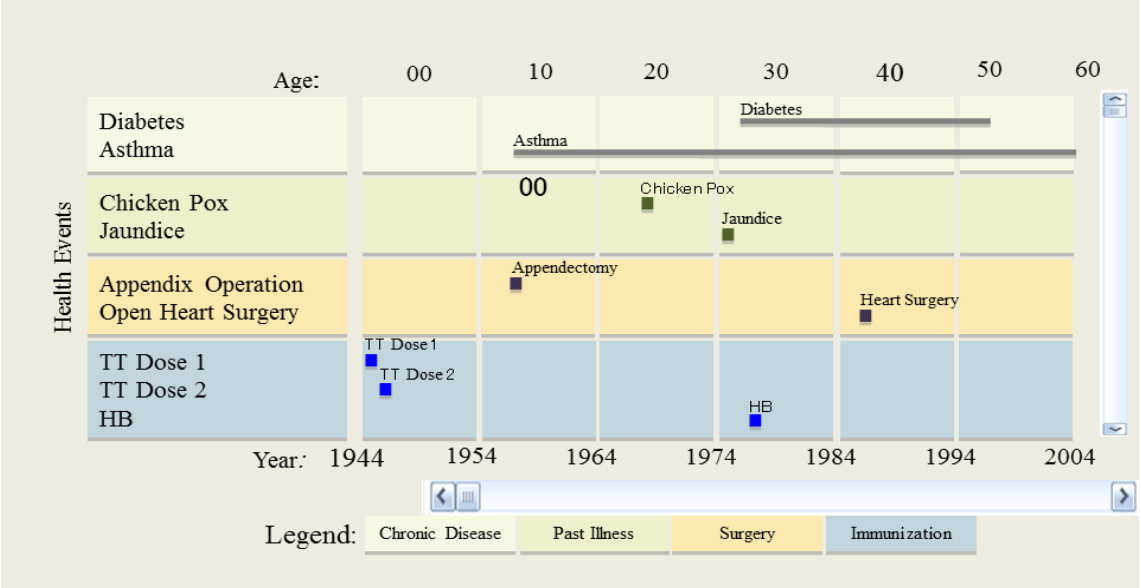

Figure 1. Visualizing health data on a Gant chart (Hossain & Ahmed, 2021).

Various literature exists to visualize medical data (Mayer et al., 2001; Powsner & Tufte, 1994). Additionally, visualization in a medical context is not specific that one technique fits all situations. (Torsvik et al., 2013) I have also proposed a research study to compare four different visualization techniques, including one table and three-line graphs. They concluded that simple laboratory test results could be visualized through a table, whereas line graphs are utilized to visualize more complex and multiple laboratory test results.

The data in the proposed study that is taken from the cancer registry (Krefteregisteret) is a type of clinical data (EHR). The proposed thesis study involves both tabular and graphical visualization to visualize the cancer registry data.

3 Method

This section provides a complete overview of the activities employed so far in the proposed thesis study. It involves a brief overview of each exercise, such as research design and settings, literature overview method, data collection sources, and ethical considerations towards collected data. A short description of each activity is shown in **Table 1**.

Sr. No.	Activities	Description	Purpose
1	Research design and settings	It involves how the research has been designed by applying DSR. It also involves who owned the project and how I am interested in the project.	To let the reader, know which DSR design method has been used for the proposed study. It also allowed the reader to see the project's description, scope, and worth.

2	Literature overview method	It describes how the literature has been collected from different databases.	It helped review the tools and techniques that helped carry out the proposed thesis study.
3	Data collection sources	It includes how the data was collected from three major sources: document study, cancer registry (Kreftregisteret), and prototype evaluation.	It helped in collecting data that contributed to answering the research question.
4	Ethical considerations	It involves the description to make sure the ethical perspectives are employed so far in the study.	It helped to encourage the participants to participate in the workshop by ensuring that their data would be kept secure by applying ethical principles.

Table 1. The activities involved in the method chapter.

3.1 Research design and settings

This section briefly covers how the research is designed by applying DSR paradigms. It also includes an overview of the research settings, who owned this research project, and how I am involved in this project.

3.1.1 Research design

The proposed study follows the three-cycle view of DSR, inspired by (Hevner, 2007). Its three-cycle picture is shown in Appendix – A. First is the 'Relevance Cycle' initiate DSR, which does not take only the requirement as input but also defines the acceptance criteria to evaluate the research results. The proposed study has collected the requirements from various sources, as mentioned in the data collection section of the same chapter. It also defined the acceptance criteria by defining three goals that will help evaluate the research results. These goals are also described in the data collection section in **Table *4***.

Second is the 'Design Cycle,' which is the heart of the DSR project. Research activities in this cycle iterate rapidly between building an artifact, its evaluation, and subsequent feedback to refine the design artifact further. (Simon, 1996) also described this cycle as generating design alternatives and evaluating them against the requirements until a satisfactory design is achieved. The requirements from the relevance cycle are input for the design cycle.
In contrast, design and evaluation theories are drawn from the rigor cycle. It is essential to understand the dependencies of this cycle with the other two cycles. The proposed study's design cycle involves designing and evaluating an artifact (prototype) that answers the research question. Various visualization techniques are used to prepare the artifact, and a combined approach consisting of 'IT-system in use' and 'goal-based evaluation' strategies is used to evaluate the artifact, inspired by (Cronholm & Goldkuhl 2003). A brief description of how the artifact was designed and evaluation performed is shown in the "artifact description" and "evaluation" chapters, respectively.

Third is the ‘Rigor cycle’ that provides past knowledge of scientific theories and engineering methods to the research project. The proposed study tried to find the relevant literature to inform the design of the proposed research. In this regard, a variety of visualization techniques are explored from the knowledge base to design the artifact.

A brief overview of how the data collection has been performed, the artifact is designed, and the evaluation of the artifact conducted is briefly shown in **Figure 2**.

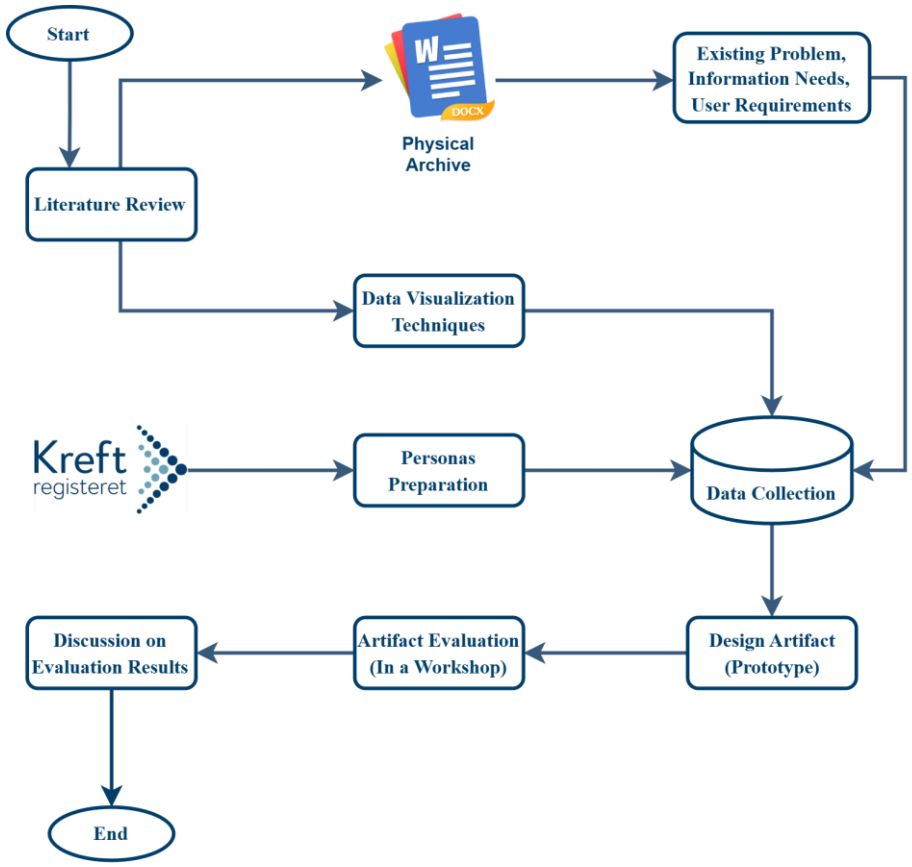

Figure 2. A flowchart of the proposed methodology.

3.1.2 Research settings

SINTEF (a research institute in Norway) has owned this project named “VisMeg." It was initiated in 2021 by the cancer registry (Kreftregisteret) in Norway. The project involves identifying problems and understanding information needs and user requirements. It also requires a digital service against the problem, needs, and user requirements. I become part of this project after the formal interviews and meetings process. I have shown them my previous work that I have done each semester. After an in-depth assessment, they finally hired me as a master's student in their project. Participating in this project provided a practical and professional learning environment to enhance my skills and led me to complete my master’s thesis study.

3.2 Literature overview method

This section involves how the literature has been searched from online databases by combining keywords. It also includes the literature selection criteria of how and which type of research articles are chosen.

3.2.1 Literature search strategy

The literature has been searched from two databases named Scopus and PubMed. Scopus is one of the most famous databases and includes research articles from almost all domains. The 'screening program,' 'cervical cancer,' 'medical data,' and 'visualization' keywords are used to search the relevant articles using 'AND' as a search operator between them. I got a total of 324 research articles, and the count of searched articles against each combination of keywords is shown in **Table *2***. Apart from online databases, an article (on workshop procedure and findings) was also taken through a physical archive from the project team at SINTEF.

Keywords	Scopus	PubMed	Total
"Screening program" AND "Visualization"	34	15	49
"Cervical Cancer" AND "Visualization"	74	92	166
"Medical data" AND "Visualization"	145	64	109
Total	253	171	324

Table 2. Literature identification for the proposed thesis study from two online databases.

3.2.2 Literature selection criteria

Literature selection is strictly restricted to literature and data collection for the proposed thesis study, which is purely based on visualizing the complex cervical cancer registry data to the public. The data must be presented in a way that should not raise uncertain worry and be understandable for both the screening participants and healthcare professionals. In this regard, the literature has been selected based on the following criteria:

- Articles are written in English language only.
- Articles with empirical evidence and related to computer science.
- Articles are purely related to visualizing medical data, cervical cancer, and screening program.
- Articles that followed the guidelines of DSR and visualization techniques.

3.3 Data collection

It represents the way that how researchers collect data from empirical domains (Bryman, 2012). However, it can also refer as data generation (Stenbacka, 2001). It involves activities such as selecting, capturing, extracting, and noting data. It defines and visualizes through standard data collection methods such as questionnaire study, interviewing, observation study, document study, artifact study, intervention study, participant observation, test study, lab-based design study, practice-based design study, self-reporting, and focus group study (Goldkuhl, 2019). The proposed thesis study collected data from a literature review, cancer registry (Krefregisteret), and prototype evaluation. A brief description and analysis of data collection are shown in **Table 3**.

Sr. No.	Data	Data collection source	Description	Analysis
1	Document data	Produced by SINTEF	The document consisted of two workshops with 17 female participants. It also consists of applying rapid analysis of participants' feedback.	Interpretation of the document and articulation of information needs, user requirements, and current problems from a patient perspective.
2	Patient history data	Cancer registry (Kreftregisteret) via SINTEF	Actual patient data in Excel sheets consisting of multiple patients record with different test types and test results.	Selection of two patients to create two different de-identified personas: one with a simple test history and one with a more complex test history.
3	Prototype evaluation data	A physically conducted workshop with six participants. Initially, all were elaborated on the problem. Demonstrations of prototypes were provided to each participant. They answer the questions individually in a Google form.	Each participant provided their feedback, perceptions, and preferences about three different types of visualization screens for simple and complex personas.	Empirically assess the design prototype. • Goal-based evaluation • Articulate: What are the goals of the prototype? Compared to the information needs, user requirements, and problems identified in #1 above.
4	Prototype evaluation data	Three online Zoom sessions were conducted with one person at a time. The same structure is employed to collect the responses as in #3 above.	Same as in #3 above.	Empirically assess the design prototype. See #3 above.
5	Prototype evaluation data	Workshop with team cancer registry (Kreftregisteret). Their perceptions and responses were saved in a recording.	Same as in #3 above.	Empirically assess the design prototype. See #3 above.

Table 3. Overview of data collection from various sources along with analysis.

3.3.1 Data collection from the document

Documents present a variety of data sources to conduct qualitative research (Bryman, 2012; Hodder, 1994). It plays a vital role in developing and pertaining IS artifacts that produce various design documents such as information models, goal models, process models, use-case models, database

models, architecture models, and interaction models. The IS researchers may also find admirable interest in other documents such as policy documents, legislative documents, evaluation reports, contracts, meeting minutes, email correspondence, or manuals. The researchers can search the documents through a physical archive or via an internet source to generate data from the documents. **Figure 3** shows the data generation process from the documents presented (Goldkuhl, 2019).

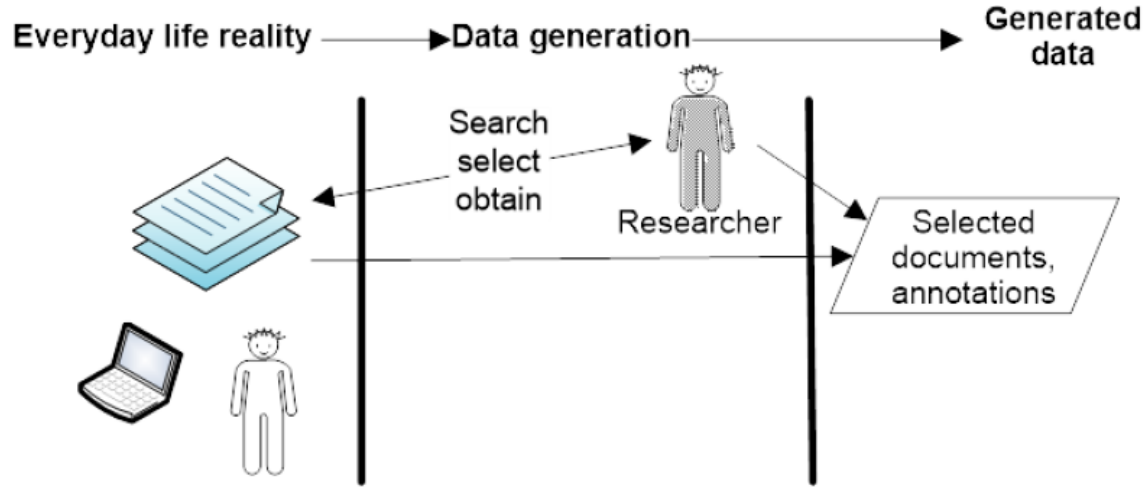

Figure 3. The process of generating data from a document study (Goldkuhl, 2019).

The proposed thesis study collected data by reviewing the document presented by (Klonteig et al., 2023) and is searched through a physical archive via team SINTEF. They conducted two co-design workshops of two hours with seventeen participants divided into two groups, each with one facilitator. The workshop started with signing consent forms for each participant and giving blank papers (as templates emulating a mobile screen) to draw sketches for a superficial persona. They were instructed to visualize the solution for the given personas. Each facilitator presented the findings of one group to the other to mutually share the design ideas. The process was repeated using another more complex persona than the previous one. The sketches designed by the participants helped reveal their problems with the existing system and identify information needs and user requirements.

Problems in the existing system

First, no centralized digital platform is available (currently) where the participants can access their test histories. They need to inform them when they will receive the test result. For instance, if they receive the test results, that can be via a text message, call, or email, which may lead the participants to an uncertain worry about understanding the exact meaning of the test result.

Most of the participants were found familiar with the screening test, whereas some were not familiar. Unfortunately, most participants could not understand the exact meaning of the type and result of several screening tests even though they still needed an appropriate and suitable explanation of the test results from Google.

Some participants also needed help understanding an appropriate number of follow-ups for the next test date. It took three years for everyone to follow the 'one fits all' strategy. The reminders were also introduced to remind the participants of the next test date, but one said what if I do not receive a reminder. Then how is it a technical mistake or not the appropriate time for the next date?

Information needs
First, the participants required information about different types of tests, like when and why a particular test would be taken to prevent the risk of developing precancer. They were also still determining the exact meaning of positive or negative test results if they had not educated themselves.

Second, the participants required knowledge about medical codes and terms (utilized in the test results) with proper explanations. Participants suggested using non-medical terms on the test reports whenever possible. For instance, one suggested using "cell test" rather than "cytology". On the other hand, some participants still recommended using medical terms but with extra information in a deeper layer. A similar scenario holds in case of positive or negative test results as detected or not detected. The medical terms should be used in such a way that must be understandable for the participants.

Third, the participants also required decision support for the next test date and an appropriate number of follow-ups in case of both normal and abnormal results. They also want to know why a test has been taken and when the next test will be conducted. Further, they are required to know the proper explanation of why to wait for one, two, three, or more years for the next test.

User requirements
The participants generally required some architectural information about the digital service, and the first page must be clear and understandable. It requires how the additional information, like notes and hyperlinks, should be in the application. Further, it involves visualization of test history in a clear and easily understandable way. It also requires the transfer history of tests to other countries.

The current problems, information needs, and user requirements helped prepare this thesis study's goals. Each goal concerning current problems, information needs, and user requirements is shown in **Table 4**.

	Goals	Sub-goals
Current problems	Evaluate whether the solution to existing problems is fulfilled or not.	• No centralized digital platform. • Communication of test results and test history. • Understanding of test results and test history.
Information needs	Evaluate whether the information needs of the participants are fulfilled or not.	• Medical codes and terms. • General information about test types and the meaning of test results. • Decision support for the next test date and several follow-ups.
User-requirements	Evaluate whether the information needs of the participants were fulfilled or not.	• Architectural information (the first page should be clear and easy to understand). • Additional information like notes and hyperlinks. • Communication preferences (notification about the test result, time to the next test, and wording while conveying the results). • Visualization of the test result. • Visualization of test history.

		• Transfer history of tests in other countries.

Table 4. Goals and sub-goals of the proposed thesis study.

3.3.2 Data collection from cancer registry (Kreftregisteret)

Data is also collected from the cancer registry (Kreftregisteret). They provided a small set of systematic actual patient data as a sample in an Excel sheet. The data was received in three Excel sheets, each containing different types of tests, including Human Papilloma Virus (HPV), Cytology (Cyt), and Histology (Hist). Initially, I needed help understanding a wide variety of test code results and terminologies in each type of test. I manually explored the data deeply, each test type, associated terms, and cervix cell change grades (like normal, mild cell changes, moderate, severe, and invasive cancer). I take help from the cancer registry website and other online sources to understand each term clearly. After understanding and analysing various tests and terminologies, I prepared two personas representing two types of participants. Having simple test history involves a test with normal test results. Second, having complex test history involves multiple tests with different test results. The purpose of selecting two types of personas is to check to which extent the visualization of simple and complex test histories will look and provide the screening participants with an understanding of the data. The detail of both personas is as follows:

Persona – I
This persona has a simple test history as a participant; she began taking tests when she was 28. She took tests quite frequently, sometimes twice a year, sometimes once a year; the most prolonged interval was five years. All her test results were normal. The details of each test result are shown in Appendix – B.

Persona – II
This persona has a highly complex test history. The persona started taking cytology tests at 36, then one two years later, and four years later. In 2006, persona probably had some symptoms, so she took three histology tests, all indicating a high degree of cell changes. One year later, she took a cytology test, which showed that she had mid-cell changes. Half a year later, she did another cytology test with the same result. She took one more half year later, which was the same result. At the same time, she also did 2 HPV tests; while one showed negative, another revealed that she had the HPV virus without indicating which type. Four months later, she did a histology test, and it showed that she had a high degree of cell changes. Three months later, she did 2 HPV tests and two histology tests. This time, the HPV tests showed contradictory results again. One of the histology test results showed a high degree of cell changes, while another one was invalid.

Half a year later, in 2007, she did a cytology test, and the result showed that there was still the likelihood that she had a high degree of cell changes. She did 2 HPV tests, again, with contradictory results. Later that year, she took two histology tests; one showed that she had a medium degree of cell changes, and another revealed a high degree of cell changes. She did a cytology test two years later, and the result was normal. One year later, she did two cytology tests; one showed that the high degree of cell changes cannot be ruled out. Another one showed a low degree of cell changes. One year later, she did an HPV test, and it showed that she had HPV virus type 16. So, she did a cytology test at the same time, and it showed a low degree of cell changes. Four years later, she did a cytology test with the same result; half a year later, she repeated the same test, and the result remained the same. The detail of each test result is shown in Appendix – C. The information needs, user

requirements, and the two personas (Persona – I and Persona – II) were utilized to design the prototype of the digital service for the screening participants and are shown in next chapter – 4.

3.4 Ethical considerations

The proposed thesis study involves some ethical considerations related to the data collected from the participants. It consists of the participants' feedback on the prototype's evaluation. The participants also signed a consent form to ensure that the privacy rules and policies would not be violated. The proposed thesis study followed the four ethical principles offered by (Myers & Venable, 2014).

Privacy: One of the most critical points is to deal with sensitive data collected during the workshop. It should be used with utmost responsibility at all design science process stages to avoid discrimination. The information will also be kept secure and used only for designing a digital service.

Accuracy: The personal data, information, and feedback collected from the participants during the workshop are accurate.

Property: The data will be used for designing a digital service for the screening participants to help them see their test results, test history, follow-ups, and new test dates. SINTEF owns the project in collaboration with the cancer registry (Kreftregisteret). So, both will hold all the data.

Access: Belongs to the project team at SINTEF and the cancer registry. All other persons who did not participate in the process should not be able to access any information or data if the participants do not give permission.

4 Artifact description

This section provides an overview of the artifact description, including what the artifact is and how it is designed. The artifact consists of a prototype following various visualization techniques and two personas designed in section 3.3.2.

DSR help design the solution as an artifact that could be a construct, model, instantiation, or method (Peffers et al., 2007). The proposed thesis study involves designing an artifact using the data collected in Chapter – 3, the appropriate visual designing platform, and data visualization techniques. The visuals can be in the form of a (clickable) high-fidelity prototype of the digital service. The digital service prototype was designed using Figma as an online prototyping tool. The prototype is designed to visualize the test results and test history by focusing on the existing problems, information needs, user requirements, and personas. The screenshots of the prototype are shown in **Figure 4**, **Figure *5***, **Figure 6.**

Figure 4 shows three types of test result visualization: the tabular visualization of the test results, the more straightforward (simpler) visualization without using any table to present the test result, and the graphical presentation of the test result. Each visualization includes information about the latest test result as 'detected' or 'not detected' along with its type and date. Further, it provides links to a detailed view of the test result, follow-up, and download the result. The detailed view shows

some extra information about the detailed description of the test code and its brief and understandable meanings. The third form of visualization includes the test result severity grades that show where a participant's test result is either invalid, low grade, high grade, or severe. The invalid result means the sample needs to be more suitable for the assessment. In the rest cases, the sample remains ideal for the test and is found either as normal, borderline, mild cell change, moderate or severe. Normal and borderline come under low grade, whereas mild cell change, moderate, and severe come under high grade.

Figure 4. The prototype shows three types of test result visualization.

Figure 5 shows three types of test history visualization for persona – I: first tabular, second line graph, and third a bar graph. Tabular visualization shows the past test history in the most accessible clinical record format, including test date, type, participant age, and result as 'detected' or 'not detected.' It includes links to a detailed view of the follow-ups against each test. It also provides a link to download a test result. Line graph visualization shows the test history on a line where the x-axis represents the participant's age, and the y-axis represents the year in which a test is conducted. The graph shows different shapes for three types of tests. The rectangle shape is used for the HPV test, the Cyt circle, and the His star. Three different colors for each test type are also used: green for 'not detected,' red for 'detected,' and yellow for 'invalid'. Bar graph visualization showing the year-wise test history on a bar. The same shapes and colors are used for the bar and line graphs.

Figure 6 shows the test history visualization for persona – II with similar visualization techniques used for persona – I. Even shapes and color combinations are also identical. The purpose is to evaluate the visualization screens from the users to understand which type of visualization is easier to understand in the case of both personas.

Figure 5. The prototype shows three types of test history visualization for persona – I.

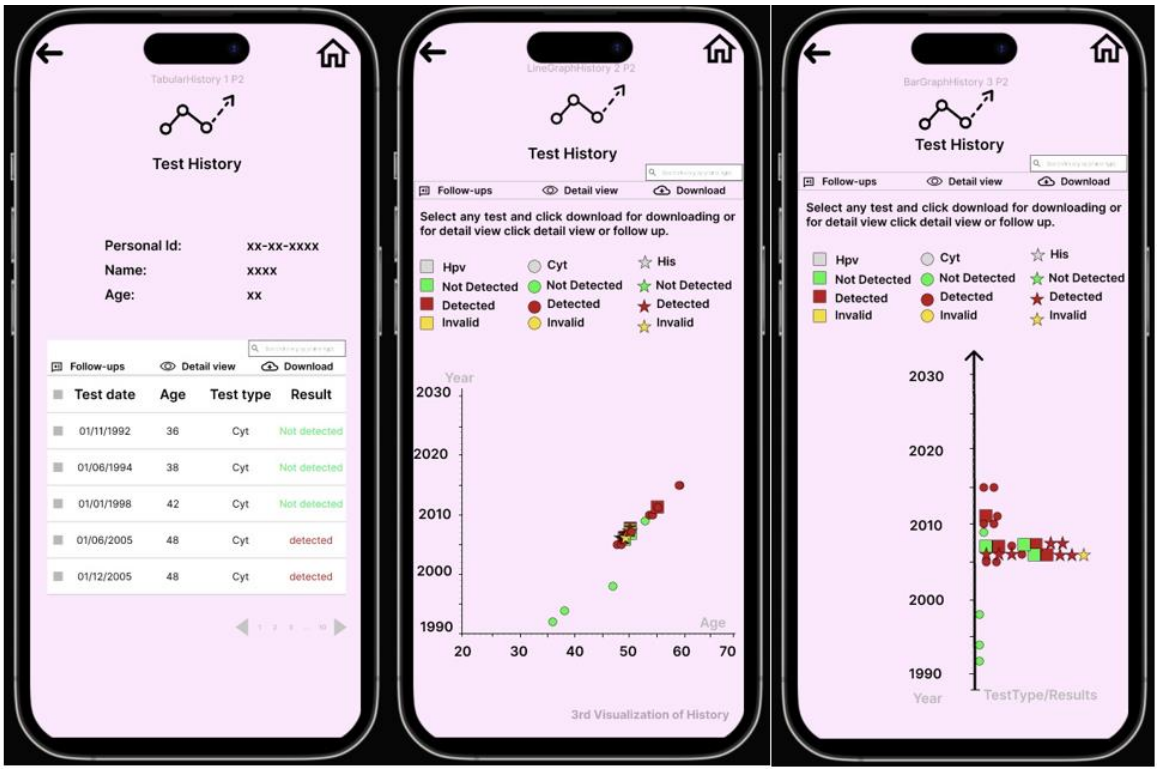

Figure 6. The prototype shows three types of test history visualization for persona – II.

Some more screens are designed to fulfill other subgoals of the three primary goals. The above screens answer the significant research challenges, and the rest answer the minor research challenges (see Appendix – D, E, and F). Appendix – D represents three screens' data: 1) login screen that asks the user to enter the Bank ID to log in to the cervical cancer screening environment. 2) main screen that shows a welcome text about the cervical screening program. 3) profile screen that shows the participant's profile, including personal information. Appendix – E represents three screen's data: 1) Dashboard that shows the main functionality page of the application, which involves a separate link to show the test results, test history, follow-ups, next test date, book new test date, and time, my profile, and information about the meaning of various types of test codes. 2) The upcoming test date shows the information about the next test date to the participants. 3) book a new test date and time; it allows the participants to book their upcoming test date and time-based on their relaxed date and time that suits them. Appendix – F also represents three screens, 1) test code information, which helps the participant see the meaning of several test types. 2) test code info database, which shows sample information about a test code from the cancer registry (Kreftregisteret) database. 3) follow-ups allow the participants to see the follow-up procedure for the next tests.

Once the prototype is designed, the next activity is to demonstrate them in a user-suitable context to get their feedback on various visualization techniques.

5 Evaluation

This section involves an overview of the evaluation strategies that show the different strategies and which approach will be suitable for the proposed study. It also includes an overview of how the artifact is demonstrated in user suitable context. Further, it involves a discussion of the results obtained after the evaluation.

5.1 Evaluation strategies

This section involves a brief overview of how the designed artifact has been evaluated. It is evaluated by applying one of the most suitable IS evaluation techniques depending on the evaluation context, inspired by (Cronholm & Goldkuhl, 2003). They proposed an article to evaluate six different types of evaluation techniques in IS. They stated how one can decide to perform an evaluation based on its context. To do this, first, it is mandatory to understand the strategies that come under two important questions wherever performing an assessment: "What to evaluate" and the second is "How to evaluate."

5.1.1 Strategies that answer what to evaluate

(Cronholm & Goldkuhl, 2003) Distinguished between two strategies that answer what to evaluate. First is 'IT-system as such,' and second is 'IT-system in use.' The first strategy does not require any user involvement during the evaluation. It only requires the IT system and possibly the documentation as a data source and evaluator who evaluates the IT system. The possible data source for an evaluator under the first strategy is also shown in **Figure 7**.

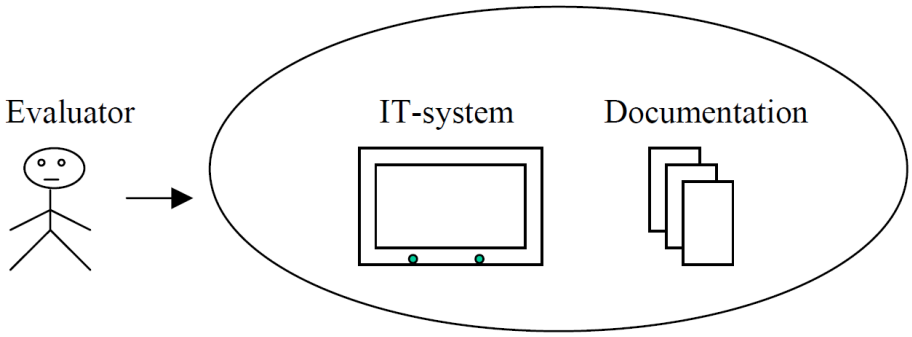

Figure 7. Possible data sources in IT systems are as such (Cronholm & Goldkuhl, 2003).

The second strategy must involve user interaction with the IT system. It also requires observation of interaction and documentation. If there are fewer data sources, the evaluator can pick those few sources for the evaluation, but user involvement is mandatory in this strategy. The data source under the second strategy is shown in **Figure 8**. One significant difference between both strategies is that the second strategy has more data in hand.

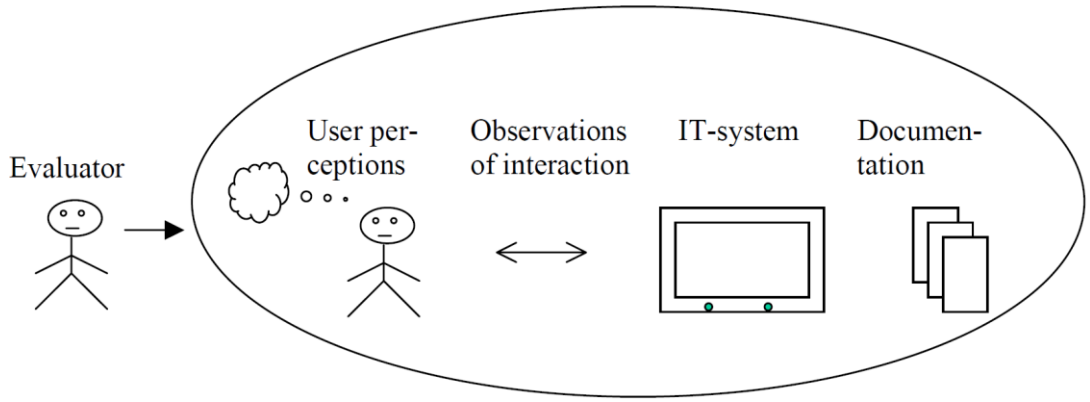

Figure 8. A possible data source in the IT system is used (Cronholm & Goldkuhl, 2003).

5.1.2 Strategies that answer how to evaluate

(Cronholm & Goldkuhl, 2003) Distinguished between three strategies: first is the goal-based evaluation that requires explicit goals from the organizational context that drive the evaluation. It is also defined as measuring the extent to which a program has achieved clear objectives (Pr et al., 1990). Second, goal-free evaluation is a more imperative approach (Powell & Walsham, 1993; Remenyi & Sherwood-Smith, 1999). It does not require such explicit goals. It is an inductive and situation-driven strategy. Third is a criteria-based evaluation that involves clear criteria (such as heuristics, checklists, or principles) used as a yardstick. For instance, (Nielsen, 1995; Nielsen & Molich, 1990) Nielson's heuristic evaluation principles are very famous for criteria-based evaluation.

5.1.3 Evaluation strategies used in the proposed thesis study

The proposed thesis study includes a prototype as an IT system, an Excel sheet as a document, and user interaction with the prototype. In this regard, the 'IT system in use' strategy allows user involvement. On the other hand, it has its own specified goals to evaluate the solution against the

current problems, information needs, user requirements, and comparison of various visualization techniques. In this regard, a goal-based evaluation strategy would be better to use.

The proposed thesis study used the combination of both 'IT-system in use' and 'goal-based evaluation' strategies for the evaluation. It is a deductive approach (Cronholm & Goldkuhl, 2003) in which the evaluator wants to decide whether the goals have been fulfilled. It's also a qualitative process that evaluates if the goals of the proposed thesis study were fulfilled. In other words, the qualitative process describes how the goals are fulfilled and up to what extent due to which the approach is known as deductive.

5.2 Evaluation process

It could involve using the designed artifact in the user's suitable context to solve one or more instances of the problem (Peffers et al., 2007). Its use could involve simulations, experimentation, proof, case study, or any other activity (Peffers et al., 2007). It requires resources and includes knowledge about using the designed artifact to solve the problem. The proposed thesis study conducts a workshop to demonstrate the prototype to the participants. It consisted of nine female participants; brief information about participants and workshop context is shown in **Table 5**.
I contacted a company that arranged a meeting setup (with six female participants) to demonstrate the prototype with them. These participants are working in different occupations. Apart from these six participants, I contacted three international female participants and arranged an online Zoom meeting to demonstrate the prototype and get their feedback on the various types of visualization of test results and test histories. I also presented this prototype to the stakeholders from the cancer registry (Kreftregisteret) by calling a meeting via SINTEF. The meeting was recorded from start to end to receive their feedback, perception, and preferences.

Participant Id	Sex	Age	Occupation Status	Context	Workshop duration
P1	Female	26	Air hostess	Physical workshop	2 hours 40 mins
P2	Female	27	Air hostess		
P3	Female	29	Teacher		
P4	Female	28	Air hostess		
P5	Female	31	Waitress		
P6	Female	29	Shop assistant		
P7	Female	28	Pharmacist	Online (Zoom) meeting	1 hour 10 mins
P8	Female	38	Housewife	Online (Zoom) meeting	1 hour 20 mins
P9	Female	39	Govt. Servant	Online (Zoom) meeting	1 hour 0 mins
P10	Male	Around 45	Employed at cancer registry (Kreftregisteret)	Physical meeting at SINTEF	40 mins
P11	Female	Around 45			
P12	Female	Around 30			

Table 5. Information about participant's workshop context.

Workshop procedure: The workshop procedure was divided into three phases; the first corresponded to the preparation of workshop material, the second was about the runtime support during the workshop, and the third was about the participant's remarks after the workshop.

- **Workshop/meeting preparation** – I design a Google form (see Appendix – G) for the participant to fill out to share their feedback, perception, and preferences after evaluating the prototype. This form includes general questions regarding their age, previous experience with cervical cancer, and feedback (by answering the questions designed against each goal) on various visualization methods of the test results and history. A link for the prototype (made on Figma) was also prepared to share with each participant. The prototype was presented to the participants on a 52 inches large screen by connecting it to the laptop. The same Google form and Figma prototype link were used to get the feedback, perception, and preferences of the participants who participated online through the Zoom meeting. In the case of engagement with the cancer registry team, only the prototype was presented to them. Their feedback, perception, and preferences were recorded during the meeting with their proper consent. A sample text of their recorded data is shown in Appendix – H.
- **Support during the workshop/meeting** – In the first 60 mins, each participant of the workshop was informed about the project along with its purpose, the existing problems with the system, the purpose of the workshop, two personas along with issues, terms, and three types of visualization utilized so far in the prototype. They were also presented with the purpose of why three types of visualization screens are used for the test result and test history. The exact scope was intimated to the participant who joined online through a Zoom meeting. In the case of the cancer registry team, they were not presented with the problem and personas as they already knew about it.
- **Remarks after the workshop/meeting** – The participants were excited to see its launch in the market sooner. So that it could save the lives of many women and it would help them for their better health. The cancer registry team also admired the work and suggested further improving the design.

5.3 Evaluation results

This section shows evaluation results against each goal of the proposed thesis study. It includes a brief explanation of the fulfillment of goals against each problem, information need, and user requirement. Three primary goals were identified in the method chapter and are as follows:

- Evaluate whether the solution to current problems is fulfilled or not.
- Evaluate whether the information needs of participants were fulfilled or not.
- Evaluate whether the user requirements are fulfilled or not.

5.3.1 Evaluate whether the solution to current problems is fulfilled or not.

This goal evaluates whether the design artifact is fulfilling the current problems. **Table 6** represents the current problems, participants' feedback, and an explanation of how the designed artifact fulfills each current problem.

Sr. No.	Current problems	Feedbacks	Explanation
1	No centralized digital platform.	“It would be better to have the digital service solution at Helsenorge.no website. So that all the data be available in one place apart from using multiple applications.” – (P8). “We need this application at the market asap, and it will save many women's lives. Thank you for sharing this with me and putting your knowledge and passion into this topic.” – (P5). “Separate phone application is better so I can see the results anytime on my phone. I prefer to use a separate app.” – (P4).	The designed artifact fulfills the goal of providing a centralized digital platform that makes the data available in one place. Participants preferred that the solution be embedded in a separate digital application or at the national health website (helsenorge.no).
2	Communication of test results and test history.	"I attempted the cervical cancer test, and they said they would call if they found anything, so they never me called about any result. I would recommend having this application so that I can see my test results independently.” – (P1). “When I attempt my cervical cancer test. It said that I had some abnormalities and that I needed to do another test, and that they had booked it for me. When I got to my second test, it was way more things that they had to do than I was aware of. And I had not gotten any info about it at all. They had to cut out more and bigger pieces of me, and I would bleed for 2-3 days. It was scary and sudden. I never really received my results but was told to continue doing my tests every year. Which I haven't done because of this experience.” – (P4).	The designed artifact would communicate the test results and history to the participants. It fulfills the current problems that participants sometimes do not get any response from the primary care doctors, and some other problems, such as those reported by P4, are also fulfilling to communicate the information about test procedures, test results, and follow-up motivations in a detailed view.
3	Understanding of test results and test history.	“I received my results by phone in my mail. But it was not very informative. Suppose this application comes into the market. It would help me get clearer information about our test results." – (P5).	The designed artifact also fulfills the problem of understanding test results and history, as the participants' feedback is illustrated.

Table 6. Evaluation of current problems, participant’s feedback, and explanation.

5.3.2 Evaluate whether the information needs to be fulfilled or not.

This goal is to evaluate whether the design artifact is fulfilling the information needs. **Table 7** represents the information needs, participants' feedback, and an explanation of how the designed artifact fulfills each information need.

Sr. No.	Information needs	Feedbacks	Explanation
1	Medical codes and terms	“I really like the part where you elaborated each test code and type in an easy way without searching it over Google or any other online sources.” – (P1). “Overall, it was easily understandable. The information about test codes and types is clear and easy to understand.” – (P8). “You did the best in that you added all the necessary information in the application. It is good that there is no need for the participants to search anything from any unauthentic source." – (P10).	The proposed artifact fulfilled the information needs about the medical codes and terms as participants one and ten responded. Other participants also found satisfied with the medical types and terminologies.
2	General information about test types and the meaning of test results.	“It gives easy access to all information you need and even personal information and test results with information and description of each test in detailed” – (P6). “I really like the symbols and color codes you used to differentiate each type of test. It makes it easy for the participants to differentiate the type of each test result and the meaning of test results” – (P11). “Loved the colors of the results. Loved the pink background.” – (P3).	The designed artifact also fulfilling the general information of the test type and meaning of test results in an easily understandable way, as participants stated.
3	Decision support for the next date and number of follow-ups	“It’s great and understanding, good to have the new test date repeated on the screen so it follows you on each side” – (P6). “Tabular is very good to get to see the date for the new test date everywhere, so you get reminded of the testing date” – (P1). “Graphical one is the type of the most convenient result. All can be easily seen from normal to complex data and follow-up time.” – (P8).	From the participants' feedback, the designed artifact fulfills the information needed for decision support for the next test date and follow-ups.

Table 7. Evaluation of information needs, participant’s feedback, and explanation.

5.3.3 Evaluate whether the user requirements are fulfilled or not.

This goal is defined to evaluate whether the design artifact is fulfilling the user requirements. **Table 8** represents the user requirements, participant feedback, and an explanation of how the designed artifact fulfills each user-provider provision.

Sr. No.	User-requirements	Feedbacks	Explanation
1	Architectural information (the first page should be clear and easy to understand)	“Good looking and informative. I liked the color coding of the results!” – (P3). “It’s more user-friendly. More visible and simple to understand” – (P9).	The participant responses are clearly showing that the screens look user-friendly, more visible, informative, and simple to understand. So, it is fulfilling architectural information requirements.
2	Additional information like notes and hyperlinks	“I like the browsing feature of tabular view; it feels easier to navigate” – (P1). “The best one. Informative and easy to navigate. I liked the white background of the table! And the hyperlinks to the right. Loved the hyperlinks” – (P3) “I find it easy to understand and easy to navigate, even with the more complicated person.” – (P4).	The user requirements about the notes and hyperlinks are also fulfilling as the participant feedback shows that it feels easy to navigate, loved the hyperlinks, and found it easy to understand.
3	Communication preferences (notification about the test result, time to the next test, and wording while conveying the test results)	“Easy to understand, nothing complicated.” – (P2). "Most of the information is understandable, and the wording is also nice. There is no word found that hurt. Even abnormal test results are also shown in a graphical view, which shows at which stage you are right now. This is a nice way of communicating test results to the participant" – (P7).	The user requirement about communicational preferences is also fulfilling as participants' feedback is nothing complicated, most of the information is understandable, and the wording is lovely and communicated in a friendly way that does not hurt the participants.
4	Visualization of test results	“The tabular visualization is the most understandable because it’s a straightforward diagram with everything you are looking for.” – (P5). “I like the graphical screen because it’s easier to understand for everyone and has great access to everything.” – (P6). “Tabular can get results immediately without any focus” – (P7). “For me, test results simpler and more is easily understandable.” – (P8).	The test results of participants are shown using three types of visualization techniques. Most participants showed interest in tabular test results, and few showed interest in simpler ones. One showed her great interest in graphs as it shows the severity grade of a participant's test result. To sum up, three different visualization screens fulfill the user's requirement to visualize the test result.
5	Visualization of test history	“I like the tabular history most as it’s easy to understand and structural. It's also easy to understand how and where you can click for	Test history is visualized through three different types of visualization techniques. Most of

		more information. But I also do like the graph in the line graph history" – (P4). "For me, and thinking about elderly people, I think the easiest one to understand and to use for finding all the information would be the Tabular History. For ordinary people aged 20-50, I would say the line graph history is the best because this one is the most advanced one with a better overview at one page. You do not have to click on the next page to see all the results" – (P5). "The line graph history is great. It's the one I like the most because it's understanding for me and gives me an overview of where to go and find the details" – (P6). "I like the scale you showed in the graphical view, like if it's when you investigate explanation and stuff. It shows where you are right now and how far you are from cancer" (P11). "Tabular and line history both are understandable. In my opinion, I would prefer the line graph as it represents each test with a different symbol." – (P12).	the participants gave feedback that they liked the tabular form. Few also liked the line graph and bar. They feel more comfortable in line and bar graph visualization. Anyways, the user requirement to visualize the test history is also fulfilled with the help of three different types of visualization techniques.
6	Transfer history of tests in other countries	"It must be accessible as one of my friends migrated to another country, and there, she did not find her past history of tests, and the primary doctor was also unable to understand which test she had attempted earlier" – (P5). "If it gets operational, then it must be accessible in other countries. If one person is there on her next test date, then she can do her test over there" – (P9).	The user requirement to transfer the test history to another country can also be fulfilled with the help of a designed artifact, as it is centralized in one place.

Table 8. Evaluation of user requirements, participant feedback, and explanation.

Overall, the participants found satisfied and excited to use its market version soon. Their feedback and perceptions show that all the goals of the proposed thesis study have been fulfilled successfully.

6 Discussion

This section provides an overview of the discussion section from multiple perspectives. It also includes a brief overview of the contributions from the proposed thesis study. I analyze and visualize the cancer registry (Kreftregisteret) data to answer the research question: How can the digital service be designed to visualize cervical cancer registry data for the screening participants in an easily

understandable way? For this, qualitative research has been conducted. The proposed study collected data from various sources to design a digital service that aims as a solution against the current problems, information needs, and user requirements. The participants also evaluated the prototype to evaluate the goals of the study. A combined approach consists of an 'IT system in use' and 'goal-based evaluation' (Cronholm & Goldkuhl, 2003) used to evaluate whether the study's goals were fulfilled. Three primary goals were defined to answer the proposed thesis study. A discussion on each goal is provided a head like how each goal is fulfilled to answer the research question.

First, evaluate whether the solution to current problems is fulfilled or not. It involves three further sub-goals to meet: 1) no central digital platform available, 2) communication of test results and test history, and 3) understanding of test results and history. The participants were facing problems against these three sub-goals, and the evaluation results of the proposed study showed that these problems are fulfilled through the design artifact (prototype). For instance, in **sub-goal 1)**, some participants responded that they needed a digital solution as a separate application, and some stated to add it to the national health website (helsenorge.no). The proposed artifact answers this problem that can be deployed over the health website, or it can also be used as a separate application. In **sub-goal 2)**, the participants stated that they often did not receive the test results as they were asked at the time of the screening test that they would be intimated if any issue was found in their test results. Whereas they remain worried about their test results being either satisfactory or did not receive the intimation due to any communication problem. The proposed artifact resolves this problem of the participant by communicating their test results directly through the digital service. In **sub-goal 3)**, the participants need help clearly understanding the test results and history. Some participants said that they received their test results, but most of the time, they were unable to understand their results. The participants found the test results and test history very clear, understandable, and concrete, but one participant stated that follow-up frequency is available after a few clicks. It can be added to the main screen of the test results, but it would be made the screen messy and complex by having multiple things on one screen. So, it would be better to show the follow-up as shown in the designed artifact.

Second, evaluate whether the information needs to be fulfilled or not. It involves three further sub-goals to meet: 1) medical codes and terms, 2) general information about test types and the meaning of test results, and 3) decision support for the next test date and several follow-ups. The evaluation results of the proposed study show that these needs are fulfilled in the design artifact (prototype). For example, in **sub-goal 1**), participants found detailed information regarding test codes and understandable medical terms. They like the database part (of the cancer registry) in a proposed artifact that provides authentic information instead of searching from Google or any other unauthentic source. Information from other sources may create worry in understanding medical terminologies and the meaning of test code (result in the form of code). So authentic information would make the participant more trustworthy and lessen their stress in understanding the test result. In **sub-goal 2**), most of the participants found satisfaction with the proposed artifact. They claimed that it gives easy access to all the information that a participant need, including personal information, test results in a more detailed way, and a description of each test in detail. Few really like the symbols and color codes that have been used to differentiate each type of test. It makes it easy for the participants to differentiate the type and meaning of each test result. One of the employees from the cancer registry (Kreftregisteret) mentioned adding a little bit of focus on using the words “cytology” and “histology” because if the woman does not know what it is, then it will be difficult for them to understand it. While designing such a type of design, it is essential to differentiate test types and results with some visuals that make the results more understandable and

exciting to look at the visuals. Empirical data also shows to find the user's understandable terms for the subtest types that can be understandable. In **sub-goal 3)**, participants said It's excellent and understanding to have the new test date repeated on the screen so it follows you on each side and follow-up time can be easily seen. The evaluation results clearly show that the user's information needs against decision support for the next date, and several follow-ups are also fulfilled clearly.

Third, evaluate whether the user requirements are fulfilled or not.It involves further six sub-goals to meet: 1) Architectural information (the first page should be clear and easy to understand), 2) Additional information like notes and hyperlinks, 3) Communication preferences (notification about the test result, time to the next test, and wording while conveying the test results), 4) Visualization of test results, 5) Visualization of test history, 6) Transfer history of tests in other countries. The evaluation results of the proposed study show all these requirements are fulfilled in the designed artifact (prototype). For example, in **sub-goal 1)**, participants stated that screens look user-friendly, more visible, informative, self-explanatory, and simple to understand. So, it is fulfilling architectural information requirements. In **sub-goal 2**), participants said that the browsing feature of test histories seems easier to navigate. One said I loved the screens' pink background and the table's white background; the hyperlinks are straightforward to understand and navigate, even in more complicated test history. The responses of these participants claim that the proposed artifact fulfills the requirement of additional information like notes and hyperlinks. This information plays an important role while interacting with such types of systems. In **sub-goal 3**), user requirements about communicational preferences are also fulfilled as participants' feedback is: “nothing complicated, most of the information is understandable, the wording is also nice and communicated in a nice way that does not hurt to the participants." The proposed study claims that the participants are communicated with the screening results (test result, test history, and next test data) digitally in one place”. This platform would notify them instead of any traditional (previous) method where sometimes participants are not communicated with their test results. In **sub-goal 4**), visualization preferences also vary among younger vs. older participants, as (Lokka et al., 2018; Siu et al., 2011) stated. The results of the proposed study also showed a diverse range of preferences due to a variety of age group participants. Participants' feedback on various types of test result visualization shows a diverse range of preferences. For example, test results are shown in three different ways from which. One participant stated that the tabular way is the easiest and most understandable. I mostly preferred the tabular form of test results as they are easy to understand, well organized, and very detailed and concrete for any age group. One other participant stated that the simpler visualization is better than the others as my mother is too old, and this simpler visualization would be best to understand for her and other ladies at the old age group. On the other hand, one more stated that the graphical is a more reliable visualization as it describes the graph to participants, showing at which level they are standing. Either at a low, intermediate, or high level of cervical cancer risk. To conclude, it's all about the personal preferences of the participants from different age groups. The proposed study involves a solution employing multiple types of visualization techniques. Visualizing the result in the actual digital service is possible using tabular and graphical views. So, it would help multiple age groups of the participants. In **sub-goal 5**), we discuss the visualization of test history, which is also performed using three different visualization techniques. Many liked the tabular form as it is easy to understand (Torsvik et al., 2013) and stated table visualization is simpler and easier (compared with three other visualization techniques) to understandable for any age group. Whereas the results of the proposed study also show that a line graph is best to visualize test history comparatively to bar graph visualization in the case of simple test history. In the case of complex test history, participants like the bar graph and the line graph also but with a zoom option in the line graph to see the bigger view of each test history. The proposed study claims that visualization preferences change depending on the complexity of the data. The proposed study

found different visualization preferences from the same participants when they saw the visualization of two personas with simple and complex test histories. For example, they preferred the line graph if the test history was simple. On the other hand, the line graph provides messy visualization in case of complex test history. In such cases, the participant preferred bar graph visualization, which is more understandable when there are a huge number of test histories in a small duration of time. In **sub-goal 6**), transferring the test history to another country is also fulfilled in the designed artifact as it is centralized in one place, and one can access her test history wherever she is migrated. Migrant women tested less than non-migrant women due to less knowledge and a lack of interest in the screening program (Marques et al., 2021). Other reasons, such as access to healthcare services, relations with healthcare workers, and cultural and language barriers, are also highlighted. The proposed study shows that equal access to healthcare services should be given to all women (either migrant or non-migrant) to participate in the screening program apart from cultural, language, or other barriers. The proposed artifact would enhance women's participation in the screening program and decrease the rate of cervical cancer with the help of the proposed artifact. Overall, the proposed artifact is fulfilling all the user requirements.

Awareness of participants in cervical cancer screening programs is not enough regarding their procedure, cost, or distance (Datchoua Moukam et al., 2021). For example, one participant stopped attempting the cervical cancer screening test due to a bad experience because she was unaware of the screening test procedure and unclear communication of the test results. She reported in the feedback that when she attempted her first test, they asked her if an issue was found in her test result. So, she needed to come again and do another test and did not aware her how the test sample would be taken. When she arrived again on the said date, they took a more significant piece of her cervix. It was wondered and fearful for her, and they asked her to do this test every year without providing any test result, but she did not visit again due to a particularly scary happening. All this happened because she was unaware of the screening procedure and was not mentally prepared for that. In this regard, the proposed study confirmed that each participant is informed of the test procedure and test result with the help of using a variety of visualization techniques in the digital service. One can find all the information through some clicks by their access to the service.

The evaluation results confirmed that each sub-goal of the proposed study is fulfilled against three essential goals: current problems, information needs, and user requirements.

The quality of the research has been assessed with the help of four criterion: 1) credibility, 2) Reliability, 3) confirmability, and 4) transferability, proposed by (Lincoln et al., 1985). First is the credibility that represents the correct and right understanding of data collect through various sources, and the participant’s feedback collected via Google form and recorded presentation. I analysed the participants feedback deeply in a relax time as I have received in an excel sheet and recorded data in a pdf file. So, the feedback of the participants is understood clearly which show the credibility of the work. Second is the reliability that means how much the data is reliable. To ensure it, all the data has been collected and kept carefully. Third is the confirmability which means that the results are achieved from the actual data apart from one’s personal data or characteristics. The findings of the proposed study are also obtained based on the actual feedback data. Fourth is the transferability that ensured that the readers of the proposed study can access the transferability of its findings to other context to work on its future opportunities.

The proposed study produces a major contribution: building and evaluating the prototype. The prototype is constructed through the data collected from various sources. After the successful construction of the prototype, the prototype was evaluated by conducting a workshop with six

participants physically, three online via Zoom, and three (from the cancer registry, Kreftregisteret) were presented physically. Their feedback was collected in a Google form except for the cancer registry participants; their responses were recorded during the presentation. I evaluated each participant's responses to verify whether the goals of the proposed study were fulfilled. A theoretical contribution that has been found from the designed artifact is that the participant might prefer different visualization depending on the complexity of the data.

The designed artifact in the proposed study adds an artefactual contribution to the research (Ågerfalk & Karlsson, 2020). They stated that an article must clearly contribute knowledge to qualify for publication in any Information Science (IS) research journal. They distinguish and contrast the difference between three types of contributions (theoretical, empirical, and artefactual) and their two implications (on research practice and domain practice), as shown in **Figure 9**. The proposed thesis study would add an artefactual contribution to the research.

	Implications	
Contributions	Implications for research practice	Implications for domain practice
Theoretical: New or modified theory, or parts thereof.	Opportunities for analysing, explaining or predicting a phenomenon differently.	Opportunities for (improved) theory-informed action.
Empirical: An account of a phenomenon or details of a phenomenon not previously covered by research or covered to a limited extent.	Opportunities for generalising to theory and to other empirical representations, and empirically informed design of artefacts.	Opportunities for getting informed about a phenomenon, for benchmarking, and for empirically informed change.
Artefactual: Description of proposed new or modified artefact(s).	Opportunities for creating empirical accounts, and for theorising about a class of artefact.	Opportunities for taking advantage of new or modified artefacts.

Figure 9. Three types of knowledge contribute to their implications (Ågerfalk & Karlsson, 2020).

The last row of **Figure 9** shows an artefactual contribution along with its implications. It represents the type of contribution that involves the introduction of a new or modified artifact. In short, the artefactual contribution opens the door regarding empirical accounts. Later, empirical contribution opens future opportunities for theoretical contributions. The proposed thesis study produces an artefactual contribution to visualize the cancer registry data for screening participants in an easily understandable way.

7 Conclusion and future work

The proposed thesis study has been performed to collect data about how a digital service can be designed to visualize cervical cancer registry data for the screening participants easily. The data has been collected from multiple sources, including a document study, cancer registry (Kreftregisteret), prototype evaluation received from physical workshops, online Zoom meetings, and recorded data. The data from the document study helped in knowing the current problems in the existing system, information needs, and user requirements. The data taken from the cancer registry enabled the designing of an artifact (in the form of a prototype) to answer the proposed research question. The data collected from prototype evaluation helped answer whether the goals of the proposed study were fulfilled. The evaluation results show that the designed artifact successfully fulfilled the study's goals and answered the research question.

Due to time limitations, it took a lot of work to practically deploy the solution into its real environment website. In the future, it can be implemented in its real environment for the screening participants so that they can see their test results, test history, new follow-ups, and new test dates on their own.

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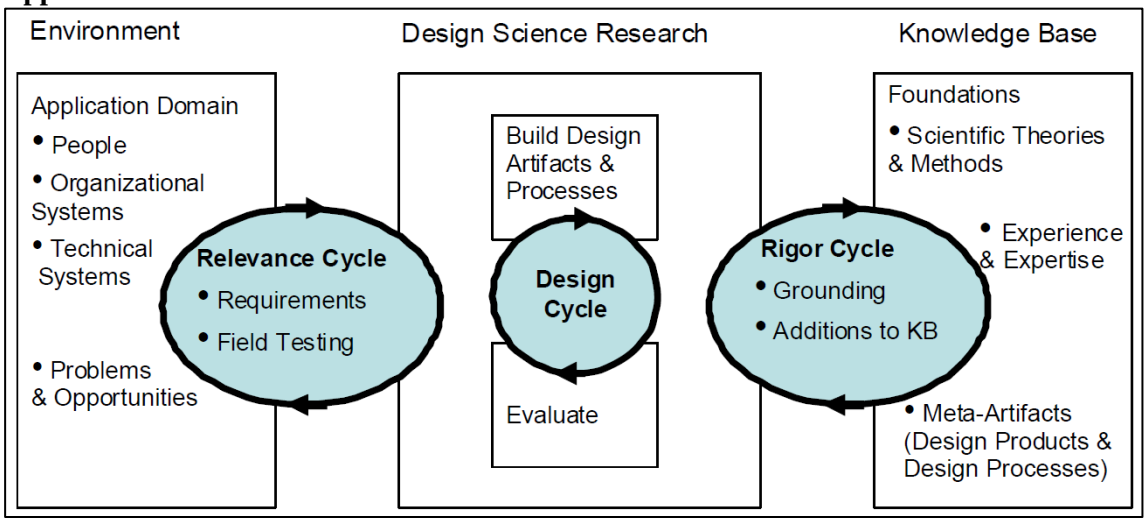
Appendix

Appendix – A



Appendix – B

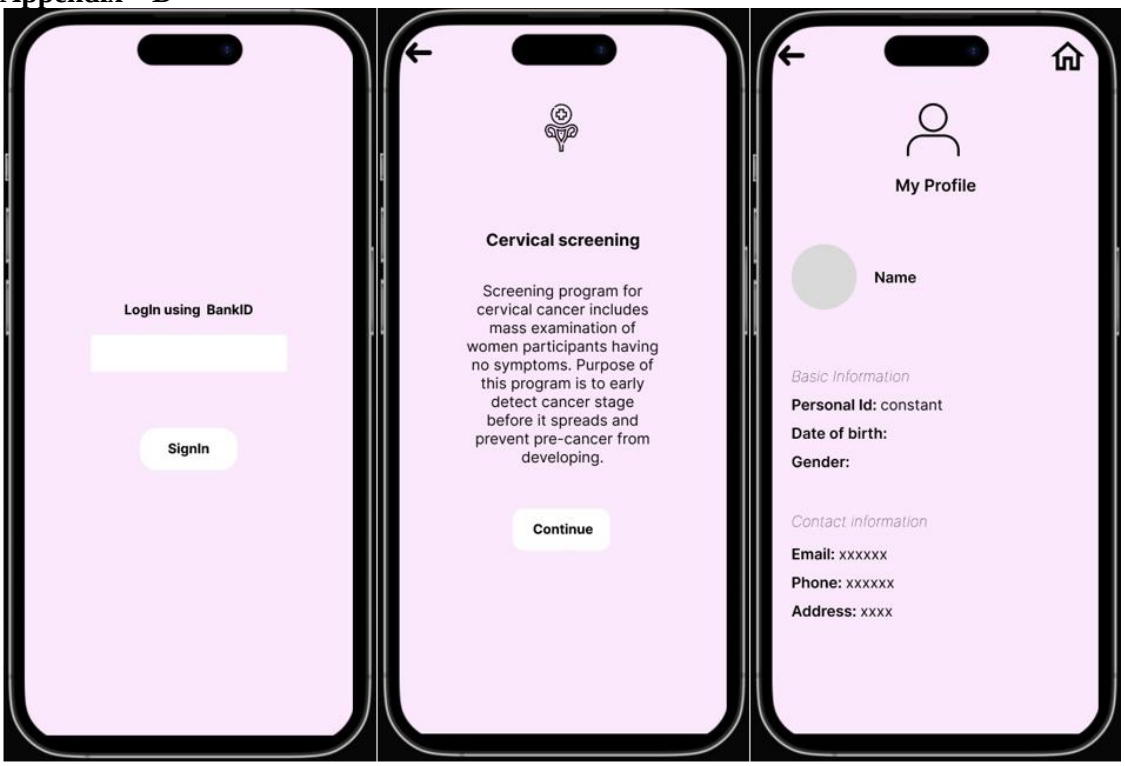
	Besvart_dato	Alder	Person_Id	Foedtaar	Hovedmorfologi	Lab_nr	Topografi
Cyt	01/12/1993	28	0000000	1965	00100	1	83000
Cyt	01/08/1994	29	10000150	1965	00100	14	83000
Cyt	01/11/1995	30	10000150	1965	00100	14	83000
Cyt	01/06/1997	32	10000150	1965	00100	14	83000
Cyt	01/06/1998	33	10000150	1965	00100	14	83000
Cyt	01/09/2001	36	10000150	1965	09010	16	83000
Cyt	01/02/2006	41	10000150	1965	00100	16	83000
Cyt	01/08/2006	41	10000150	1965	00100	16	83000
Cyt	01/11/2008	43	10000150	1965	00100	16	83100
Cyt	01/08/2009	44	10000150	1965	00100	16	83000
Cyt	01/12/2009	44	10000150	1965	00100	16	83100
Cyt	01/10/2010	45	10000150	1965	00100	16	83100
Cyt	01/07/2011	46	10000150	1965	00100	16	83100
Cyt	01/05/2013	48	10000150	1965	00100	20	83100

Appendix – C

	Proyetakingsdato	Test datoo	Besvart_dato	PersonId	Alder	Foedtar	Hovedmorfologi	Test type	Test resultat	HPV type	Lab_nr	Topografi
Cyt			01/11/1992	10000060	36	1965	100	1	83000		1	83000
Cyt			01/06/1994	10000060	38	1956	100				1	83000
Cyt			01/01/1998	10000060	42	1956	100				1	83000
His	20/09/2004		01/09/2006	10000060	48	1956	80702				15	83000
His	20/09/2004		01/09/2006	10000060	48	1956	80702				15	83000
His	22/09/2004		01/09/2006	10000060	48	1956	80702				15	83000
Cyt			01/06/2005	10000060	49	1956	69100				15	83000
Cyt			01/12/2005	10000060	49	1956	69100				15	83000
Cyt			01/06/2006	10000060	50	1956	69701				15	83000
HPV	31.05.2006	07.07.2006		10000060	50	1956		3	0		51	
HPV	31.05.2006	13.07.2006		10000060	50	1956		4	1		51	
His	20/09/2006		01/09/2006	10000060	50	1956	80702				15	83000
HPV	19.12.2006	09.01.2007		10000060	50	1956		3	0		51	
HPV	19.12.2006	05.01.2007		10000060	50	1956		4	1		51	
His	20/12/2006		01/11/2006	10000060	50	1956	80702				15	83701
His	20/12/2006		01/11/2006	10000060	50	1956	9000				15	83701
Cyt			01/07/2007	10000060	51	1956	80701				15	83000
HPV	28.06.2007	18.07.2007		10000060	51	1956		3	0		51	
HPV	28.06.2007	18.07.2007		10000060	51	1956		4	1		51	

His	29/08/2007		01/09/2007	10000060	51	1956	74007				15	83010
His	16/10/2007		01/10/2007	10000060	51	1956	80702				15	83701
Cyt			01/04/2009	10000060	53	1956	100				15	83000
Cyt			01/02/2010	10000060	54	1956	80701				15	83000
Cyt			01/04/2010	10000060	54	1956	69100				15	83000
HPV	11.02.2011	18.02.2011		10000060	55	1956		3	1	16	15	
Cyt			01/03/2011	10000060	55	1956	69701				15	83000
Cyt			01/01/2015	10000060	59	1956	69701				15	83000
Cyt			01/06/2015	10000060	59	1956	69701				15	83000

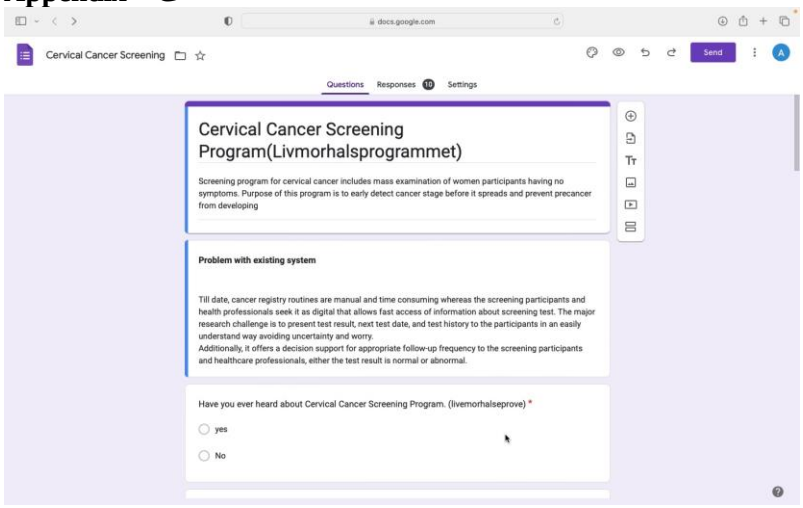
Appendix – D



Appendix – E

Appendix – F

Appendix – G



Appendix – H