Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Dept. of Information Security and Communication Technology

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The Norwegian Infection-Tracing App analyzed from a Socio-technical Perspective

Master's thesis in Information Security
Supervisor: Stewart James Kowalski
Co-supervisor: Slobodan Petrovic
July 2021

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Abstract

The Norwegian government introduced April 2020 the Smittestopp app solution in two versions as a digital mean to trace the spread of the corona infection in the Norwegian population. The software's functionality, security, and privacy compliance got massive criticism. Eventually, the first version of Smittestopp was canceled, the 2nd version reluctantly adopted by the citizens.

This study conducts a Root-cause analysis of Smittestopp's socio-technical system using methodologies and models related to socio-technical Root-cause analysis and system dynamics. The goal of this research is to study enabling and limiting factors when the authorities during a crisis introduce a disruptive application.

The research indicates in the first period of the pandemic, the Norwegian public sectors was in a state of chaos but regained more control during the first three quarters 2020.

The Root-cause that resulted in Smittestopp version I cancellation, relates to deficiencies essentially in technology, privacy, and information security. The deficiencies were at large corrected in version II.

Issues related to Smittestopp version I created a negative legacy inherited by the 2nd version of Smittestopp. The legacy caused an erosion of citizens trust, and further a reluctance to adopt Smittestopp II.

The research finds that under chaotic situations as a national crisis, the citizens privacy is in risk of violation. When order is regained, compliance of privacy regulations is given more attention.

To conduct a multi-perspective socio-technical root cause analysis, the study proposes an improved method for Root-cause analysis (RCA) that combines well-known socio-technical methods. The proposed improved socio-technical root cause analysis provides better insight into Root-causes related to interdependent socio-technical systems.

Sammendrag

Den norske regjeringen innførte april 2020 Smittestopp-appen i to versjoner som et digitalt middel for å spore spredningen av koronainfeksjonen i den norske befolkningen. Programvarens funksjonalitet, sikkerhet og overholdelse av personvern fikk massiv kritikk. Til slutt ble den første versjonen av Smittestopp kansellert, den andre versjonen ble lastet ned av innbyggerne langsommere enn forventet.

Dette studiet gjennomfører en rotårsaksanalyse av Smittestopps sosio-tekniske system ved bruk av metoder og modeller relatert til sosio-tekniske rotårsaksanalyse og systemdynamikk. Målet med dette studiet er å studere muliggjørende og begrensende faktorer når myndighetene i krisetid innfører en omdiskutert applikasjon.

Studiet viser at i den første perioden av pandemien, var den norske offentlige sektoren i kaos, men fikk tilbake mer kontroll i løpet av de tre første kvartalene 2020.

Rotårsaken som resulterte i kansellering av Smittestopp versjon I, er hovedsak relatert til mangler innen teknologi, personvern og informasjonssikkerhet. Manglene ble i stort korrigert i versjon II.

Problemer relatert til Smittestopp-versjonen I introduserte et negativt inntrykk av digital smittesporing som Smittestopp II måtte håndtere. Dette negativet inntrykket forårsaket over tid en erosjon av innbyggernes tillit, og ytterligere en motvilje til å laste ned Smittestopp II.

Studiet finner at under kaotiske situasjoner som en nasjonal krise, er det risiko for at borgernes personvern brytes. Når mer ordren er gjenvunnet får etterlevelsen av personvernet mer oppmerksomhet.

For å gjennomføre en fler-perspektiv sosio-teknisk rotårsaksanalyse, foreslår studien en forbedret metode for rotårsaksanalyse (RCA) som kombinerer velkjente sosio-tekniske metoder. Den foreslåtte forbedrede sosio-tekniske rotårsaksanalysen gir bedre innsikt i årsaker knyttet til gjensidig avhengige sosio-tekniske systemer.

Preface

This is a master's thesis written during the during the period of summer 2010 until spring 2021 to complete a master's degree in information security.

The this documents a project related to a Root-cause analysis of challenges related to the Norwegian COVID-19 virus tracing application. The idea for the research started as Smittestopp got massive negative attention related to privacy during the spring 2020. Thus, the idea developed to research topic related to a socio-technical Root-cause analysis of the Smittestopp's surrounded ecosystem and related socio-technical systems.

The reader should be familiar with socio-technical terms, models and term related to information technology. Although, methodologies related to the research are elaborated in the thesis. Thus, the thesis should be available for all readers with interest in cause, effect, events, and activities related to the Smittestopp ecosystem.

Acknowledgement

I would like to thank my supervisors, Stewart Kowalski and Slobodan Petrovic, for their guidance and valuable supervising during the project.

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1 Introduction

1.1 Topic covered by the project

In the fight against the COVID-19 pandemic early 2020, Norwegian Government introduced a digital tool to aim the challenge of tracing the COVID-19 virus in the Norwegian population.

The application for digital virus tracing, named Smittestopp, is part of an ecosystem involving multiple socio-technical systems interacting. For example, the socio-technical systems related to, *the Norwegian Government, the bureaucracy represented by Norwegian Institute of Public Health (NIPH), the contractor, and the citizen*.

The lifespan of the Smittestopp virus tracing applications faced challenges related to privacy, information security, technology, and user adoption. Thus, investigating these challenges by conducting a *multi-perspective socio-technical Root-cause analysis*.

As such the topics covered by this project is related to socio-technical methodologies and modelling techniques. This includes *Socio-technical systems modelling, Security by Consensus (SNC) models, and System Dynamic models*. These models are used to elaborate the involved socio-technical systems, Root-cause candidates, and the interaction between causes and the involved socio-technical systems. Further the SBC-models applied in the study are used to elaborate potential measures.

To add a dynamic perspective, the research covers *System Dynamics*. This is applied to model the interaction of cause and effects in *Systems Dynamic modelling*.

The research process was partly conducted as workshops. Thus, *Group Model Building* was applied as methodology to facilitate the workshops.

Further, the study analyzes the state of order using the *Cynefin framework* for sensemaking. In addition, *Root-Cause analysis (RCA)* is a topic at the core of this research

1.2 Keywords

Socio-technical, System dynamic, Information Security, Root Cause analysis, Case study, Security by Consensus, Group model building, Cynefin, Ishikawa diagram

1.3 Problem description

Due to the COVID-19 crisis the Norwegian government introduced the Smittestopp digital solution as a mean to trace the spread of the corona infection in the Norwegian population.

Prior to the launch of the Smittestopp-app, the process, functionality, security and privacy intrusiveness of the software got massive criticism (Moe, 2020) in the press, social media and blogs. The media stated that the application has severe challenges related to information security and privacy. The criticism originated from a broad spectrum of expertise including software developers, IT-professionals, information security experts, journalists, and lawyers (Sandvik, 2020a).

Smittestopp continued receive negative attention with issues related to technology, data protection, and lack of transparency in the communication (Sandvik, 2020a).

By 15th of June 2020 the Norwegian Data Protection Authority issued a formal warning to the Norwegian Institute of Public Health (NIPH) that they were considering a temporary ban on the app due to the app being disproportionately intrusive with respect to personal data (Norwegian DPA, 2020b). For all practicalities this caused NIPH to pull the first version of Smittestopp from the marked and delete all collected data. As such, it is not controversial to argue that Smittestopp version I was a limited success.

Data from NIPH showing the number of downloads and active users of Smittestopp (Figure 1 below) shows that Smittestopp was not meeting the target market penetration of 60% of the Norwegian population over 17 years (Brækhus, 2020).

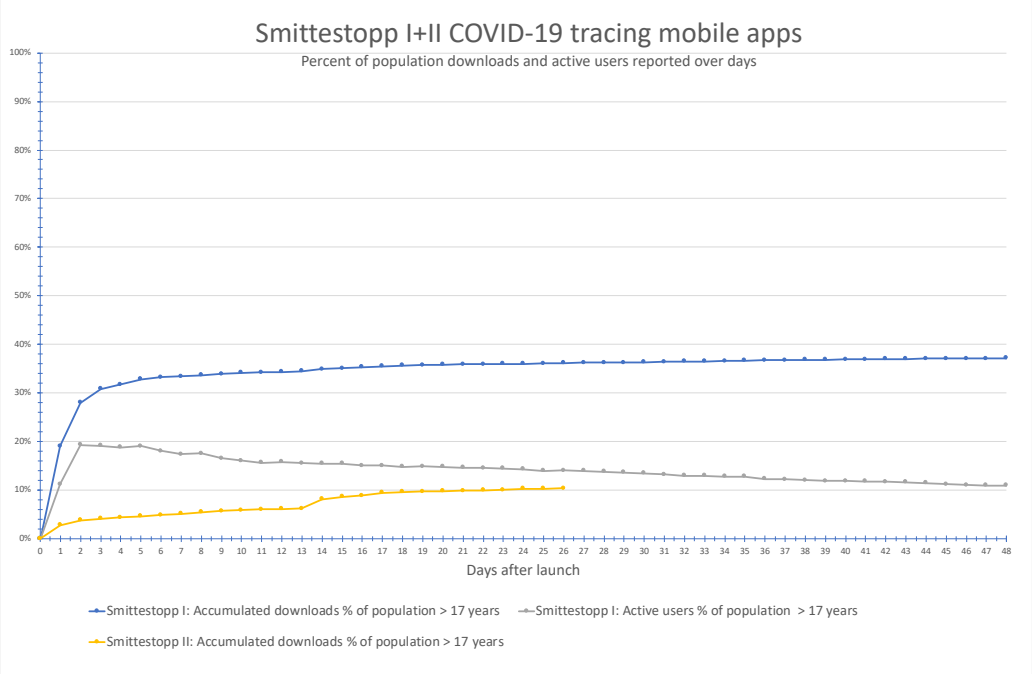

Figure 1: Smittestopp apps, number of downloads

Smittestopp was followed by a total makeover called Smittestopp II. The new software has corrected near all issues related to the first version of Smittestopp (privacy, technical, etc.). But, as the graph shown by Figure 1, the number of downloads is even less than the first

version. This is an indication that something has changed related to Norwegian citizen eager to download and use a COVID-19 virus tracing application.

Smittestopp is part of a larger socio-technical system with stakeholders from both public and private sectors, involving legal issues, citizen rights, technology, and information security challenges amongst other. The application has been revised from several perspectives like technical and security (Lilleng et al., 2020; Ministry of Health and Care Services, 2020a, 2020b), legal and privacy (Hovland, 2020; Norwegian DPA, 2020a; Sandvik, 2020b). But it is challenging to analyze Root-cause when reviewing a single perspective at a time, and not analyze the Smittestopp as a socio-technical system with many interacting and interdependent parts.

Thus, the Root-cause analysis this research has found (Abubakar, Zadeh, Janicke, & Howley, 2016; Huynen & Lenzini, 2018; Wangen, Hellesen, & Torres, 2018) do not have an approach that simultaneously:

- encourage a multi perspective approach
- analyze the dynamics of cause and effects
- consider causes of an eroding character.

To accommodate this, the study will conduct a Root-cause analysis of the socio-technical system Smittestopp using methodologies and models related to socio-technical Root-cause analysis and system dynamics. Applying such methodologies will aim the goal of this research to study enabling and limiting factors when the authorities during a crisis introduce a disruptive application.

1.4 Justification, motivation, and benefits

This study is conducted as a Root-cause analysis of the Norwegian government launch of the Smittestopp COVID-19 virus tracing application with the potential to contribute with a structural multi-perspective approach for analyzing unexpected results in socio-technical system interdependent factors. The motivation for applying a multi-perspective approach is related to observed challenges of creating a logical chain of explanation when potential causes are interrelated or eroding over time. Some examples are eroding citizen trust over time related to privacy, technology, or usability.

Applying a multi-perspective approach gives the benefit of conducting Root-cause analysis on problems that has multiple causes that are interdependent and each contributing to the (unwanted) end-result.

1.5 Research questions, propositions, and planned contributions

The two versions of the Norwegian digital COVID-19 virus tracing application were launched in 2020 as a response to the emerging COVID-19 pandemic. There are several topics related to the two versions launched related to the interaction of the socio-technical system(s) involved, the lawfulness and the citizens eagerness to adopt the application

In addition, this study aims to apply a Root-cause analysis methodology that enlightens cause and effects from a socio-technical perspective.

Based on this the following research questions, propositions and contributions are planned in this study.

1.5.1 Research Question 1, proposition, and contribution

The Norwegian initiative Smittestopp for a digital COVID-19 virus tracing application involved an ecosystem of actors, structures, and technology. Based on this the first research question is:

RQ1: Seeing the Smittestopp app from a socio-technical system perspective. What are the key components in this socio technical system, and how do they interact?

Smittestopp is one of the means in the Norwegian governments battle against COVID-19 virus. It is a software solution aiming virus tracing in the Norwegian population. But the software itself is only one technical piece on a complex landscape involving interdependent elements like; civil rights, funding, law, norms in the Norwegian society, strategic decisions, and a mix of organizations part of public, private and research sectors.

Thus, related to RQ1 this research first proposition is:

PR1: The Smittestopp software solution is part of a multitude of interacting socio-technical systems.

Further, since the Smittestopp application is one cog in a complex socio-technical machinery, an natural approach to identify the interconnected factors is to leverage methodologies and models provided by socio-technical studies (Cooper & Foster, 1971; Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Dangerfield, 2020; Goodman, 1991; D. H. Kim, 1999; Richardson, 2020; System Dynamics Society, 2020), and framework for sense-making in complex socio technical systems (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003).

To facilitate this the study will related to RQ1 and PR1 contribute with:

CO1: The study will provide socio-technical and systems dynamic models identifying key components and interrelationship in the Smittestopp socio-technical system.

1.5.2 Research Question 2, proposition, and contribution

During crisis draconian measures are often implemented, and sometimes laws related to privacy is overruled for the benefit of e.g., public health. Given this, research question two is:

RQ2: How are citizens lawful rights to privacy balanced against the societies need for virus tracing during a national crisis?

In the case of protecting the citizens privacy, The Norwegian Data Protection Authority was continuously evaluating the effect of the virus-tracing versus the intrusiveness of the Norwegian citizens privacy performed by the Smittestopp application in a state of emergency caused by the COVID-19 pandemic.

This leads to the following proposition related to RQ 2:

PR2: *In chaotic situation invoked by a national crisis like the COVID-19 pandemic, citizens privacy stated by law is violated and restricted.*

To elaborate the restriction of citizens privacy in the Smittestopp ecosystem, it is natural to use both the models provided by contribution CO1 and existing literature related to the lifespan of Smittestopp.

Thus, related to RQ2 and PR2 this study will contribute with:

CO2: *This study will analyze the balance between violating citizens' lawful rights to privacy and a mean necessary to support a crisis related to the Smittestopp ecosystem.*

1.5.3 Research Question 3, proposition, and contribution

Download data of the first version of Smittestopp shows that the Norwegian citizens were eager to adopt the virus tracing application in the first period. The data showing number of downloads related to Smittestopp II shows a much slower progression. This is the basis for research question number three:

RQ3: Why was Norwegian Citizens reluctant to adopt the second version of COVID-19 tracing app, Smittestopp II?

The aim of Smittestopp was to provide an effective aid in the Norwegian government´s battle against COVID-19, but it failed to provide this. Some restrictions were expected; restrictions by law, technical challenges related to software development, required robustness, responsiveness, and security. Other limiting factors are not that obvious e.g., growth of user base to gain critical mass, required trust and good-will from citizens, transparent and honest communication between governmental representatives and citizens.

This leads to the following proposition related to RQ 3:

PR3: *The citizens reluctance to adopt Smittestopp version II was related to multiple factors like previous experience, technical problems, privacy issues, and eroded citizen trust and goodwill.*

To confront the matter of questions provided by RQ3 and PR3 this study will contribute with:

CO3: *This study will analyze main cause of actions leading up the reluctance of adopting Smittestopp by utilizing socio-technical (Kowalski, 1994a) and system dynamic modelling (Kim, 1999; Wolstenholme, 2003).*

1.5.4 Theoretical contribution

Root Cause Analysis (RCA) is considered as a core discipline in the information security (Huynen & Lenzini, 2018; Wangen et al., 2018) to analyze incidents, gain learning, experience and improve to prevent future incidents.

Other studies (Huynen & Lenzini, 2018; Wangen et al., 2018) suggests methodologies to mitigate socio-technical risk related to information security. Although, it is not found in this research the perspectives of the state of order in related socio-technical system(s), the

interaction of interdependent socio-technical systems, and the dynamic perspective. This motivates the following research question:

RQ4: How can socio-technical Root-cause analysis processes be improved by combining existing well-known methodologies?

This leads to the following proposition related to RQ 4:

PR4: *Applying existing socio-technical methodologies to root-cause analysis processes improves the insight of causes related to interdependent socio-technical systems*

As stated in the contributions (CO1, CO2, and CO3) the methodologies this study applies is related to socio-technical system dynamics. As the Figure 19 below outlines, the research applies a combination of methodologies known from socio-technical analysis and system dynamic modelling.

Thus, the theoretical contribution of this study is:

CO4: *The theoretical contribution this study is a research process combining known methodologies and modelling techniques known from socio-technical systems (Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Goodman, 1991; D. H. Kim, 1999; Richardson, 2013, 2020; Richardson & Andersen, 1995), and lean quality thinking (Ishikawa, 1985; Renee & James, 2010; Womack & Jones, 1996), and sensemaking in complex and complicated contexts (David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)*

1.5.5 Scoping and Bounding the Study

Due to limited time and resources this study's bounding is limited to findings related to Smittestopp. In addition, the models are limited to *key aspect,* and not a full elaboration of all aspects that possible can affect the Smittestopp socio-technical system.

Further, this applies to the provided system dynamic models as well. Their purpose is to serve as a thinking tool, and not model every real-life aspect.

A risk is that essential elements are missed during the research, and the actual Root-cause or dependencies are overlooked. This is further discussed in chapter 4.2.3.5

Considerations and interpretations regarding applied laws, compliance and potential violations of laws and regulations are not part of this study. Where such topics are relevant, this study applies considerations and interpretations from other sources. For example, the Norwegian DPA.

Further, is not part of this study to elaborate the effectiveness of the virus tracing application.

Although, many countries have national COVID-19 virus tracing application, this study only includes the Norwegian virus tracing application.

2 Background and Related work

In this chapter is the background related to this research and the related work.

The background chapter below provides an overview and introduction of surrounding context, birth, and lifecycle of Norwegian initiative for digital COVID-19 virus tracing application, Smittestopp.

Further below is the chapter elaborating the work related to this study. In sum the related work is a collection of two categories:

- Literature review of selected work related to Root Cause Analysis (RCA)
- Related work to tools, methods and methodologies applied in the research

2.1 Background

This chapter provides an overview and introduction of surrounding context, birth, and lifecycle of Norwegian initiative for digital COVID-19 virus tracing application, Smittestopp.

As mentioned in in chapter 1.3 Problem description, there are several events and data related to the history of the Smittestopp, and this chapter elaborates relevant events and data. As such, a visualization of relevant events and activities is illustrated in Figure 2 below as a timeline. The timeline illustrated in Figure 2 below is a central source of information in the Root-cause analysis conducted in this research.

Further the quantitative data related to Smittestopp version I and version II used in the Root-cause analysis is elaborated below. The data was collected to Smittestopp I and II was partly collected through NIPHs webpage for key results (Norwegian Institute of Public Health, 2021a) partly by requesting data from NIPH.

Below is a summary of the report from the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a). It concludes that there is room for improvement in several areas of how the Norwegian Government and the public sector handled the COVID-19 pandemic. Further the report creates a solid foundation to understand the situation the Norwegian society faced because of the pandemic.

Norwegian Ministry of Health and Care Services (HOD) appointed by 8th of April an independent expert group to review the first version of Smittestopp (Ministry of Health and Care Services, 2020a). The report from the expert group (Lilleng et al., 2020) gives this research insight in the first version of the Smittestopp application with respect of matters related technical, privacy and information security. Thus, the findings of the report are a valuable information resource in the Root-cause analysis process conducted in this research.

2.1.1 Smittestopp – Timeline

As mentioned in in chapter 1.3 Problem description, there are several events and data related to the history of the Smittestopp. This research is based on central events related to Smittestopp and data related to downloads of the app. Thus, this chapter elaborates relevant events and data.

The visualization of relevant events and activities is collected in Figure 2 below as a timeline. A detailed timeline with references to sources can be found in Appendix 1 below.

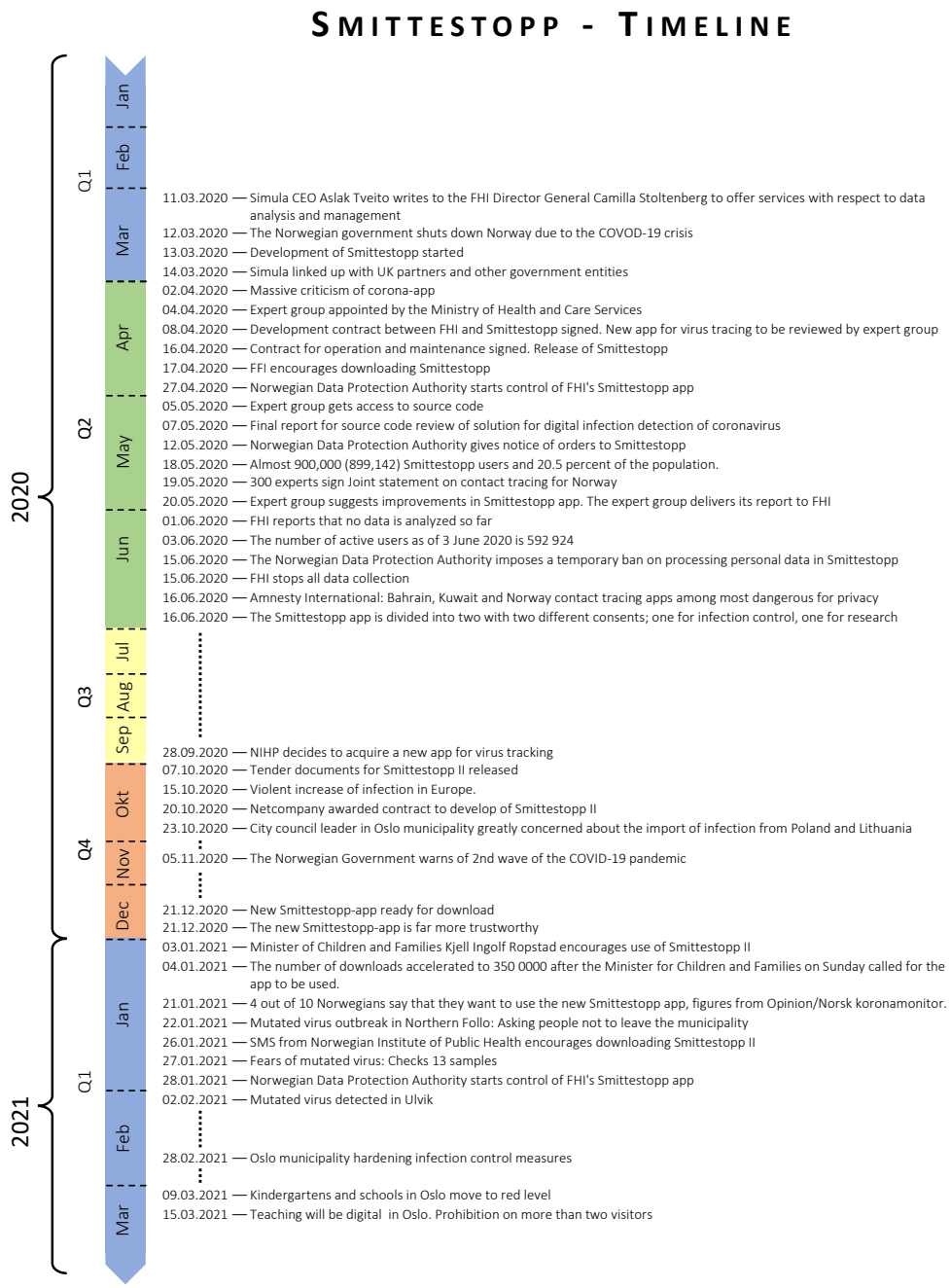

Figure 2: Timeline Smittestopp I+II

As illustrated in Figure 2 the timeline includes events from March 2020 to March 2021.

The initial start of Smittestopp as the Norwegian digital COVID-19 tracing application started 13th of March 2020 by Simula reaching out to NIPH and offering services with the initiative to provide digital COVID-19 virus tracing capability (Sandvik, 2020b).

After the shutdown of the Norwegian society 12th of March the progress related to Smittestopp accelerated as the timeline shows in Figure 2. The development of the solution started 13th of March with Simula as the contractor, but although the official contract

between NIPH and Simula was not signed before 8th of April. This order of events is quite unusual in a regulated market as the public sector.

Meanwhile criticism from lawyers, journalists, etc. against such collection of proximity data stated to emerge. The Government answered the emerging criticism by appointing an independent expert group to review the quality with technical, privacy and security perspectives. The results from the independent expert group are further elaborated in chapter 2.1.4 below.

As shown in the timeline the first version of Smittestopp was released 16th of April 2020, but only 8 days after the Norwegian Data Protection Authority starts control of NIPH's Smittestopp app with regarding potential privacy issues.

Several more events on the timeline relates to privacy compliance. By 12th of May 2020, Norwegian Data Protection Authority gives notice of orders to Smittestopp related to privacy issues (Norwegian DPA, 2020c). By 19th of May 300 experts sign Joint statement on contact tracing for Norway with focus on the principle of upholding the citizen's data protection rights.

As the timeline in Figure 2 in mid-June 2020 shows that focus on privacy compliance ended up with the Norwegian DPA temporary banned Smittestopp I (Norwegian DPA, 2020b) and NIPH stopped collecting data and deleted exiting data.

NIPH's further plan for Norwegian COVID-19 tracing app emerged mid-September (Norwegian Institute of Public Health, 2020c). After a procurement process Netcompany was chosen as the contractor to develop the next version of the Norwegian COVID-19 virus tracing application to be named Smittestopp II. This app was based on the same software as the Danish virus tracing initiative, and the app was ready for download 21st of December 2020. In general surveys tells that the Norwegian citizens was positive to adopt the new version of Smittestopp.

The timeline further shows that the pandemic hit the Norwegian society with outbreaks of more contagious COVID-19 mutants resulting of strict measures to control the outbreaks.

This sums up the major events and activities related to the timeline illustrated in Figure 2 above. Thus, it is a central source of information in the Root-cause analysis conducted in this research.

2.1.2 Smittestopp – Related data

This chapter elaborates the quantitative data related to Smittestopp version I and version II that will be used in this research. The data was collected to Smittestopp I and II was partly collected through NIPHs webpage for key results (Norwegian Institute of Public Health, 2021a) partly by requesting data from NIPH. The dataset used in this research related to Smittestopp I can be found in Table 14, Appendix 2 below. Note that data related to Smittestopp I is removed from the NIPHs webpage at the present time of writing.

Data related to Smittestopp II was collected from through NIPHs webpage for key results (Norwegian Institute of Public Health, 2021a). Note that due to a change in collected data, active users are not available. The dataset used in this research related to Smittestopp II can be found in Table 15, Appendix 3 below. Also note that even the dataset stops at 27th of

April 2021, Smittestopp II continued collecting data, but the data was no longer relevant for this research.

The graphs shown in Figure 3, Figure 4, Figure 5 and Figure 6 are different views of the datasets (see Appendix 2 and Appendix 3) related to both versions of Smittestopp.

The first graph shown in Figure 3 projects the data for the whole period of Smittestopp I and II to illustrate the time span between the two versions.

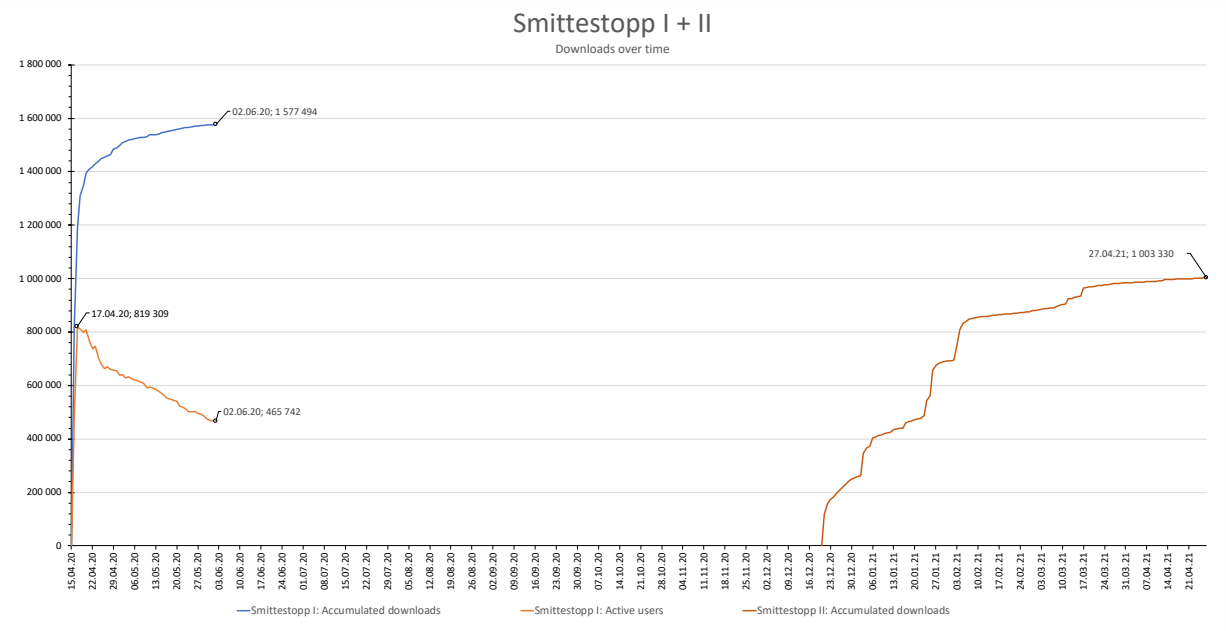

Figure 3: Downloads over time Smittestopp I+II

The graph showing a huge interest to download Smittestopp I. Only after one day 810 690 citizens had downloaded the app. At the same time, the number of active users is not following the same pattern. One day after launch the graph of active users starts declining, and active users is 370 502 less than accumulated downloads at that date. Active users continue to decline throughout the lifetime of Smittestopp I.

Smittestopp II's development of downloads shows in Figure 3 a more careful progression than the rapid increase of download related to Smittestopp. This indicates that something has changed the Norwegian citizens eagerness to adopt a COVID-19 virus tracing app.

Figure 4 below shows this more clearly as the datasets from Smittestopp I and II is aligned with respect of days after launch.

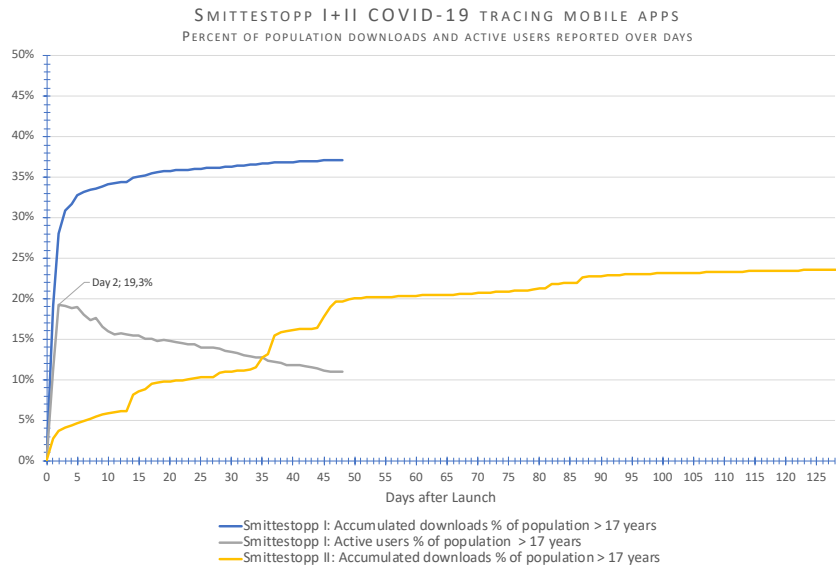

Figure 4: Downloads from launch date: Smittestopp I+II

The X-axis of the graph in Figure 4 shows number of days after launch for both versions of Smittestopp while the Y-axis shows percentage of the Norwegian population older than 17 years. The graph shows that Smittestopp I reached a max adoption of 37% of the population while Smittestopp only reached 23,6% even Smittestopp II's dataset is nearly three times longer.

The graph in Figure 4 above Figure 34 with data related to accumulated downloads adds valuable insight. The graph shows both the download progression of both Smittestopp I and II days after the launch date. Data series shown in Figure 4 are:

- Smittestopp I: accumulated downloads
- Smittestopp I: active users
- Smittestopp II: accumulated downloads

Note that data related to active users in Smittestopp II not available due to restrictions in collection of user data.

The data in Figure 4 above shows that the download rate of Smittestopp I was considerable higher than Smittestopp II. After only 5 days more than 33% of the population had downloaded Smittestopp version I. This indicates the Norwegian citizens listened to the encouragement given by the authorities to download Smittestopp. This aligns well the fact that the Norwegian citizens in general have high trust in the authorities (Kleven, 2016). Despite the high number of downloads, only two days after launch Smittestopp I was experiencing a drainage of users. Something caused users to delete the app quickly (discussed in chapter 4.2.3.5 below).

The graph illustrating Smittestopp II accumulated downloads shows a slower progression compared to Smittestopp II. This indicates that something has changed the citizens eagerness to download Smittestopp.

To indicate whether major events have impact on the adaption rate, Figure 5 below, correlates selected major events with the graph of accumulated download related to Smittestopp II.

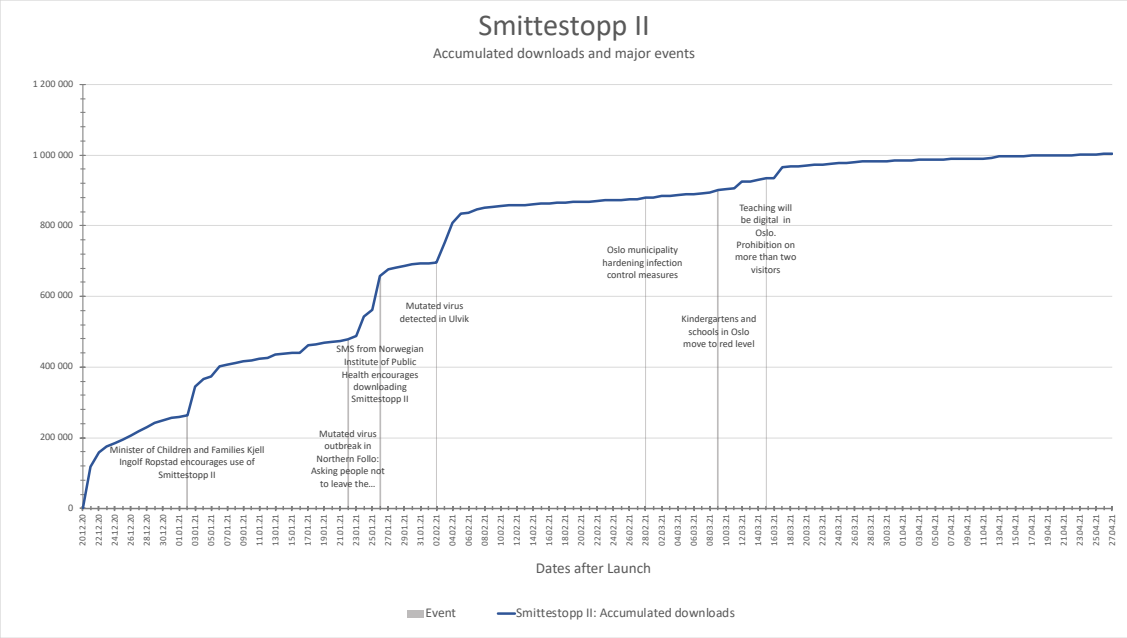

Figure 5: Smittestopp II: Accumulated download and major events

Figure 5 shows that some events correlate with jumps in the download rate, others not. Although there is a correlation between some major events and jumps in download rate, this research does not claim *causality* in the findings. The data in Figure 5 is rather an interesting observation. Some of these observations is that close to communication activities encouraging to download and use Smittestopp, the graph shows jumps in number of downloads. In addition, mutations changing in how contagious of the virus is, seems to increase the eagerness of the citizen to download Smittestopp II.

Figure 6 below, shows also the dataset related to Smittestopp II downloads, but views both number of downloads (blue graph, left Y-axis) and downloads in percentage of the Norwegian population over 17 years (orange graph, right Y-axis).

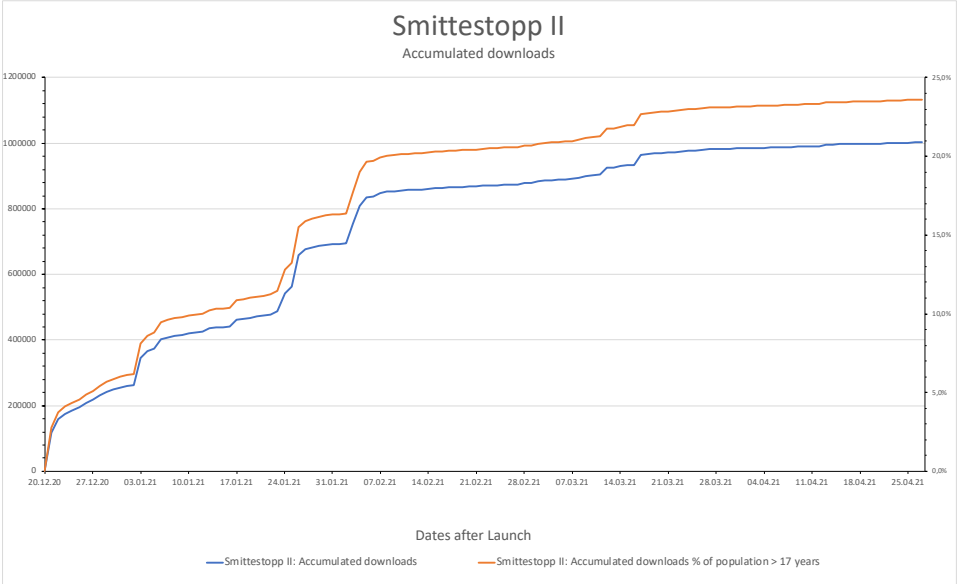

Figure 6: Smittestopp II: Accumulated downloads in numbers and percentage of population

The graphs elaborated in this chapter shows that there was a change from Smittestopp I to Smittestopp in the citizen's eagerness of adopt the virus tracing application. This finding will be further elaborated in chapter 4 below describing the results of the research.

In addition, the graph in Figure 4 above shows that the percentage of actual Smittestopp I adoption, 37% of the population, was lower than the target, 60% (Brækhus, 2020). This research will not discuss what percentage of adoption is sufficient since that is a topic that is under debate (Singer, 2021; Wymant et al., 2021) at the present time of writing.

The graph in Figure 34 below with data related to accumulated downloads adds valuable insight. The graph shows both the download progression of both Smittestopp I and II days after the launch date. Data series shown in Figure 34 are:

- Smittestopp I: accumulated downloads
- Smittestopp I: active users
- Smittestopp II: accumulated downloads

Note that data related to Smittestopp II and active users is not available due to restrictions of collected user data.

The data Figure 34 shows that the download rate of Smittestopp I was considerable higher than Smittestopp II. After only 5 days more than 33% of the population had downloaded Smittestopp version I. Despite the high number of downloads, only two days after launch Smittestopp I was experiencing a drainage of users.

This indicates the Norwegian citizens listened to the encouragement given by the authorities to download Smittestopp. This aligns well the fact that the Norwegian citizens in general have high trust in the authorities (Kleven, 2016). Although, something caused users to delete the app quickly. Candidates for this behavior are *issues raised related to privacy, security, technical and user experience*. Looking at the timeline (see Figure 2 above and detailed timeline in Appendix 1 below) the public in general was not aware of privacy and security issues until weeks after launch of Smittestopp I. Thus, this does not align with that data that shows a decrease in active users only two days after launch. Thus, it is plausible to assume that loss of Smittestopp I users was *not related to privacy or security issues. Rather technical or issues related to the user experience is more likely*. One known issue raised only one day after launch of Smittestopp was extensive power consumption (Plikk, 2020).

The graph illustrating Smittestopp II accumulated downloads shows a slower progression compared to Smittestopp II. This indicates that something has changed the citizens eagerness to download Smittestopp.

2.1.3 The Report from the Norwegian Coronavirus Commission

The report from the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a) was released 14th of April 2021 after a thorough review of the Norwegian Government handling of the COVID-19 pandemic. A summary of relevant findings and recommendation are included in this study since it sums up the state of the Norwegian public sector when the country was hit by the national crisis. The literature sources for the summary below is at large the full report (Norwegian Coronavirus

Commission, 2021a) and the English summary (Norwegian Coronavirus Commission, 2021b).

The report (Norwegian Coronavirus Commission, 2021a) consists of more than 450 pages. Thus, the summary in this chapter is rather comprehensive, but is necessary to describe the state of affair the Norwegian Government, the Norwegian public sector and the Norwegian citizens was facing its's largest crisis since World War II.

Further, the Norwegian Coronavirus Commission report (Norwegian Coronavirus Commission, 2021a) provides data for the discussion in chapter 0 below. The discussion applies the Cynefin framework (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) to find the order of complexity the Norwegian Government was facing when the pandemic crisis emerged.

As stated in the (Norwegian Coronavirus Commission, 2021a), Wednesday 26th of February 2020 the first case of COVID-19 was confirmed in Norway. This should mark the beginning of what would prove to be the greatest crisis in Norway since World War II. All parts of society were affected.

The report from the commission concludes that the authorities in overall have handled the pandemic well in a demanding situation for the country. The authorities adapted quickly to the challenging situation and took decisions of crucial importance during the evolution of the crisis. As shown in Figure 7 below, Norway has a year into the pandemic, one of the lowest mortality rates and its economy is among the least affected in Europe. A very important point from (Norwegian Coronavirus Commission, 2021a) is that the authorities would not have been able to succeed without the population supporting the infection control measures. *The high level of trust in one another and in the is one of the factors that equipped the Norwegian society to deal effectively with the crisis*.

The commission states that the authorities knew that a pandemic was the type of national crisis most likely to occur and to have the greatest negative impact. Further, it is the Government that is responsible for emergency preparedness planning of appropriate scale. *Yet they were unprepared when the COVID-19 pandemic arrived with widespread, severe effects*.

In addition, *the government has in its emergency preparedness efforts paid little attention to how risk in one sector is affected by risks in other sectors*. The pandemic has made the interdependencies *between* and need for interaction *with* different sectors obvious.

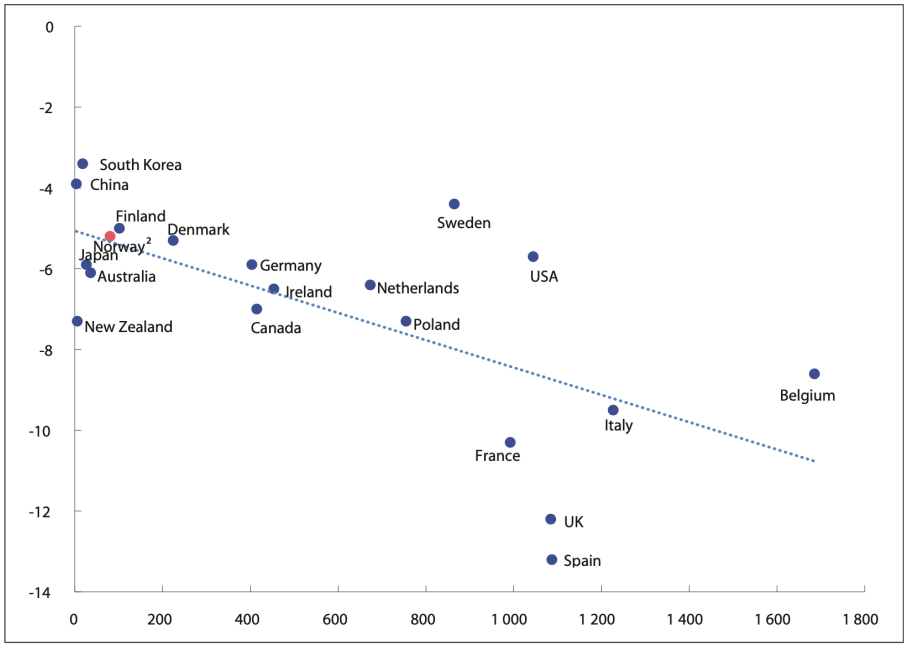

Figure 7: Number of COVID-19-related deaths per million inhabitants (horizontal axis) and percentage change in GDP[1] (vertical axis). Selected countries, 2020. (Norwegian Coronavirus Commission, 2021b)

The Commission states in (Norwegian Coronavirus Commission, 2021a) that *the Government was right to impose comprehensive infection control measures on 12 March 2020*. At that time, little was known about the effect of infection control measures, and there was great uncertainty about the virus situation itself. Thus, being decisive, rather than waiting for more information, was the correct course of action.

The decisions to introduce comprehensive infection control measures on 12 March 2020 should have been taken by the Government, not the Directorate of Health. Under Article 28 of the Constitution of the Kingdom of Norway, such matters of importance are to be taken up in the Council of State. The decisions to introduce what the Prime Minister described as the "most sweeping measures Norway has seen in peace- time" affected all of society, undermined citizen rights, and clearly constituted a matter of importance.

As pointed out in (Norwegian Coronavirus Commission, 2021a), *at the beginning of the COVID-19 pandemic, the authorities did not ensure that the infection control measures were in line with human rights and the Constitution*. During crisis situations like this pandemic, there is a risk of violating of the Constitution and human rights guarantees, and of infringements on citizen rights. The authorities in such situations must take extra care to ensure a potential crisis is addressed within the frameworks set by Norway's Constitution and general human rights. That did clearly not occur when the pandemic erupted.

During the COVID-19 pandemic, Norwegian authorities have employed infection control measures to an extent no one had previously imagined or planned for. To suppress the virus

[1] Measured as the difference between the OECD's 2020 growth estimates for GDP as issued in December 2020 and November 2019 (Norwegian Coronavirus Commission, 2021b)

[2] Mainland Norway

and then keep the infection rates low, the authorities have used powers granted under the Act Relating to the Control of Communicable Diseases, among other legislation, to impose several measures that have intruded significantly into the private domain and undermined the rights of Norwegians. No Western country had foreseen tackling a pandemic in such a way, and as such there has been a paradigm shift.

Substantial municipal-level responsibility for infection control in Norway is a strength. Norwegian municipalities have been instrumental in containing local outbreaks by such means as testing, isolation, contact tracing and quarantine, and by taking actions authorized by the national Act Relating to the Control of Communicable Diseases. *However, the Government and the Directorate of Health have been slow in informing municipalities and obtaining their input about decisions to be carried out at the local level*.

Norway's Act Relating to the Control of Communicable Diseases has been crucial in addressing the crisis but should be amended. However, the Act is not explicit enough in requiring democratic control when quick decision-making is needed to address a communicable disease. In addition, the division of responsibility between the central and municipal levels of government is not made sufficiently clear in the law.

The authorities have largely succeeded in communicating to the population. The Government has communicated openly about the uncertainties over how the pandemic would develop and how well the infection control measures would work. The Coronavirus Commission states that the openness has helped to promote trust. Further, that the majority of the population expresses confidence in information received from health authorities during the pandemic.

The Government lacked a plan for handling imported infections when a new wave of the transmission emerged in Europe in autumn 2020. A characteristic in Norway's pandemic response has been a tendency to push minor decisions upwards in the administrative hierarchy, and this may have affected the Government's ability to view issues in an overall perspective. As such, the Government made numerous individual assessments resulting in eased restrictions going into summer 2020 but did not assess its relaxation policy. Thus, no plan existed for responding to an increase in cross-border transmission.

Although the pandemic affected everyone, the effects have varied at large demographically and geographically. While Some municipalities had no COVID-19 cases, *the toll on Oslo and several other municipalities with the burden of strict infection control measures over prolonged periods has been heavy*.

The pandemic weighs heavily on children and young people, and the effects may prove long-lasting. As a result of extensive home schooling and digital instruction during the pandemic, lower motivation and subpar learning conditions can be experienced. Thus, further lead to higher dropout rates and/or a lasting impact on job opportunities later in life. In addition, vulnerable children and young people have been particularly at risk during the pandemic.

The cost of the pandemic to Norway's economy will be high as the COVID-19 pandemic triggered Norway's most severe economic recession since World War II. In March 2020, registered unemployment quadrupled in a matter of weeks. Although the rate of

unemployed declined during spring and summer, end of the year the number of people without jobs remained twice as high as before the pandemic.

Although it is too early to draw conclusions about the long-term effects of the pandemic, experience has shown that unemployment tends to persist, and the curtailment of educational services during the pandemic may undermine job opportunities for people that was in their prime youth under the pandemic. Further, reduced social contact and less physical activity may have long-term effects on health. But, (Norwegian Coronavirus Commission, 2021b) considers presently that there very little is known about the potential long-term extent of these negative effects.

As such, the report from the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a) concludes that there is room for improvement in several areas of how the Norwegian Government and the public sector handled the COVID-19 pandemic. Further the report creates a solid foundation to understand the situation the Norwegian society faced because of the pandemic.

2.1.4 The findings from the Expert Groups Code Review of Smittestopp

Prior to the launch of the Smittestopp-app, the process, functionality, security and privacy intrusiveness of the software received massive criticism (Moe, 2020) in the press, social media and blogs stating that the application has severe challenges related to information security and privacy. The criticism originated from a broad spectrum of expertise including software developers. IT-professionals, information security experts, journalists, and lawyers.

As a response to this criticism, the Norwegian Ministry of Health and Care Services (HOD) appointed by 8th of April an independent expert group (Ministry of Health and Care Services, 2020a) assigned to review the Smittestopp software solution as a whole. The mandate (Ministry of Health and Care Services, 2020b) describes the expert groups assignment as two deliverables:

1. A publicly available report reviewing whether the Smittestopp software solution takes proper care of information security and privacy.
2. A report excerpt from public disclosure delivered to Simula, Norwegian Institute of Public Health (NIPH) and HOD identifying possible information security vulnerabilities that must be rectified.

According to the public available report (Lilleng et al., 2020) the Smittestopp software solution has three overall architectural components:

- The app (Android or iOS) installed on the citizen's mobile phone
- A cloud solution based on Microsoft Azure delivered by Norwegian Health Net (NHN)
- Web applications delivered by NIPH and NHN

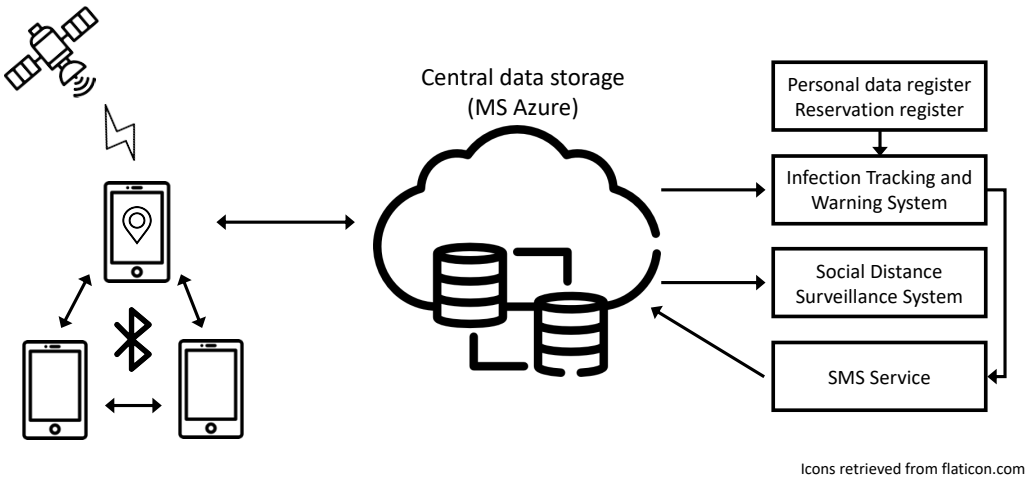

Figure 8: Smittestopp; Architectural overview and data flow (Lilleng et al., 2020)

The summary of the Smittestopp review in this study is limited to the information available in the pubic report (Lilleng et al., 2020).

The expert group categorize findings in three categories: the app, the backend system and warning system. According to (Lilleng et al., 2020), findings related to the app are mainly collection of data beyond what is listed in the privacy policy of Smittestopp (app-version, telecom operator, device description, etc.). Expert group states the app user should have the possibility to opt out the collection of this data in the onboarding process.

Reported findings related to the backend is mainly related to the session handling between the user device and Azure IoT Hub[2]. The session handling is implemented as an everlasting connections string. This is a vulnerability enabling replay attacks or spoofing if only one legitime transmission is recorded by an adversary and reused.

The report points out that meta information (what, who, when) related to the data collected is deleted when the user removes the app. In addition, the citizens should have access to collected information through a separate system.

The expert group reports that the Smittestopp solution warning system suffers from poor source code quality. This results in a code base with low maintainability, and this can further lead to issues related to security vulnerability. Further, the report finds weaknesses in methodologies used in the implementation of the warnings system, and the choice as SMS as a communication channel. SMS is an unsecure channel exposed both for fraud and spoofing.

Combining the two purposes of data collection in the Smittestopp application, virus tracing and evaluation of infection control measures, is challenging. This relates both to the target number of active users estimated to experience effect (Brækhus, 2020) of the application and the intrusiveness of Norwegian citizens privacy. Regarding active users required to

[2] Managed service to enable bi-directional communication between IoT devices and Microsoft Azure (https://azure.microsoft.com/en-us/services/iot-hub/)

trace virus effectively was estimated to be 60% of the Norwegian population. According to (Lilleng et al., 2020) this is an ambitious goal. On the other hand, only 10% active Norwegian users are required to get sufficient data for evaluation purposes of infection control measures (Lilleng et al., 2020). By bundling two objectives for data collection, more Smittestopp users may download the application. But since there was no possibility to opt out of data collected for other purposes than infection control, the legal foundation for the application was not considered to comply with GDPR.

Centralized data storage is considered to give higher data quality than data stored locally og each user device, and the short time-to-marked also advocates for selecting a centralized data storage at least to other options was available like the Google and Apple Exposure notification API (Apple and Google, 2020). On the other hand, a data leakage of such vast amount of personal data due to a hacker attack or technical failure would cause devastating consequences.

Collection of users GPS data is only necessary for research purposes and evaluation of infection control measures. Thus, the virus tracing function could be fulfilled without collecting user locating GPS data.

Usage of Google and Apple Exposure notification API was not technical feasible when the expert group was reviewing the Smittestopp.

Further the method, *k-anonymity*[3] (Sweeney & Samarati, 1998), used to anonymize user data is not considered sufficient to secure citizens privacy. The report recommends applying a stronger methodology for data anonymization like *differential privacy*[4] (Cheruvu, 2018; Dwork, 2011).

Open sourcing Smittestopp is considered by the expert group as a mean to ensure a robust and secure solution by enable continuously review, improvement and bug-fixing by a large community.

Smittestopp is categorized as type of digital solution expected to evolve rapidly. Thus, the methodology used for software development must be based on an agile and iterative approach.

The expert group summarize findings in two statements; both information security and data privacy related to Smittestopp is not sufficiently protected.

Finally, the expert group gave the following recommendations related to Smittestopp version I:

- Split objectives for data collection and make it possible to opt out
- Remove all unnecessary data

[3] K-anonymity is a key concept that was introduced to address the risk of re-identification of anonymized data through linkage to other datasets. For k-anonymity to be achieved, there need to be at least k individuals in the dataset who share the set of attributes that might become identifying for each individual. (https://www.privitar.com/blog/k-anonymity-an-introduction/).

[4] "Differential privacy describes a promise, made by a data curator to a data subject: you will not be affected, adversely or otherwise, by allowing your data to be used in any study, no matter what other studies, data sets, or information from other sources is available" (Dwork, 2011)

- Implement safer methodology for anonymization (differential privacy where data is retrieved for aggregated data sets
- When the validation period is over, migrate to a distributed solution
- Migrate to a distributed solution for data collection
- Use Open Source as much as possible as the source code
- Continually review the solution as such, the data processing purpose, and the effect of the solution

The report from the expert group (Lilleng et al., 2020) gives this research insight in state of the first version of the Smittestopp application with respect of matters related technical, privacy and information security. Thus, the findings of the report are a valuable information resource in the Root-cause analysis process conducted in this research.

2.2 Related work

This chapter elaborating the work related to this study. In sum the related work is a collection of two categories:

- Literature review of selected work related to Root Cause Analysis (RCA)
- Related work to tools, methods and methodologies applied in the research

The literature review in chapter 2.2.1 below can at largely by summed up that the reviewed work is relevant with respect to Root-cause analysis, but they do not fulfill the requirements to the Root-cause analysis in this research: the perspectives of multi-layer socio-technical systems and systems dynamics.

As such the rest of the chapters below elaborates tools, methods and methodologies applied in the research and that further as components in the research process proposed in chapter 3.2 below. The topics covered in these chapters are:

- Socio-technical framework for digital contact tracing
- Socio-Technical System models
- Security by Consensus (SBC) models
- Group Model Building
- System Dynamic Modelling
- Ishikawa Diagrams (Double-Q Diagrams)
- Behavior Over Time (BOT) Diagrams
- Cynefin – Framework for sense-making in a complex and complicated world

2.2.1 Review - related work Root Cause Analysis

This chapter reviews a selection of related work regarding Root Cause Analysis (RCA):

- “Empirical Case Studies of the Root Cause Analysis Method in Information Security” (Wangen et al., 2018)
- “An Information Security Management for Socio-Technical Analysis of System Security” (Huynen & Lenzini, 2018)
- “Root Cause Analysis (RCA) As A Preliminary Tool Into The Investigation of Identity Theft” (Abubakar et al., 2016)

The review of the related work sums up that all has included socio-technical elements in the research. Even so, from a socio-technical point of view, none of them includes socio-technical and system dynamic analysis that emphases interaction and interdependencies between multiple socio-technical systems. As such, although the reviewed work is relevant with respect to Root-cause analysis, they do not fulfill the requirements to the Root-cause analysis in this research: the perspectives of multi-layer socio-technical systems and systems dynamics.

2.2.1.1 Review 1: "Empirical Case Studies of the Root Cause Analysis Method in Information Security" (Wangen et al., 2018)

"Empirical Case Studies of the Root Cause Analysis Method in Information Security" (Wangen et al., 2018) adopts the seven-step RCA-process proposed by (B. Andersen, 2006):

1. *Problem understanding*
2. *Problem Cause Brainstorming*
3. *Problem Cause Data Collection*
4. *Problem Cause Data Analysis*
5. *Root Cause Identification*
6. *Problem elimination*
7. *Solution implementation*

The study (Wangen et al., 2018) applies the RCA-process above on three case studies.

- Comparison of information security risk assessment and RCA results from an analysis of an issues related to access control violations
- Test of RCA analysis as a tabletop tool by modelling an information security incident primarily through available technical documentation
- Determine the Root-causes of a denial-of-service incident at small security awareness organization

(Wangen et al., 2018) identified the tools listed in Table 1 below in the selected case studies supporting the RCA-process steps. Note that in phase 2 "Problem Cause – Brainstorming" no tool was identified.

RCA Phase	Tool name
1. Problem Understanding	Performance Matrices
	Critical Incident
	Swimlane Flowchart
2. Problem Cause - Brainstorming	
3. Problem Cause - Data Collection	Interviews
	Check Sheet
	Incident Data Analysis
4. Problem Cause - Data Analysis	Affinity Diagram
	Relationship Diagram
5. Root Cause Identification	Fishbone Diagram (Ishikawa Diagram)
	Five Whys
6. Problem Elimination	Systematic Inventive Thinking
	Countermeasures Matrix
7. Solution Implementation	Tree Diagram

Table 1: RCA-tools used in selected case studies (Wangen et al., 2018)

From a socio-technical analytic point of view, all the selected cases studies in (Wangen et al., 2018) seems to operate in a single socio-technical system. Even, so the work does not

document the socio-technical systems in action using socio-technical modeling (Kowalski, 1994a) or demonstrate the dynamics in the cause-effect relationship by applying system dynamic modelling (Dangerfield, 2020; System Dynamics Society, 2020).

2.2.1.2 Review 2: "An Information Security Management for Socio-Technical Analysis of System Security" (Huynen & Lenzini, 2018)

"An Information Security Management for Socio-Technical Analysis of System Security" (Huynen & Lenzini, 2018) is concerned about the technical and social aspects at the Root-causes of security incidents and how they can hide security vulnerabilities. With respect to this concern (Huynen & Lenzini, 2018) propose a methodology supporting analysts to reason about the socio-technical causes of observed incidents.

(Huynen & Lenzini, 2018) name the methodology S-CREAM (Cognitive Reliability and Error Analysis Method for Socio-Technical Security) is based on the RCA-process CREAM (Cognitive Reliability and Error Analysis Method) (Hollnagel, 1998).

There are five challenges (Huynen & Lenzini, 2018) aim to cover in the proposed methodology related to migrate RCA-methodologies from a safety to a security context:

C1: Addressing the lack of knowledge and structured data
C2: Investigating Attacks
C3: Creating reusable knowledge
C4: Match patterns of known attacks
C5: Being flexible

The proposed methodology consists of four steps:

1. Data Collection and Investigations (address C1)
2. Retrospective Analysis (address C2)
3. Generalisation (address C3)
4. Security Analysis (address C4)

C5, Being flexible, is addressed by offering customization of the tool related to S-CREAM.

In (Huynen & Lenzini, 2018) the methodology is tested on a case of analyzing risks related to the introduction of one-time-password provided by Yubikeys nano USB security token.

The methodology (Huynen & Lenzini, 2018) does include socio-technical elements like human, training, and mental factors. Although, (Huynen & Lenzini, 2018) does not introduce the aspects socio-technical systems or systems dynamics in the proposed methodology for RCA. In addition, the interaction of multiple socio-technical systems is not a topic covered in (Huynen & Lenzini, 2018).

Thus, (Huynen & Lenzini, 2018) seems to be a methodology targeted for cases involving single case and single socio-technical systems in the RCA-analysis.

2.2.1.3 Review 3: "Root Cause Analysis (RCA) As A Preliminary Tool Into The Investigation of Identity Theft" (Abubakar et al., 2016)

"Root Cause Analysis (RCA) As A Preliminary Tool Into The Investigation of Identity Theft" (Abubakar et al., 2016) is provides a discussion and suggestion of how to apply RCA in the investigation of identity theft. (Abubakar et al., 2016) does not propose an own RCA methodology, but refers to (Doggett, 2005) regarding methodology.

Social-technical elements are discussed in (Doggett, 2005) like *law enforcing agencies*, *government policies* and *social engineering*. Further identity theft is presumably a case involving several socio technical systems. But, (Doggett, 2005) does not include any methodologies or models to structure the elements and their relationship. Neither the notion of socio-technical systems or system dynamics.

2.2.2 A socio-technical framework for digital contact tracing

A framework that can serve as a comparable yardstick in similar studies are valuable. This research related to the Norwegian initiative for digital COVID-19 virus tracing. As such the study "A socio-technical framework for digital contact tracing" (Vinuesa, Theodorou, Battaglini, & Dignum, 2020) introduces a method to rate a digital COVID-19 tracing application according to a certain set of 19 predefined characteristics. The characteristics are grouped in:

- Impact on the citizens
- Technology
- Governance of the application

(Vinuesa et al., 2020) rates 4 other digital COVID-19 tracing application the result from those ratings creates a comparable baseline for this study (se Figure 19 and chapter 4.2.3.1 below).

2.2.3 Socio-Technical System models

Problem solving or investigation of incidents rarely results in a single Root-cause. Typically, there is a chain of interacting events of technical and social character that are the combined cause of a given outcome.

The interaction of, and relation between these technical and social variables are often referred to as a *socio-technical system (Cooper & Foster, 1971)*.

Stewart J. Kowalski describes "In IT Insecurity: A Multi-disciplinary Inquiry" (Kowalski, 1994a) elaborates a socio-technical system by adding "Culture"- and "Structure"-subcategories to the social category, and enriching the "Technical" with the subcategories "Methods" and "Machines"

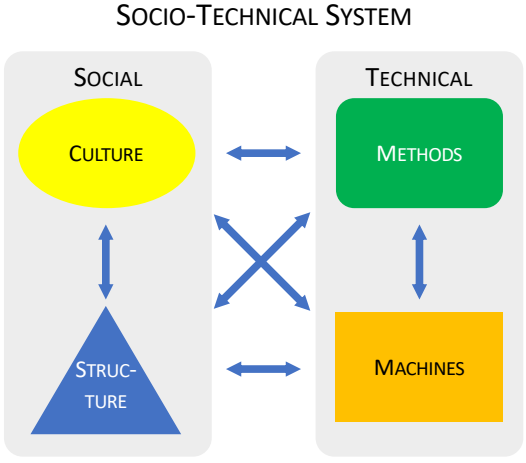

Figure 9: A Socio-technical system (Kowalski, 1994a)

Social-technical systems as shown in Figure 9, serve both as an analytical tool for categorizing and performing root-cause analysis. In addition, the concept can also broaden to model interaction between several related socio-technical systems. E.g., dependencies and interaction between governmental and organization level.

The approach presented in (Kowalski, 1994a) that that adopts the concept with layers of interdependent and interacting socio-technical systems is also applied in this research. Layers of interacting socio-technical applies very well to the research approach in this study since the Root-cause analysis includes a number of actors in each socio-technical system.

2.2.4 Security by Consensus (SBC) models

The origin of the Security by Consensus (SBC) model was presented on the 1990 IEEE Computer Society Symposium on Security and Privacy as a framework for developing secure communication protocols. The model was further developed and published in 1991as a framework for comparing national computer policies (Kowalski, 1994a).

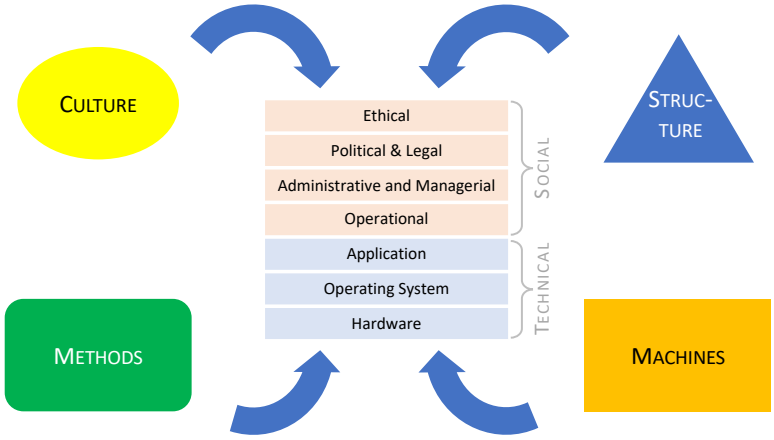

Figure 10: SBC Model and Technology abd Social Change (Kowalski, 1994a)

(Kowalski, 1994a) elaborates the usage of the SBC model as a mental tool for checking potential interdependencies related to technical and social aspects. As shown in Figure 10 above, an element from either the culture, methods, structure, or machines category are inserted and traversed through the layers in the model. At each layer, potential deficiencies are mapped out that hinder the layers to be a complete stack of integrated layers. An example could be the introduction of smart card for identity control (Kowalski, 1994a). The process starts from the bottom checking required hardware, traversing up checking operating system requirements. The process continues until each layer is elaborated related to relevant technical and social aspects.

SBC modeling is a key element in socio-technical analysis (Kowalski, 1994b, 1994c) as it is in this research as well. Thus, this work has applied the concept from that research as part of the overall research process in this study (see chapter 3.2 below).

2.2.5 Group Model Building

Group Model Building is a modelling technique involving a small or larger group in the process of developing models (Richardson & Andersen, 1995). The general idea is to involve participants that possess expertise in a busines domain but are not savvy modelers. Group Model Building is common in the field of system dynamics, and origins back to 1988 from efforts of developing dynamic models related to the health care sector (D. F. Andersen & Richardson, 1997).

To avoid potential pitfalls in the Group Modell Building process, (Richardson & Andersen, 1995) suggests the process is supervised by 5 roles with separate responsibilities to ensure a successful modelling processing. These 5 roles and responsibility are:

Facilitator	Group facilitator and knowledge elicitor. Pays attention to group process, the roles of individuals, and the business of drawing out knowledge and insights from the group.
Modeler/Reflector	Focuses on the model that is being explicitly/implicitly formulated by the facilitator and the group. Both the facilitator and the modeler/reflector are experienced system dynamics modelers.
Process Coach	Focuses on the dynamics of individuals and subgroups within the group. The process coach in (Richardson & Andersen, 1995) tends to serve the facilitator.
Recorder	Writes down or sketches important parts of the group proceedings. Reconstruction of the thinking in the group should be allowed with the notes of the modeler/reflector and the facilitator, and the notes and drawings made by the recorder.
Gatekeeper	Filled by a person within who carries internal responsibility for the project, initiates it, helps frame the problem, and identifies appropriate participants. Further works with the modelling support team to structure the sessions and participates as a member of the group.

(Richardson & Andersen, 1995) suggests that the roles listed above is occupied with different individuals to gain maximum effect, but this is limited by the resources available to act as process support.

To facilitate an effective Group Modelling building approach (D. F. Andersen & Richardson, 1997) suggests the modelling rely on fairly sophisticated pieces of small group process called “scripts”. A script is, in essence, a small recipe describing essential tasks and outcomes. Although a script contains detailed descriptions, it must be expected and taken in to account that the live modelling session deviates from the script. Thus, a modelling session/conference consist of a sequence of such scripts that creates a stream of group activities producing products like stakeholder analysis, problem description, and model sketches.

(D. F. Andersen & Richardson, 1997) outlines numerous scripts like planning modelling conferences, how to schedule conferencing days, clarifying products, recommendations to avoid common pit falls and the essence, the model building process.

This research applies the principles of Group Model Building in the workshops conducted as part of this study (see chapter 3.2). But has not the available resources to staff all the roles described above. Although it is a limiting factor that the researcher implements all roles.

2.2.6 System Dynamic Modelling

To describe System Dynamic Modeling, it is useful to break it down and describe each term separately.

First is the term *system*, as used in the context of this thesis. A *System* (D. H. Kim, 1999) is a group of interacting, interrelated or interrelated parts that together forms a complex and complete whole that has a specific purpose. Further, without the interdependency and common purpose, it is not a system but only a collection of parts.

(D. H. Kim, 1999) lists key characteristics that defines systems:

> ***Systems have purpose***
> ***All parts must be present for a system to carry out its purpose optimally***
> ***The ordering which the parts are arranged affects performance of a system***
> ***Systems attempt to maintain stability through feedback***

Further, elaborating and analyzing systems is referred to as *System Thinking*. According to (D. H. Kim, 1999) system thinking involves an unique vocabulary for describing systemic behavior. Thus system thinking can be thought of as a language for communicating about complexities and interdependencies related to systems (Goodman, 1991). In addition, system thinking offers a range of techniques for visually capturing and communicating system interrelation and behavior (D. H. Kim, 1999).

System Dynamics is a computer-aided approach for strategy and policy design (Richardson, 2020; System Dynamics Society, 2020), and applies to dynamic problems arising in literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.

As such, *System Dynamic Modelling* is practicing one of the tools common to use in *system thinking* to model *system dynamics* in a *system* according to the description above.

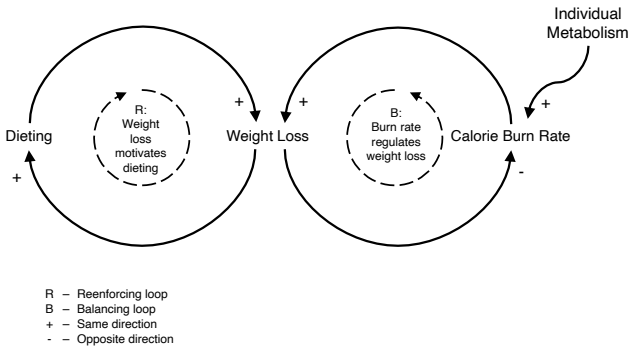

Figure 11: "Limits to Success" System Dynamic Archetype: "The Dieting Bind" (D. H. Kim, 1992)

Figure 11 above, shows a simple example system dynamics Causal Loop Diagram (CLD) model; a "Limits to Success" archetype representing the system dynamics of dieting (D. H. Kim, 1992).

Other related work applies systems dynamics and model as the core of the research. Examples of such are studies of system dynamics related to the COVID-19 pandemic situation (Pornphol & Chittayasothorn, 2020) and innovation (Milling & Maier, 2020).

In contrast this research applies a simplified adoption of systems dynamic modelling that serves as a thinking tool to add a dynamic perspective as one of the perspectives of the Root-cause analysis.

2.2.7 Ishikawa Diagrams (Double-Q Diagrams)

Ishikawa diagrams were created in 1943 Kaoru Ishikawa as a thinking tool. He described usage and application of the diagrams in his book *"What is total quality control? : the Japanese way"* (Ishikawa, 1985) published in 1985.

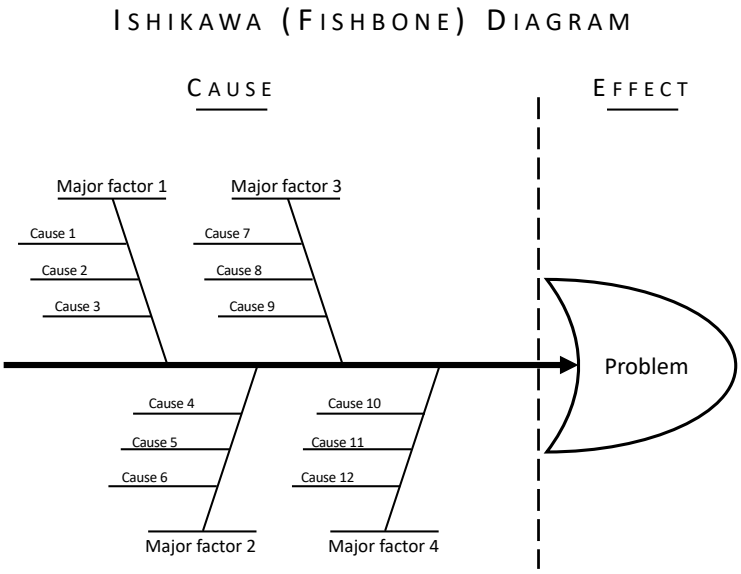

Figure 12: Ishikawa (Fishbone) Diagram (Ishikawa, 1985; Renee & James, 2010)

Ishikawa diagrams are often referred to as "*Fishbone Diagrams"* or *"Double-Q (QQ) Diagrams"* where the "Q"s stand for *qualitative* and *quantitative* (D. H. Kim, 1992).

Figure 12 above shows the concepts of an Ishikawa diagram. The main purpose of the diagram is to serve as a thinking tools in Root-cause analysis. An Ishikawa diagram is separated in a cause side (the "body" of the "fish") and an effect side (the "head" of the "fish") (Renee & James, 2010). At the effect-side the effect, or problem is described. While the cause side is populated with "fishbones" each representing a major factor that potentially could contribute to the described problem or final effect. Each "fishbone" is further populated with "ribs" representing candidate causes found during the root-cause analysis.

This study applies a modified version of the standard Ishikawa diagram shown in Figure 12 above, and aspects from the Socio-technical model described in Figure 9 above.

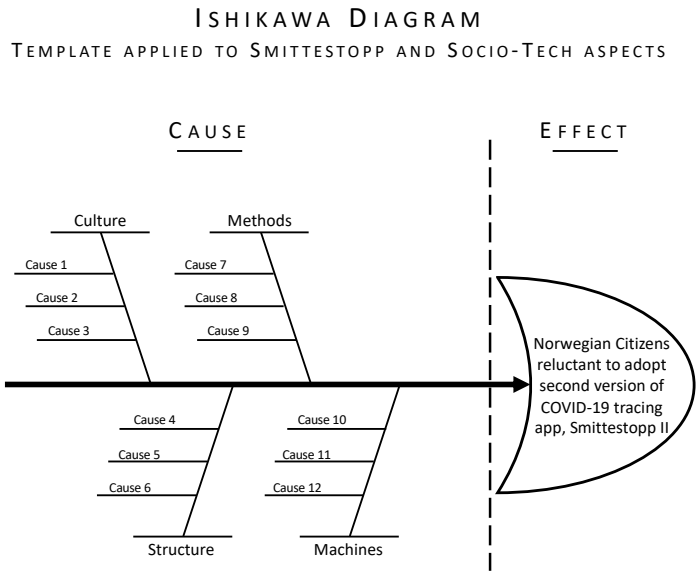

Figure 13: Ishikawa diagram applied to Socio-technical analysis and the failure of the Smittestopp

The purpose of a modified version of a Ishikawa diagram as illustrated in Figure 13 above, is to facilitate for socio-technical system model thinking (Kowalski, 1994a) in an early phase of the Root-cause analysis. Categorizing causes in the Ishikawa diagram in *culture*, *structure*, *methods*, and *machines* eases the creation of the latter socio-technical model as described in chapter 2.2.3 above.

2.2.8 Behavior Over Time (BOT) Diagrams

Behavior Over Time (BOT) diagrams visualize the behavior and development of related variables over time. By visualizing behavior of related variables in the same graph, the graph makes a tool to gain a more explicit understanding of the variables interrelationship (D. H. Kim, 1992).

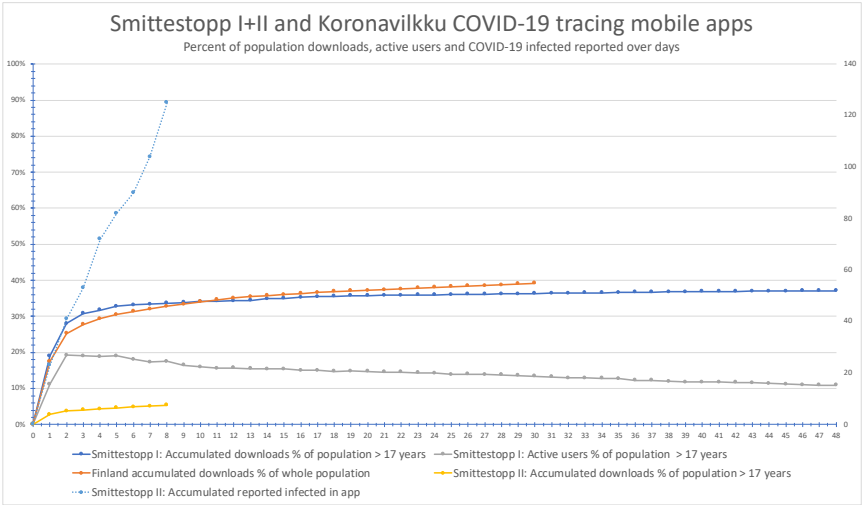

Figure 14: Example BOT Diagram: Market absorption of COVID-19 virus tracing mobile apps

Figure 14 above shows a simple example of a BOT diagram visualizing variables related to trends of downloads, usage, and infection tracing of several COVID-19 virus tracing apps.

According to (D. Kim, 2010) BOT diagrams can help break the data availability dilemma by building causal theories before we gather the necessary data. Developing such causal theories reduces the risk of becoming restricted by the limitations of the data that is readily available. In short, BOTs guide the use of data, but are not data-bound. Thus, the application of BOT diagrams in this research is used as a tool to confirm or refute candidate theories during the Root-cause analysis.

2.2.9 Cynefin – Framework for sense-making in a complex and complicated world

The *Cynefin*[5] *Framework (David Snowden, 2002; D. Snowden et al., 2020; David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)* is a "sense-making" device developed to make sense of the complexities made visible when relaxing the assumption of order, rational choice, and of intent.

As stated in (D. J. Snowden & Kurtz, 2003), the Cynefin framework is derived from several years of action research into the use of narrative and complexity theory in organizational knowledge exchange, decision-making, strategy, and policy-making.

The Cynevin is a *sense making* model and not a *categorization* model. In a categorization framework e.g., four quadrants are often presented by a classic two-by-two matrix. Examples of such are Gartner's Magic Quadrants (Gartner, 2021). Typically, in a categorization framework, there is a category that is the optimal, or preferable, compared to the other categories. In a categorization model *the framework precedes the data*. (David J. Snowden, 2010). This make this type of model very fast in usage since the data is placed directly into appropriate categories in the model and decide accordantly. The danger according to (David J. Snowden, 2010), is that subtle differences are not caught until it is too late. Thus, categorization models are good for exploitation, but are poor for exploration of periods of change.

In a sense making framework as Cynefin, *data precedes the framework*. The framework (or pattern) emerges from the data in a social process (David J. Snowden, 2010). As such, as more data is collected, the context system that is operating becomes evident.

As shown in Figure 15 below, the Cynefin consists of five *domains*[6]: four named, and the central unnamed. The named domains are further categorized in ordered and un-ordered dimensions. The characteristic of the named domains[7] is described below.

[5] *Cynefin,* pronounced ku-nev-in, is a Welsh word that signifies the multiple factors in our environment and our experience that influence us in ways we can never understand (David J. Snowden & Boone, 2007)

[6] The terms "system", "context" and "domain" is used about each other as the framework has evolved (David Snowden, 2002; D. Snowden et al., 2020; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003). This study uses the term "domain".

[7] The naming of some of the domains has changed during the evolution of the framework. This study uses a combination where applicable, to ease understanding and explanation.

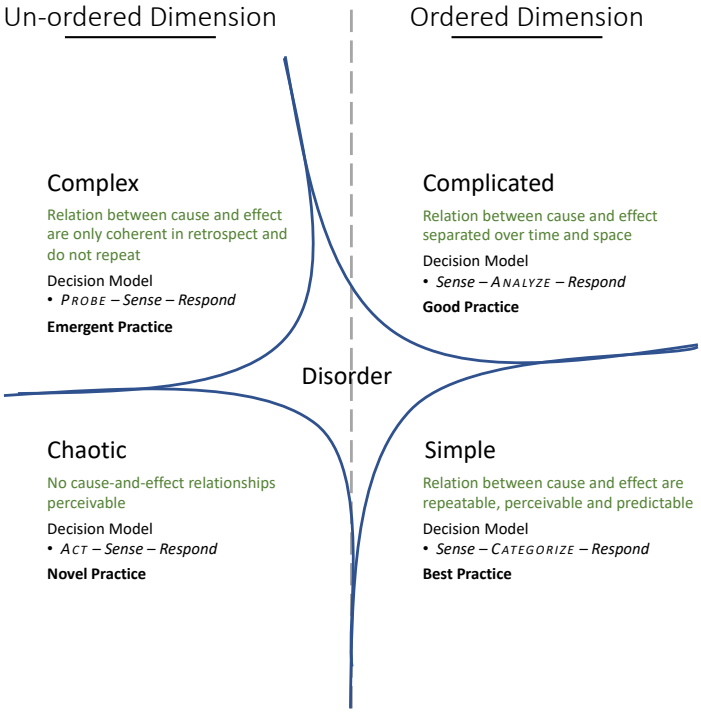

Figure 15: The Cynefin Framework (David J. Snowden & Boone, 2007)

In the center is the fifth domain, disorder, this domain applies when it is unclear which of the other four domains is predominant (David J. Snowden & Boone, 2007).

Analyzing the Norwegian public sector's state of order at certain periods of time is part of this research to understand the context surrounding decisions related to Smittestopp. Thus, the Cynefin framework is applied to conduct such an analysis (see chapter 0 below).

2.2.9.1 Simple (known) Domain – the Domain of Best Practice

Simple domains are characterized by stability and a clear causality between cause and effect that are discernible and obvious to everyone. In this domain of "known knowns", decisions are unquestioned since all parties share a common understanding. Typically, areas that are little subject to change usually belong here.

In the simple domain straightforward management and monitoring is required. The decision pattern in this domain is *sense, categorize, and respond*. As such, assess (sense) the situation, categorize, and then base the response on established practice.

Problems arise in the simple domain as well. First, due to oversimplification potential issues may be incorrectly classified. An example of this risk is leaders who constantly ask for condensed information, regardless of the complexity of the situation.

Second risk in this domain is entrained thinking. That can hinder new ways of thinking if leaders are blinded by perspectives acquired through experience, training, and success.

The third risk is complacency. This can cause a lacking situation awareness and changes requiring swift reactions as ignored.

2.2.9.2 Complicated (knowable) Domain – the Domain of Experts

Complicated domains may contain multiple right answers, and the relationship between cause and effect is typically separated over time and space. This is the realm of "*known unknowns*." Thus, the decision pattern in this domain is *sense, analyze, and respond*.

Good practice, as opposed to best practice, is appropriate in the complicated domain due to that investigating several options is required in this domain.

Experts typically dominate this domain, and that a protentional danger is that they fall into the pitfall of *entrained thinking*. Entrained thinking can cause those innovative suggestions by nonexperts is overlooked or dismissed, and result in lost opportunities.

2.2.9.3 Complex Domain – the Domain of Emergence

This is an un-ordered domain to which much of contemporary business has shifted to the realm of *"unknown unknowns"*. Thus, in this domain, we can only understand in retrospect why things happen, and then maybe discover an emerging pattern by conducting experiments that are safe to fail (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003).

In this domain leaders must patiently allow the path forward to reveal itself. As such the decision pattern in the complex domains is *probe, sense, and then respond*.

Typically, this the domain with now right answers and emergent practices must be applied. Often using an experimental approach with several experiments conducted simultaneously. Successful experiments will then be the foundation for working practices and strategies.

Coming from the chaotic domain, a primary concern is the temptation to fall back into traditional command-and-control management styles. As such, leaders not recognizing that a complex domain requires a more experimental mode of management, may become impatient if not achieving aimed results.

Thus, leaders who try to impose order in a complex context will fail, but those who allow patterns to emerge, and determine which ones are desirable will succeed.

2.2.9.4 Chaotic domain – the Domain of Rapid Response

In a chaotic context, searching for right answers would be pointless. The relationships between cause and effect are impossible to determine because they shift constantly, and no patterns exist. Thus, this is the realm of *unknowables*.

In the chaotic domain a leader must first *act* to establish order, then *sense* where stability is present and from where it is absent, and then *respond* by working to transform the situation from chaos to complexity. The decision pattern in the chaotic domain is then *act, sense, and then respond*.

Yet, the chaotic domain is nearly always the best place for leaders to impel innovation since people are more open to novelty and directive leadership in these situations than they would be in other of the domains above.

2.2.9.5 Disordered Domain – the Domain of not knowing

Shown as the central unnamed area in Figure 15 above, is the fifth and last domain, the disordered domain. This domain describes the state of not knowing which domain currently

operating. If the perception of current domain is divergent, it can cause divergent and possible conflicting actions not appropriate with the actual acting domain. Thus, it is critical to understand which domain before deciding your approach to tackle the future and call for further action.

2.2.9.6 Dynamics of Cynefin domains

According to (D. J. Snowden & Kurtz, 2003) knowledge of how to move between the domains is an important aspect of the Cynefin framework since crossing domains requires a shift to a different model of understanding and interpretation. And as well, a different style of leadership.

Figure 16 below illustrates the dynamics of the in total ten patterns (D. J. Snowden & Kurtz, 2003) describing movement through Cynefin domains.

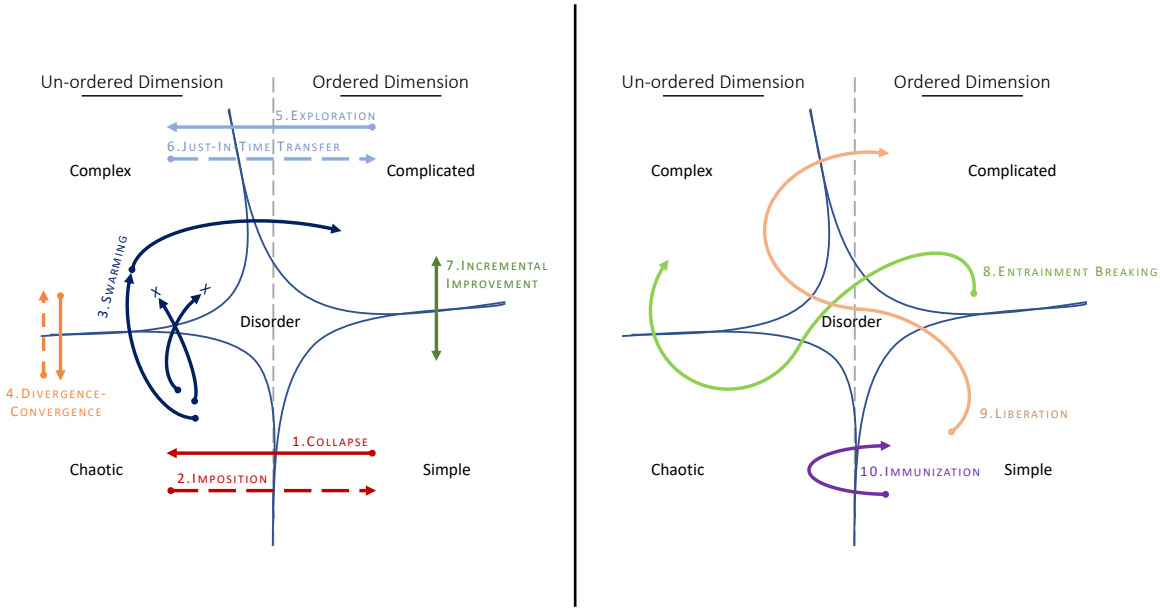

Figure 16: Cynefin dynamics - Moving between Domains (D. J. Snowden & Kurtz, 2003)

Due the scope of this study, only four dynamic patterns are further elucidated:

- Pattern 1: Collapse (Asymmetric collapse)
- Pattern 2. Imposition
- Pattern 3: Swarming
- Pattern 7: Incremental Improvement

Collapse (Asymmetric collapse)

This describes the movement from the known, Simple domain to the disastrous, unknown Chaotic domain. Typically, organizations settle into stable symmetric relationships in known space and then fail to recognize that the dynamics of the environment have changed until it is too late. The longer the period of stability and the more stable the system, the more likely it is for asymmetric threats or other factors to precipitate a move into chaos.

Imposition

The boundary between simple and chaotic domains is the strongest of the boundaries, and are described as a cliff easy to fall (D. J. Snowden & Kurtz, 2003) down from. Thus, moving from Simple to Chaotic domain can happen very quickly. On the other hand, moving directly from chaotic domain to simple requires substantial effort. As such, the imposition pattern is moving from the chaotic to the known, simple domain by force. This is frequently implemented as a Draconian imposition of order, in which the situation is so catastrophic that people accept the previously unacceptable as the price of order. The problem with this dynamic is that it introduces a new kind of stability that in turn becomes more rigid until the new order eventually breaks once again.

Swarming

Although moving from chaotic to simple domain requires substantial effort, moving clockwise from chaos to domains of more order requires less energy than the effort required by *imposition*. As such, the swarming pattern is an agile movement from the chaotic via the complex, then to the knowable, complicated domain. At first, in an emergent manner and then, selectively. A transition from the chaotic to the complex is a matter of creating multiple attractors, or swarming points. The terms "attractors" or "swarming points" can for example be several candidate measures (new procedures, organizational changes, change in management approach, etc.). The agile approach that *swarming* involves is to enforce attractors that proves effect and destroy those not having the desired effect.

Incremental Improvement

Incremental improvement is the iterative movement back and forth from the complicated to the simple domain. In a sense, the cyclic flow of information across this boundary is according to (D. J. Snowden & Kurtz, 2003) the engine of technological growth. An example is periods of disruption during technical growth temporary creates disorder. Simultaneous this release creativity to invent ideas mitigating chaos and further move the system to a domain of more order.

2.2.9.7 Summary of the Cynefin Domains

Each of the domains in the Cynefin sense-making framework are described in the chapters above. In addition to that Figure 17 Decisions in Multiple Contexts: A Leader's Guide (David J. Snowden & Boone, 2007) below sums up each domain's characteristics, decision patterns, danger signals and reactions. The matrix in Figure 17 can be used as a tool to recognize the relevant domain currently acting and provide the relevant measures to cope with the situation.

	The Domain's Characteristics	The Leader's Job	Danger Signals	Response to Danger Signals
Simple	Repeating patterns and consistent events Clear cause-and-effect relationships evident to everyone; right answer exists Known knows Fact based management	Sense, categorize, respond Ensure that proper processes are in place Delegate Use best practices Communicate in clear, direct ways Understand that extensive communication may not be necessary	Complacency and comfort Desire to make complex problems simple Entrained thinking Np challenge of received wisdom Overreliance on best practice if context shifts	Create communication channels to challenge orthodoxy Stay connected without micromanaging Don't assume things are simple Recognize both the value and limitations of best practice
Complicated	Expert diagnosis required Cause-and-effect relationships discoverable but not immediately apparent to everyone; more than one right answer possible Known unknowns Fact-based management	Sense, analyze, respond Create panels of experts Listen to conflicting advice	Experts overconfident in their own solutions or in efficacy in past solutions Analysis paralysis Expert panels Viewpoints of nonexperts excluded	Encourage external and internal stakeholders to challenge expert opinions to combat entrained thinking Use experiments and games to force people to think outside the familiar
Complex	Flux and unpredictability No right answers; emergent instructive patterns Unknown unknows Many competing ideas A need for creative and innovative approaches Pattern-based leadership	Probe, sense, respond Create environment and experiments that allow pattens to emerge Increase levels of interaction and communication Use methods that can help generate ideas, open up discussion, set barriers, stimulate attractors, encourage dissent and diversity, manage starting conditions and monitor for emerge	Temptation to fall back into habitual command-and-control mode Temptation to look for facts rather than allowing patterns to emerge Desire for accelerated resolution of problems or exploitation of opportunities	Be patient and allow time for reflection Use approaches that encourage interaction so patterns can emerge
Chaotic	High turbulence No clear cause-and-effect relationships, so no point in looking for right answers Unknowables Many decisions to make and no time to think High tension Pattern-based leadership	Act, sense, respond Look for what works instead of seeking right answers Take immediate action to reestablish order (command and control) Provide clear, direct communication	Applying a command-and-control approach longer than needed "Cult of the leader" Missed opportunity for innovation Chaos unabated	Set up mechanisms (such as parallel teams) to take advantage of opportunities afforded by a chaotic environment Encourage advisers to challenge your point of view once the crisis has abated Work to shift the context from chaotic to complex

Figure 17: Decisions in Multiple Contexts: A Leader's Guide (David J. Snowden & Boone, 2007)

2.2.9.8 EUs field guide - Managing complexity (and chaos) in times of crisis

March 2021 Publications Office of the EU released "Managing complexity (and chaos) in times of crisis - A field guide for decision makers inspired by the Cynefin framework" (Dave Snowden & Rancati, 2021). According to (Dave Snowden & Rancati, 2021), is this a field guide aiming to navigate in times of crisis using the Cynefin framework(David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) as as a compass. It proposes a four-stage approach:

1. Assess the type of crisis and initiate a response
2. Adapt to the new pace and start building sensing networks to inform decisions
3. Repurpose existing structures and working methods to generate radical innovation
4. Transcend the crisis, formalise lessons learnt and increase resilience

Further, the guide stresses the importance of setting and managing boundaries, building informal structures, keeping options open, distributing engagement, and keeping an ongoing assessment of the evolving landscape.

For all practical reasons, the field guide is an implementation of the Cynefin framework materialized in a manual or suggested process to handle a potential crisis. Thus, the reader does not need first-hand knowledge of the Cynefin frame to use and apply the field guide.

The field guide is not applied in this research as such but included the related work as another practical example and application of the Cynefin framework than this study (see chapter 0 below).

3 Choice of methods

This study is based on analysis of a concrete case related to socio-technical events and dynamics that have been played out and continue to play out.

In addition, the study is based on leveraging both quantitative data related to COVID-19 tracing application in addition to qualitative methodologies supporting Root-cause analysis.

3.1 Research design by applying the "Research Onion"

To guide the research design Saunders Research "Onion" (Karokola, 2012; Saunders, 2007; Schwaferts, 2019) illustrated in Figure 18 below is applied. This research uses the approach suggested in "Applying Saunders Research Onion"(Schwaferts, 2019) to guide the research design.

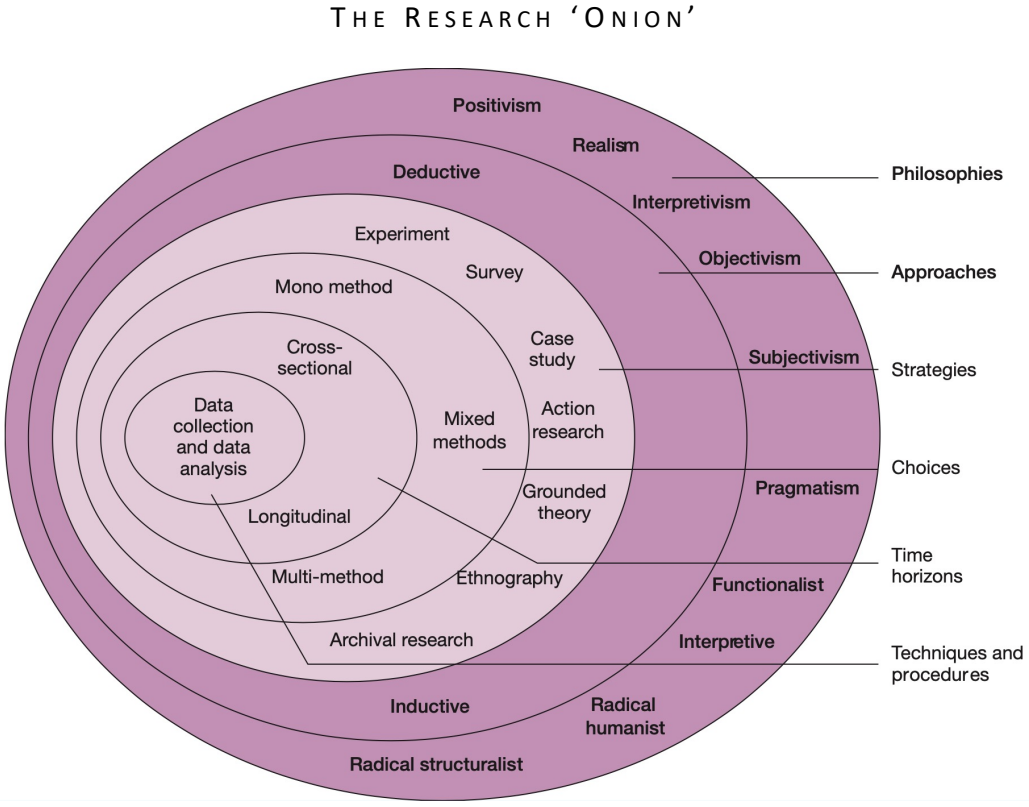

Figure 18: The Research "Onion"(Saunders, 2007)

3.1.1 The Research Onion, Layer 1 – Research Philosophy

The research philosophy decides how we choose to see the world (Schwaferts, 2019). From the candidates listed in layer 1 in the Research Onion the following are evaluated

- Realism
- Positivism
- Interpretivism
- Pragmatism

According to (Schwaferts, 2019) *Realism* is what we see is reality independent of the researcher's mind, and it has a huge importance in the natural science.

Further, *Positivism* is based on that new knowledge derives from positive interpretation of results from experiences or experiments. The target audience is assumed to only accept the research results if they are repeatable and visible facts. This requires a structured data collection based on large samples.

Interpretivism, on the other hand, accepts that the research result is understood and interpreted according to a specific context. To enable the target audience to interpret the findings, we must understand the interpretation based on findings in our field of investigation. Thus, establish understanding of the totality of a situation. Qualitative research helps to understand such specific contexts.

Further, (Schwaferts, 2019) describes *Pragmatism* as that target audience doesn't care about the philosophy, we are free to select the philosophy and methodology according the research question(s).

From the argumentation above, the main research philosophy that aligns best with this study is interpretivism, but since a pragmatic viewpoint also is important in this research pragmatism should not be excluded.

Thus, the research philosophy applied to this research is *primarily Interpretivism and subsidiarily Pragmatism*.

3.1.2 The Research Onion, Layer 2 – Research Approach

Layer 2 is related to choosing the appropriate research approach adequate to the study amongst either *Deductive* or *Inductive* approaches.

Deductive research processes are associated with generating knowledge from theory, and deductive research depends much on an approach that mostly involves collection of quantitative data (Karokola, 2012; Saunders, 2007).

Contrary to this, inductive research processes emphases a deeper understanding of real-world problems. According to (Karokola, 2012) the researcher usually becomes part of the research process, involves the use of qualitative data., and helps in developing artifacts.

In addition, inductive research is characterized by (Saunders, 2007):

- Collection of qualitative data
- More flexible structure to permit changes of research emphasis as the research progresses
- Less concern with the need to generalise

Based on this an *inductive research process* appeared is adequate in this study and as such chosen as the research approach.

3.1.3 The Research Onion, Layer 3 – Research Strategy

The topic of these research is to analyze a series of activities related to a specific case to analyze the relationship cause and effects. In other words, a root-cause analysis. Thus the natural selection for the research strategy is *Case study (Yin, 2018)*.

"Case Study Research and Applications" (Yin, 2018) states three conditions that must be considered when choosing case study as the appropriate research strategy:

1. The form of the research question(s) posed should be "how" and "why".
2. The researcher should have no control over actual behavioral elements.
3. The focus should be on contemporary events as opposed to historical events.

The form of the research questions stated in chapter 1.5 fulfills the condition that the research question(s) should be formed as "how" and "why" questions.

Regarding control over the actual behavioral elements, the researcher has no connection with the Smittestopp app neither the requirements nor decisions related to the life span, evolution, deployment, use of data and strategical decisions. *Thus, the requirement declaring the researcher should have no control over actual behavioral elements*, is present.

(Yin, 2018) use the definition of "contemporary" in the meaning of a fluid rendition of the recent past and the present, not just the present. The Smittestopp app was launched mid-April 2020 to support Norwegian virus tracing under the COVID-19 pandemic. Thus, the evets related to the app started playing out prior to the launch and are still going on in the present time of writing of January 2020. As, such this fits well in the definition of "contemporary" used by (Yin, 2018); *a fluid rendition of the recent past and the present*. In other words, the requirement of focus on contemporary events as opposed to historical is fulfilled.

3.1.4 The Research Onion, Layer 4 – Research Choices

The research has the following data available

- Quantitative data related to downloads of the Smittestopp app
- Series of events and activities from articles, media, and research papers related to the COVID-19 pandemic
- Official reports from the Norwegian public sector

Based on this, the quantitative data is not sufficient be the single source of the analysis. Thus, this study plan to apply a qualitative research approach that use the quantitative data to either confirm or refute candidate hypothesis during the study.

Thus, the study will mix a selection of qualitative and quantitative methodologies.

As such, this study qualifies to choose *mixed methods* is an adequate approach.

3.1.5 The Research Onion, Layer 5 – Time Horizons

Research Onion's layer 4 gives the option of *Cross-sectional* or *Longitudinal* time horizons. According to (Saunders, 2007), longitudinal research is to observe a phenomenon over time. E.g., following a population of people over time to observe relation between environmental changes and health.

Cross-sectional studies on the hand, study of a particular phenomenon at a particular time. (Saunders, 2007) gives an example of such in survey of the IT skills possessed by managers in one organization at a given point in time.

Although this study time horizon is more than one year, it studies one case. Despite the fact that the study includes two version of the Smittestopp app, it does not qualify as an longitudinal research. Thus, this study as a *cross-sectional research*.

3.1.6 The Research Onion, Layer 6 – Techniques and procedures

The inner layer of the Research Onion relates to chosen techniques and procedures for data collection and analysis. The chosen methodologies for data collection are:

- Literature studies to gather relevant events and activities related to Smittestopp
- Retrieve datasets related to Smittestopp downloads and active users

Further, chosen methodologies for data analysis are:

- Cynefin framework for sense-making (D. J. Snowden & Kurtz, 2003) to analyze state of order
- Illustrations of quantitative data in behavior-over-time diagrams
- A series of workshops with a facilitated group producing socio-technical models

3.1.7 The Research Onion, Layer 6 – Research Design Statement

From the discussion above related to layer 1-6 in the Research Onion can be summed up in the following research design statement (Schwaferts, 2019):

> *In order to collect data, this research decides to use literature studies and datasets in a case study. The research use data related to downloads of the Smittestopp app as quantitative data, and in addition qualitative data from the literature studies. Thus, mixed method is the choice of research methodology. Due to the nature of the case study that is a collection of single events, the time horizon is cross-sectional. The approach for analyzing data and results is based on an inductive research process. Since the target audience will interpret the results according to the context related to Smittestopp, but has a pragmatic point of view, the research philosophy is primarily Interpretivism and subsidiarily Pragmatism.*

3.2 Overall Research Process

Based on the discussion in chapter 3.1 above the overall research process chosen in this study should support:

- Mixed Methodology
- Case study research
- Analysis of socio-technical systems and systems dynamics

The design of the research process developed for this research that accommodates this is illustrated in Figure 19 below.

Main components in the process are:

- *Literature and data collection*
- *Analysis of state of order by applying the Cynefin framework*
- *Group model building*
- *Analysis of the results*

Further the group model consists of four workshops with concerning:

1. *Establish common understanding*
2. *Cause and socio-technical brainstorming using Ishikawa and socio-technical models*
3. *Cause and measure elaboration by SBC-modelling*
4. *Exploring dynamical socio-technical cause and effect relationship through system dynamic modelling*

SOCIO-TECHNICAL RESEARCH PROCESS

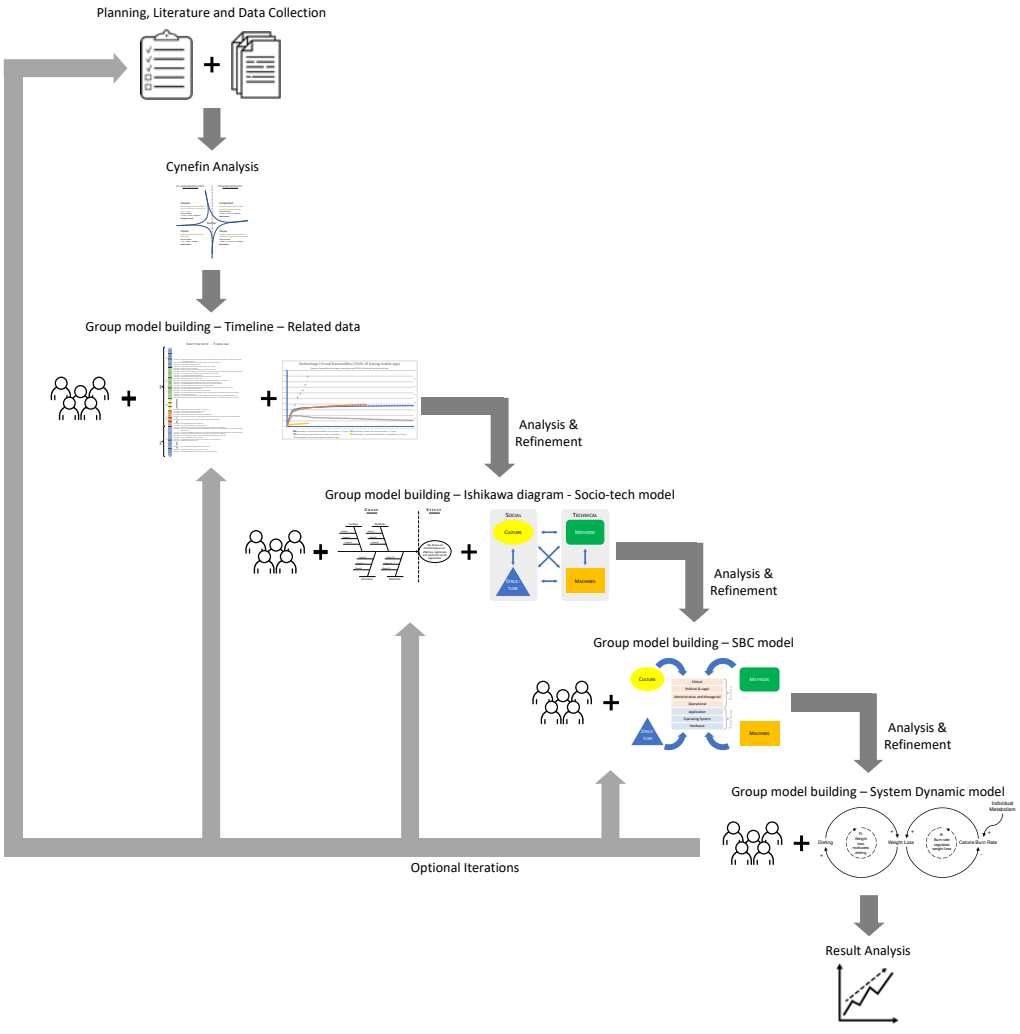

Figure 19: Overall Socio-technical research process

For research to be agile, an iterative approach has been designed into the research process. Further, the process applies a combination of supporting methodologies and models to accommodate the goals to:

- encourage a multi perspective approach
- analyze the dynamics of cause and effects
- consider causes of an eroding character

These supporting methodologies and models (described in detail below) are:

- Socio-technical system models (chapter 2.2.3)
- Security by Consensus (SBC) models (chapter 2.2.4)
- Group Model Building (chapter 2.2.5)
- System Dynamic Modelling (chapter 2.2.6)
- Ishikawa Diagrams (Double-Q Diagrams) (chapter 2.2.7)
- Behavior Over Time (BOT) Diagrams (chapter 2.2.8)

3.3 Methodology for Literature Search and Review

The research methodology chosen is *mixed methodology* with *case study* (Yin, 2018) as the selected research strategy (Saunders, 2007), thus the literature search aims to collect:

1. Literature with topics related to research questions RQ1-RQ4
2. Literature with information related to the Smittestopp case
3. Literature from comparable cases
4. Literature describing relevant studies using methodology applied in this study

Figure 20 below outlines the overall literature search and review process applied in this study.

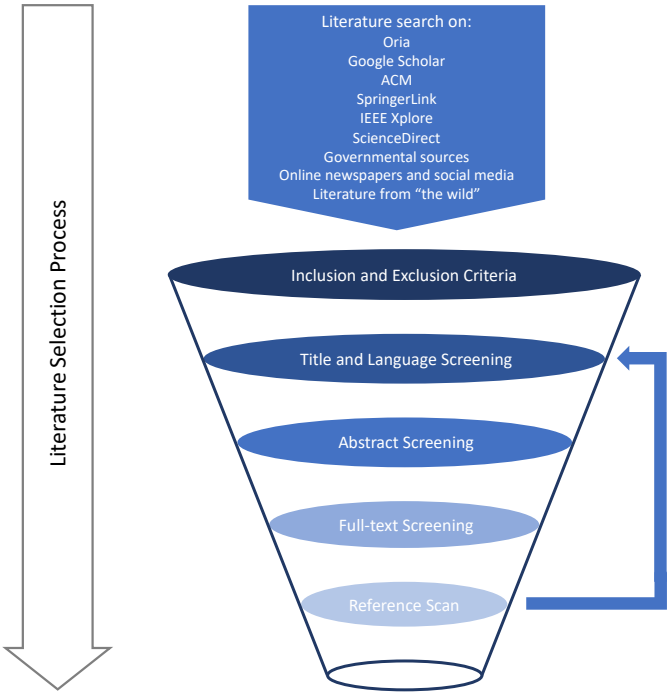

Figure 20: Literature Search and Selection Process

The literature selection process is outlined in Figure 20 above, it contains the following steps

1. Search for literature with search terms in the selected literature sources
2. Apply inclusion and exclusion criteria on search results
3. Scan title and abstract – reject if not relevant, continue process if relevant
4. Scan full text – reject if not relevant, select and continue process if relevant
5. Scan references for other relevant literature sources
6. Move to step 3 for next result in literature

The RQs in this study is framing the topics of relevance in this study. Thus, the literature search will cover topics related to RQ1-RQ4.

Literature of interest regarding the Smittestopp case is related the whole socio-technical system. In addition, literature related to the proposed research process is also of relevance.

Thus, this literature includes the following categories of sources:

CAT1 Databases with scientific papers related to RQ1-RQ3 concerning the COVID-19 pandemic, contact tracing, legal compliance during crisis and other topics related to Smittestopp

CAT2 Online newspapers and media with articles related to RQ1-RQ3 concerning the COVID-19 pandemic, digital virus tracing applications, legal compliance during crisis and other topics related to Smittestopp

CAT3 Database with scientific papers related RQ4 concerning methodologies applied in the research (se chapter 3.2 above)

The category *CAT1* and *CAT3* follow usual approach related to literature search related to scientific papers with a given set of search criteria applied on a selected set of databases.

But *CAT2* required another approach to obtain relevant literature involving continuously monitoring online newspapers, governmental web pages, press conferences, google search, and social media like Twitter and Slack.

Examples of literature of *CAT2* are technical documents of Smittestopp, literature describing events and lifespan of the Smittestopp case, literature reviewing comparable governmental virus tracing solutions, and other literature concerning the Smittestopp socio-technical system.

Although the literature source category CAT 1 and CAT 3 have different approaches to obtain relevant, their search terms and keyword are mainly equal.

3.3.1 Literature sources

The following candidate literature sources is selected for this study:

- Oria
- Google Scholar
- ACM
- SpringerLink
- IEEE Xplore

- ScienceDirect
- Governmental sources
- Online newspapers and social media
- Literature from "the wild"

3.3.2 Keywords and search terms

Below are the keywords used in the literature search.

RQ1-RQ3 "COVID-19", "pandemic", "smittestopp", "contact tracing", "digital contact tracing", "privacy", "human rights", "data privacy", "gdpr"

RQ4 "socio-technical", "socio-technical system", "system dynamics", "Cynefin framework", "root-cause analysis", "security by consensus", "sbc models", "ishikawa diagram", "fishbone diagram", "behavior over time diagram", "bot diagram"

The search terms were constructed by combining keywords listed above.

3.3.3 Literature inclusion and exclusion criteria

To bound the literature search both criteria for inclusion and exclusion is useful for selecting candidate literature and guide the search. The inclusion and exclusion criteria ensure relevance and quality for the selected literature.

3.3.3.1 Inclusion criteria

The *inclusion* criteria for literature research are:

- Articles must be related to the topic and keyword listed above either directly or indirectly
- Articles preferable peer-reviewed
- Qualitative and quantitative studies can be included

3.3.3.2 Exclusion criteria

The *exclusion* criteria for literature research are:

Literature related to RQ1-RQ3 Articles posted on social media with no links or references

Literature related to RQ4 Vendor whitepapers or literature promoting sales

3.4 Ethical and legal considerations

To conduct the Group Modelling described in chapter 2.2.5 and 3.2 above video meetings are applied. Since this involves several persons, privacy needs to be properly taken care of.

Thus, to preserve privacy there exists no recordings of the workshops. Further no personal identifying information from the workshops are used in the study.

Further, the survey conducted in this study of have fully anonymized the results.

Other ethical and legal issues have not been considered as relevant for this study.

4 Results

This chapter elaborates the results in this study. The results are primarily related to three major areas.

- The state of order in the Norwegian public sector according to the Cynefin framework (D. J. Snowden & Kurtz, 2003)
- The outcomes from the Group Modelling workshops
- The applied research process and its contribution

Findings of the Cynefin analysis below indicates that in the early days of the COVID-19 pandemic and Smittestopp the Norwegian public sector was in the Cynefin domain *Chaotic*. Thus, it is fair to presume that the general state of chaos in Norwegian public also affected the pattern of behavior related to Smittestopp's emergence and early production phase.

The Norwegian public sector regained more control during the first three quarters 2020. Thus, the state of chaos was reduced, and the operating Cynefin domain moved out from Chaotic. This study has concluded that *the Norwegian public sector the Autumn 2020 was in either or both Complex or Complicated Cynefin domain*.

Further, the Group Modelling modeling session elaborated below, managed to produce the artifacts planned: Ishikawa diagram, Socio-technical models, SBC-models, and System Dynamic models. But it required more assistance from the facilitator than foreseen under and between the Group Modelling sessions. Further, the process of a multi-perspective Root-cause analysis opened for iterative approach leading up to the found Root-causes and measures.

The results and their relations to the research questions, propositions, and contributions described in chapter 1.5 above is discussed further in chapter 5

Discussion below.

4.1 Finding State of Order using Cynefin Framework

The Cynefin framework for sensemaking (David Snowden, 2002; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) is applied to discuss and categorize the state of order that existed during the time of development and launch of Smittestopp version 1 and 2.

The Cynefin framework is described in chapter 2.2.9 above, and using the framework helps describing the perceived domain of order and the actual domain of order. In addition, the Cynefin framework describes behavior patterns and leadership course of action related to the identified domains. Relevant data sources for this are events related to Smittestopp (illustrated in Figure 2: Timeline Smittestopp I+II above and further detailed in Table 13: Detailed Timeline - Smittestopp I+II, Appendix 1) and the report from the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a).

4.1.1 Discussion of Cynefin Domains – Early days of Smittestopp I

Based on the data sources described above, the following characterized the situation the Norwegian public sector was operating in at the start of the pandemic and the environment affecting the decision to develop a digital virus tracing solution:

- The Government was unprepared when the COVID-19 pandemic arrived with widespread, severe effects
- The government had, in its emergency preparedness efforts, paid little attention to how risk in one sector is affected by risks in other sectors
- The decisions to introduce comprehensive infection control measures on 12 March 2020 should have been taken by the Government, not the Directorate of Health.
- In the beginning of the COVID-19 pandemic, the authorities did not ensure that the infection control measures were aligned with human rights and the Constitution
- During the COVID-19 pandemic, Norwegian authorities have employed infection control measures to an extent no one had previously imagined or planned for
- The Government and the Directorate of Health had been slow in informing municipalities and obtaining their input about decisions to be carried out at the local level
- The Government lacked a plan for handling imported infections when a new wave of the transmission emerged in Europe in autumn 2020
- Discussions related to digital virus tracing between Norwegian Institute of Public Health (NIPH) and contractor (Simula) started without a formal public procurement process
- Massive criticism of Smittestopp I's extensive data collection
- Smittestopp I released after only one month development
- Norwegian Data Protection Authority started control of NIPH's Smittestopp app 8 days after release

This can be further mapped into the characteristics typically describing Cynefin domains (see Figure 17 above for full description). This mapping is illustrated in Table 2 below.

Domain	Domain's Characteristic	Pre-Covid-19	Beginning Covid-19
Simple	Repeating patterns and consistent events	✓	×
	Clear cause-and-effect relationships evident to every-one; right answer exists	✓	×
	Known knows	✓	×
	Fact based management	✓	×
Chaotic	High turbulence	×	✓
	No clear cause-and-effect relationships, so no point in looking for right answers	×	✓
	Unknowables	×	✓
	Many decisions to make and no time to think	×	✓
	High tension	×	✓
	Pattern-based leadership	×	×

Table 2: Pre- and beginning Covid-19 characteristics of Norwegian public sector mapped into Cynefin domains

What Table 2 above describes as the characteristics related to pre-covid-19 is typically what characterize public sector when the society is in a normal situation: decision is based on facts, existing legislation, cause drives effects and best-practices are established and implemented. Further the discission model is Sense-Categorize-Respond.

The conclusion based on this, and the supporting data above, is that *pre-COVID-19 the Norwegian public sector was operating in the Simple Cynefin domain*.

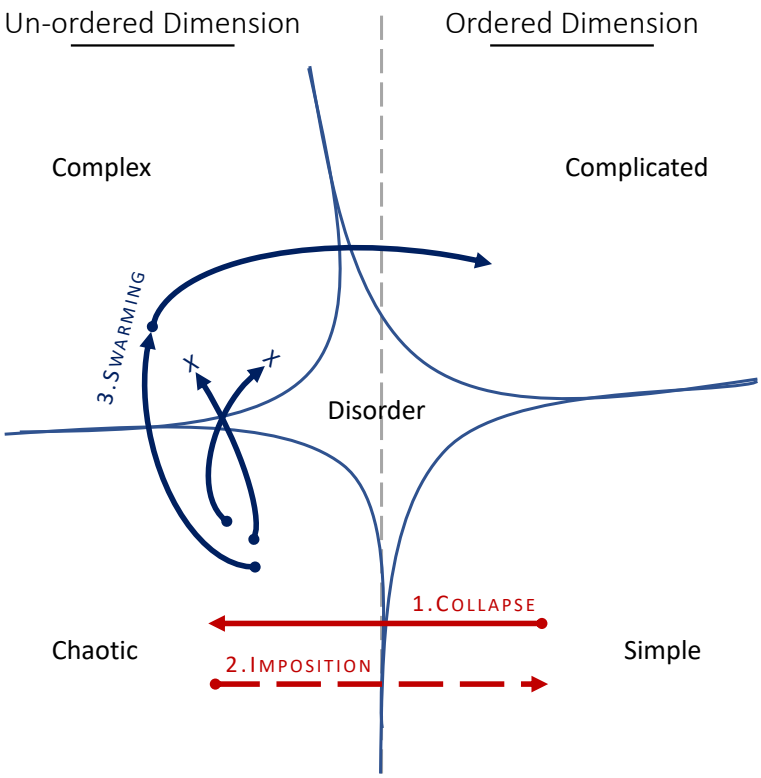

Figure 21: Cynefin Dynamics related to Smittestopp

But, as described in chapter 2.2.9.6 Dynamics of Cynefin domains and (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003), staying in the Simple domain can be quite challenging if unforeseen situations occurs. Regional or national crisis is not necessarily unforeseen situation. For example, the landslide in Gjerdrum municipality (BBCWorld, 2021) was a regional crisis that unfortunately had tragic results with both loss of economic

values and human life. Although this was a crisis, contingency plans for managing the crisis existed and in overall functioned well.

Thus, occurring crisis must be considered as situations the Norwegian public sector must consider as part of their normal operation and responsibility. The Norwegian Directorate of Civil Protection has the overall responsibility to analyze possible national crisis scenarios. The Norwegian public sector should have existing contingency plans for these scenarios. Such analysis (Norwegian Directorate for Civil Protection, 2020) are published on a yearly basis from the Norwegian Directorate of Civil Protection. A national crisis related to a pandemic is part of the analyzed scenarios.

As such, with working contingency plans an emerging crisis should result in chaos although managing the crisis requires amongst other changing decision models, processes, and practices. Thus, although a crisis might result in a push out of the Simple Cynefin domain, working and relevant contingency plans ensures that crisis is handled preferable in the Complicated Cynefin domain with a decision model based on Sense-Analyze-Respond.

This was not the situation at the beginning of the COVID-19 pandemic in Norway. Supported by sources of information outlined in the beginning of the chapter (Figure 2: Timeline Smittestopp I+II, Table 13: Detailed Timeline - Smittestopp I+II, Appendix 1, and (Norwegian Coronavirus Commission, 2021a)) it is reasonable to assume that the Norwegian Government and Public sector were not prepared for the emerging COVID-19 pandemic early 2020. In addition, the existing national contingency plans were not applicable for this kind of crisis. *This resulted in an Asymmetric Collapse (see chapter 2.2.9.6 and pattern 1 in Figure 21 above) in to the Chaotic Cynefin domain*.

In addition, a complicating factor was the pattern of leadership and course of action indicates both the Norwegian Directorate of Health and NIPH were not aware of which Cynefin domain they were operating in. Thus, according to (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) the situation of not knowing the operating domain means being in the domain of Disorder.

Table 3 below further illustrates this in the inconsistency in the patterns of behavior. The table is populated based on the same data sources mentioned above related to both the dynamics Smittestopp and COVID-19 handling in Norway. Further the recognized behavior is mapped into Cynevin characteristics (David J. Snowden, 2010; David J. Snowden & Boone, 2007).

Domain	Actual Domain	Pattern of Behavior	Beginning Covid-19
Simple		Leverage Sense-Categorize-Respond decision pattern	✓
		Act as proper processes are in place	✓
		Practice delegation of decisions	?
		Practice straightforward directives	✓
		Practice best practices	✓
		Practice that extensive communication not needed	✓
Chaotic	✓	Leverage Act, sense, respond	×
		Look for what works instead of seeking right answers	×
		Take immediate action to reestablish order (command and control)	?
		Provide clear, direct communication	×
		Pattern-based leadership	×

Table 3: Pattern of Behavior in the beginning of COVID-19

As Table 3 illustrates the patterns of behavior practiced was for the most part related to the Simple Cynefin domain, and not the required behavior of the actual domain; *Chaotic*. This fits well into the fact that existing contingency plans was not adequate for such a crisis scenario. Thus, this resulted that the pattern of behavior did not adapt fast enough to the requirements emerged by the crisis.

Summary of discussion of Cynefin Domains in the early days of Smittestopp I

As discussed above the Norwegian public sector, including the Norwegian Directorate of Health and the National Institute of Public Health (NIPH), was plunged from the Simple to the Chaotic Cynefin domain when the COVID-19 pandemic emerged. The main reason for this was related to insufficient national contingency plans to handle a crisis such as the COVID-19 pandemic. In addition, the situation was further complicated that operating pattern of behavior was not adjusted to handle a chaotic working environment.

As such, it is fair to presume that the general state of chaos in Norwegian public also affected the pattern of behavior related to Smittestopp's emergence and early production phase.

4.1.2 Discussion of Cynefin Domains – The time of Smittestopp II

28th September 2020 NIPH announced the start of a process to develop a new version of Smittestopp (Norwegian Institute of Public Health, 2020f). In this study referred to as "Smittestopp II".

In the discussion of which Cynefin domain was prominent in the autumn 2020, it is relevant to distinguish two areas of concern:

1. The Norwegian public sector as a whole
2. The sociotechnical system relevant to Smittestopp II

Related to the Norwegian public sector, there is reason to believe that there has been extensive adaption to the situation caused by the pandemic. Along with other infection control measures like use of facemasks and disposable gloves had been secured and stockpiled, other social restrictions to control the pandemic had also been implemented.

This indicates that the Norwegian public sector has moved out from the Chaotic Cynefin domain.

Meanwhile, the second wave of the pandemic was emerging (The Norwegian Government - Primeministers office, 2020; TV2 Norge, 2020) and there was a general concern of imported virus infection from countries like Poland and Lithuania (Aftenposten, 2020). As such, it is reasonable to conclude that at the autumn there still existed a magnitude of disorder in the Norwegian public sector.

Table 4 below sums of an analysis of characteristics related to Cynefin domains present at autumn 2020. *From the findings illustrated in Table 4 it reasonable to assume that in the Autumn 2020, the Norwegian public sector was either or both in the Cynefin domains Complex of Complicated.*

Domain	Actual Domain	Domain's Characteristics	Autumn 2020
Simple		Repeating patterns and consistent events	×
		Clear cause-and-effect relationships evident to every-one; right answer exists	×
		Known knows	×
		Fact based management	×
Complicated	✓	Expert diagnosis required	✓
		Cause-and-effect relationships discoverable but not immediately apparent to everyone; more than one right answer possible	✓
		Known unknowns	✓
		Fact-based management	✓
Complex	✓	Flux and unpredictability	✓
		No right answers: emergent instructive patterns	✓
		Unknown unknows	✓
		Many competing ideas	×
		A need for creative and innovative approaches	?
		Pattern-based leadership	×
Chaotic		High turbulence	×
		No clear cause-and-effect relationships, so no point in looking for right answers	×
		Unknowables	×
		Many decisions to make and no time to think	×
		High tension	×
		Pattern-based leadership	×

Table 4: Cynefin domain characteristics Norwegian public sector Autumn 2020

Dynamics related to sociotechnical system relevant to Smittestopp II is another, but not unrelated discussion. The first version of Smittestopp raised numerous issues related to privacy (Moe, 2020; Norwegian DPA, 2020b; Sandvik, 2020b), software design and information security (Lilleng et al., 2020), and irregularities in the procurement process (Anbud365, 2021).

Studying the NIHP's web page documenting the progress of the Smittestopp II project (Norwegian Institute of Public Health, 2021b) there is a clear indication that previous issues have resulted in an learning process.

The procurement process was revised, the tender documents was made available from NIPH October 7th 2020, and 86 candidate vendors was qualified to bid. Netcompany was awarded the contract to develop Smittestopp II (Norwegian Institute of Public Health, 2020a). Further, the previous issues related to privacy was mitigated. This is indicated by a dialog meeting with the Norwegian DPA October 14th 2020 and the report from the Data Protection Impact Assessment (DPIA) (Norwegian Institute of Public Health, 2020b).

Further reports from acceptance (Netcompany, 2020a) and performance testing (Netcompany, 2020b) indicates that findings in the expert group reviewing Smittestopp I has been addressed (Lilleng et al., 2020).

In addition, issues related to risk management and information security seemed to be addressed based on reports from risk analysis workshops (Norwegian Institute of Public Health, 2020d, 2020e) and penetration testing (BDO, 2020).

This together with the data sources above gives a good basis for the analysis of present Cynefin domain characteristics illustrated in Table 5 below.

Domain	Actual Domain	Domain's Characteristics	Autumn 2020
Simple		Repeating patterns and consistent events	×
		Clear cause-and-effect relationships evident to every-one; right answer exists	×
		Known knows	×
		Fact based management	×
Complicated	✓	Expert diagnosis required	✓
		Cause-and-effect relationships discoverable but not immediately apparent to everyone; more than one right answer possible	✓
		Known unknowns	✓
		Fact-based management	✓
Complex		Flux and unpredictability	×
		No right answers: emergent instructive patterns	×
		Unknown unknows	×
		Many competing ideas	×
		A need for creative and innovative approaches	✓
		Pattern-based leadership	×
Chaotic		High turbulence	×
		No clear cause-and-effect relationships, so no point in looking for right answers	×
		Unknowables	×
		Many decisions to make and no time to think	×
		High tension	×
		Pattern-based leadership	×

Table 5: Cynefin domain characteristics Smittestopp sociotechnical system Autumn 2020

The analysis shows that the state of order related to the Smittestopp sociotechnical system has moved from the Chaotic to the Complicated Cynefin domain. There is reason to believe that this transition has happened according to the Swarming Cynefin dynamic pattern (see pattern 3 "Swarming" Figure 21 above and chapter 2.2.9.6). It is also reasonable to assume that this transition has happened due to the criticism from numerous sources related to the first version of Smittestopp. The issues that was elucidated in version 1 has served as swarming "attractors" (D. J. Snowden & Kurtz, 2003) that has motivated the movement

into a Cynefin domain with more order. But having there should be noted that there was still existing unknows and a state of veiled cause-effect relationship. *This argues for the Complicated Cynefin domain, and not the Simple*.

Summary of discussion of Cynefin Domains related to Smittestopp II

As discussed above the Norwegian public sector regained more control during the first three quarters 2020. Thus, the state of chaos was reduced, and the operating Cynefin domain moved out from Chaotic. The analysis showed that it can be discussed what the relevant Cynefin domain is, but this study has concluded that *the Norwegian public sector the Autumn 2020 was in either or both Complex or Complicated Cynefin domain*.

Further the discussion above related to Cynefin domains and the Smittestopp II sociotechnical system indicates that many of the issues and criticism related to the first version of Smittestopp have been addressed. The result is that the Smittestopp II sociotechnical systems is more associated to a domain of order. Still the Autumn 2020 was still in a state of uncertainty: the second wave of the pandemic was hitting Norway together with general turbulence in the society related to pandemic control measures.

Thus, since the Smittestopp II sociotechnical system was affected by this turbulence, *it is reasonable to conclude that the relevant Cynefin domain is Complicated and not Simple*.

4.2 Results from the Group Model Building

The group model building was organized as a workshop series of 4 sessions with 5 attendees at start (1 withdrew after one session) and the facilitator/researcher in addition.

The attendees in the workshop were highly educated primarily in computer science, have long working experience (more than 10 years), and have practiced in numerous professions in several industries both in private and public sector. The attendees had little to some experience of the concepts and models applied in the workshop. This information is further elaborated in chapter 4.2.1 below.

Further, total expected outcome of all the Group Modelling sessions where:

Session 1
- Understanding of the process of the Group Modelling sessions
- Understanding of the types of models and concepts used in the modelling session
- Understanding of events and activities related to Smittestopp
- Elaborate collected data

Session 2
- A spider diagram rating Smittestopp version I and II according to the criteria described in *A socio-technical framework for digital contact tracing (Vinuesa et al., 2020)*
- An Ishikawa (fishbone) diagram outlining Root-cause candidates
- An overview of the socio-technical model related to Smittestopp
- The evolution of socio-technical models populated with Root-cause candidates
- Cause chain models

Session 3
- Overall SBC-model with causes and related measures
- SBC-models filtering out causes and irrelevant in Smittestopp version 2
- Revisited socio-technical model with remaining Smittestopp II causes and unimplemented measures
- Cause chain model with related measures

Session 4
- Simplified system dynamic model showing the actual dynamics in both Smittestopp I and II with respect to user adoption
- Simplified system dynamic model showing the dynamics in Smittestopp II with respect to user adoption and mitigated challenges

The Group Modelling modeling session managed to produce the artifacts planned: Ishikawa diagram, Socio-technical models, SBC-models, and System Dynamic models. But it required more assistance from the facilitator than predicted under and between the Group Modelling sessions.

Group modelling building concluded that:

> *Smittestopp version I had several deficiencies related to technology, privacy, information security, data management, data governance, voluntary use, and data minimization, and the deficiencies were at large mitigated in version II.*

As such, the sum of issues related to Smittestopp version I elaborated above, created a legacy of negative impression that was inherited by the 2nd version of Smittestopp. Thus, the plausible Root-cause of RQ3 is:

> *Legacy from issues related to the first version was inherited by version two causing erosion of citizens trust, and further a reluctance to adopt Smittestopp II.*

The Group modelling sessions further elaborated possible measure to remove the legacy inherited from Smittestopp I:

> *Measures are related to ensure good trust management and good communication skills, establish measurement of the virus tracing effect, and ensure adequate support capacity.*

This is further elaborated in this chapter

4.2.1 Description of the group

The size of the group attending the Group Modelling workshop was 6 participants including the researcher. After the first session 1 person left the group. The rest of the workshop was completed with 5 participants including the researcher. The researcher served as workshop facilitator, responsible for recording and analyzing the results from the modelling sessions.

Prior to the Group Modelling session, the attendees completed a survey review the groups educational level, area of expertise, working experience, and competence level related to the area of knowledge related to the study. The survey forms can be found in Appendix 5 and detailed results in Appendix 6 below.

As shown in Figure 22 below, the attendees in the workshop are highly educated primarily in computer science, have long working experience (more than 10 years), have practiced a numerous profession in several industries both in private and public sector.

Specifically, the group members consist of 75% at master level and 25 % at bachelor level. Further all is educated in computer science, and 25% is educated in mathematics as well. All group members have more than 10 years of working experience. All has practiced as IT consultants, project managers, and enterprise architects. In addition, 75% of the group members has experience from software development, 25% has been practicing management consulting, and 25% has worked with privacy. None of the group claims the have previous experience with Information Security.

Figure 22: Group modeling attendees' education and working experience

To assist the respondents of the survey to rate their own competence level, Blooms Taxonomy (Patricia, 2010) is applied as a guideline. As such, the competence levels are scored in the range of 0-6 as illustrated in Figure 23 below.

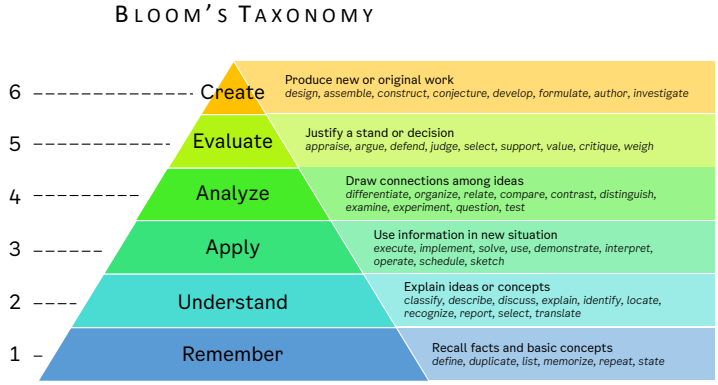

Figure 23: Bloom's Taxonomi (Patricia, 2010)

The competence areas surveyed was:

- Knowledge of Ishikawa (Fishbone) diagrams
- Knowledge of Root-cause analysis
- Knowledge of Security by Consensus (SBC) models and modelling
- Knowledge of socio-technical systems
- Knowledge of System Dynamic Models and modelling
- Familiarity with the Norwegian virus-tracing app, Smittestopp, related events and activities

Figure 24 below shows a box plot of the attendees' competence level before the group modeling workshops.

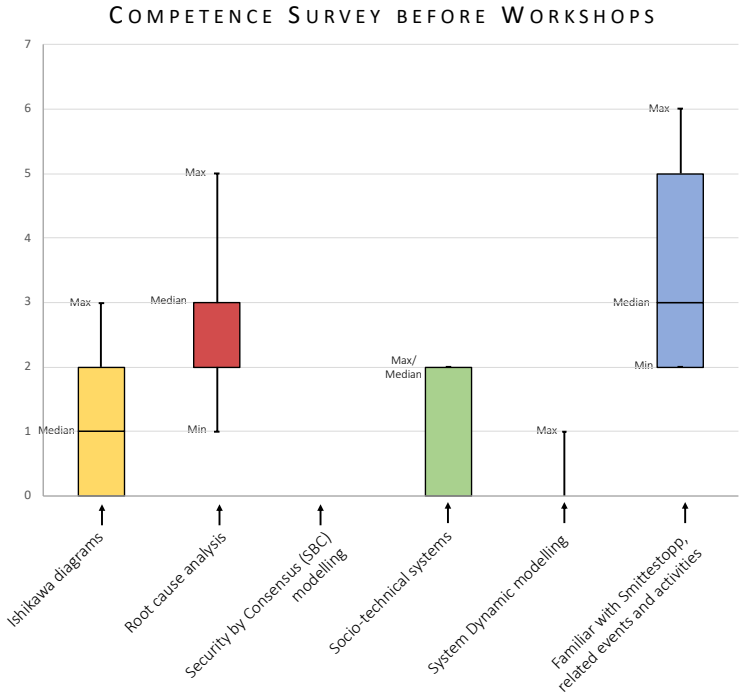

Figure 24: Competence level attendees before workshops

From the survey, it can be interpreted that the attendees have a certain level of knowledge to the Smittestopp app and the related events. Some with deep knowledge. Further, the box-diagram shows that the entire group have experience with Root-cause analysis. The group has some knowledge related to Ishikawa diagrams and socio-technical systems, but knowledge of SBC and system dynamic modelling is nearly non-existing.

As part of this study the competence level was surveyed after the all the Group Modelling sessions was completed. The general idea for repeating the survey was to investigate if the group has gained competence in the areas relevant for the Group Modelling sessions. Figure 25 below shows the result from the repeated survey after the workshops was completed.

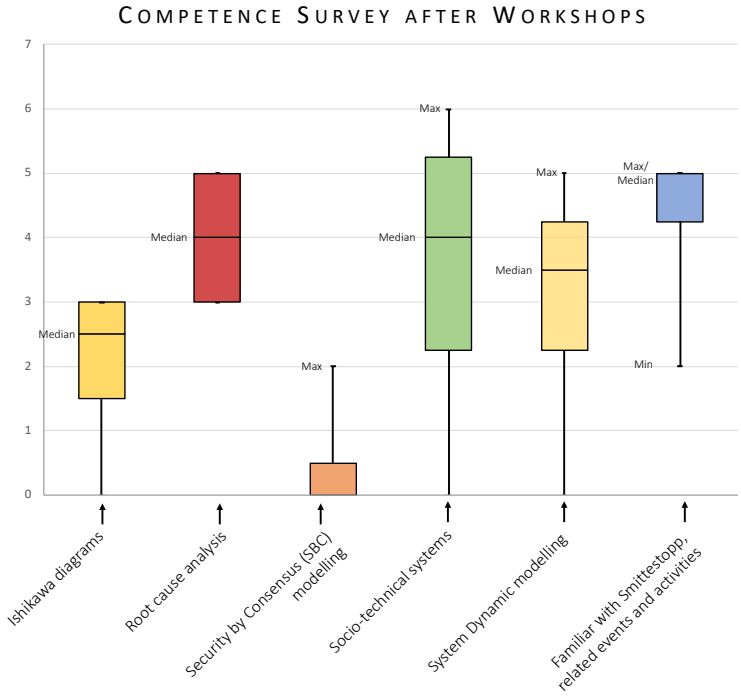

Figure 25: Competence level attendees after workshops

As mentioned above, the surveys population was 4 respondents. Thus, the size of the population is too small to claim that the results are statically significant. Although the results give an indication of learning achieved during the Group Modelling sessions.

To interpret the results in Figure 25, starting with knowledge of Ishikawa diagram the median has moved from 1 to 3. This means according to Blooms taxonomy (Patricia, 2010) that the group gone from *Remember* the concepts to actually *Apply* them. Further, regarding Root-cause analysis the median has increased from 3 to 4, and there no extreme outliers outside second and third quartile. Although the group was already known to the concepts of Root-cause analysis, they have during the workshops gained competence from *Applying* Root-cause analysis, learned not use the concept *Analytically*.

When it comes to Security by Consensus (SBC) modeling, the concept was unknown to the attendees before the workshops and the result after workshops indicates that this was difficult concept to understand since only one of the respondents answered with 2, *Understand,* related to the topic. Thus, the SBC-modelling has reached a level of comprehension on a small part of the group, and the rest of the group had little understanding of the concept even after modelling session. Although, there is no indications that the SBC-modelling was useless, but it required more effort and guidance from the facilitator.

The *Socio-technical* skill was at a median 2, indicating *Understanding*, before the workshops. After the workshop the median has increased to 4 indicating a competence level capable to use the concept of socio-technical systems to *Analyze*. It should be noted that although the group has increased their competence level, there are outlier affecting the median: one respondent claims a Blooms level of 6 *(Create),* and one respondent reports 0. Although, the result indicates that the competence related to socio-technical systems has improved during the workshops.

The Group Modelling session involving system dynamic modelling proved to be the concept most challenging to facilitate. Although the survey shows improvement, and the median is high in the Blooms taxonomy at 5 *(Evaluate)*, the experience from the modelling workshop was that the group could not apply the concept without the facilitator. Thus, the experienced Blooms level near 2, *Understand*.

Already before Group Modelling session started the group had some knowledge of the Smittestopp virus tracing app and the related events and activities. The median improved during the workshop from 3 *(Apply)* to 5 *(Evaluate)*. Although the results show some outliers, it is reasonable to believe that the knowledge related to this area has improved since Smittestopp and related activities was the main topic in all workshops.

Although the population is too small to give statically significant results, the results indicates that group has obtained competence during the Group Modelling sessions in:

- Knowledge of Ishikawa (Fishbone) diagrams
- Knowledge of Root-cause analysis
- Knowledge of Security by Consensus (SBC) models and modelling
- Knowledge of socio-technical systems
- Knowledge of System Dynamic Models and modelling
- Familiarity with the Norwegian virus-tracing app, Smittestopp, related events and activities

4.2.2 First session – Review of Timeline and Quantitative Data

The first Group Modelling session was dedicated to share knowledge related to the Smittestopp application, related events, available data, and the process of the coming workshops.

Thus, the expected outcome was:

- Establish a brief understanding of the process of the Group Modelling sessions
- Establish a brief understanding of the types of models and concepts used in the modelling session
- Establish a common understanding of events and activities related to Smittestopp
- Elaborate collected data

As such the attendees in the group were presented the overall process illustrated in Figure 19 above to prepare the audience the content of coming workshops. Further a brief introduction to Ishikawa diagrams, socio-technical systems, SBC-modelling, and system dynamics was given to the group. In addition, material describing the different concepts was sent per mail in advance of the first session.

To establish a common understanding of events and activities the timeline illustrated in Figure 2 was reviewed. The group had different insights related to Smittestopp, and the timeline was updated because of the review.

In addition, the data and graphs illustrated in Figure 3, Figure 4, Figure 5 and Figure 6 was presented to the group.

The group gained a brief understanding of the process, concepts to be applied, models to model and the Smittestopp timeline during the first workshop. Experience showed that there was too much information to digest for only one workshop. As such, relevant models, concepts, and data had to be repeated each workshop.

4.2.3 Second session – Sociotechnical Brainstorming

The second modelling workshop was related to discussions and elaboration of social-technical aspects (chapter 2.2.3 above), outlining Root-causes and rating Smittestopp version I and II.

Thus, the expected outcome was:

- A spider diagram rating Smittestopp version I and II according to the criteria described in *A socio-technical framework for digital contact tracing (Vinuesa et al., 2020)*
- An Ishikawa (fishbone) diagram outlining Root-cause candidates
- An overview of the socio-technical model related to Smittestopp
- The evolution of socio-technical models populated with Root-cause candidates
- Cause chain models

Further, the background material and data sources for these Group Modelling sessions was the events outlined overall timeline illustrated in Figure 2 above together with the referred information sources in the detailed timeline in Table 13 below. In addition, reports from NIPH (Norwegian Institute of Public Health, 2020a, 2020b, 2020d, 2020e, 2020f, 2021b), the Norwegian DPA (Norwegian DPA, 2020a, 2020b), the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a, 2021b), and reviews of the lifespan of Smittestopp (Sandvik, 2020a, 2020b).

4.2.3.1 Rating Smittestopp according to existing framework

A socio-technical framework for digital contact tracing (Vinuesa et al., 2020) is further described in chapter 2.2.2 above. Part of the workshop was used to rate used to rate Smittestopp version I and II according to the criteria in (Vinuesa et al., 2020). A feedback from the workshop attendees stated that some of the criteria was hard to relate to Smittestopp. In addition, it stated that some criteria were missing. Among them, criteria related to procurement process, communication, and vendor relationships.

Description of the criteria, scoring guide and rating is further detailed in Appendix 4 below.

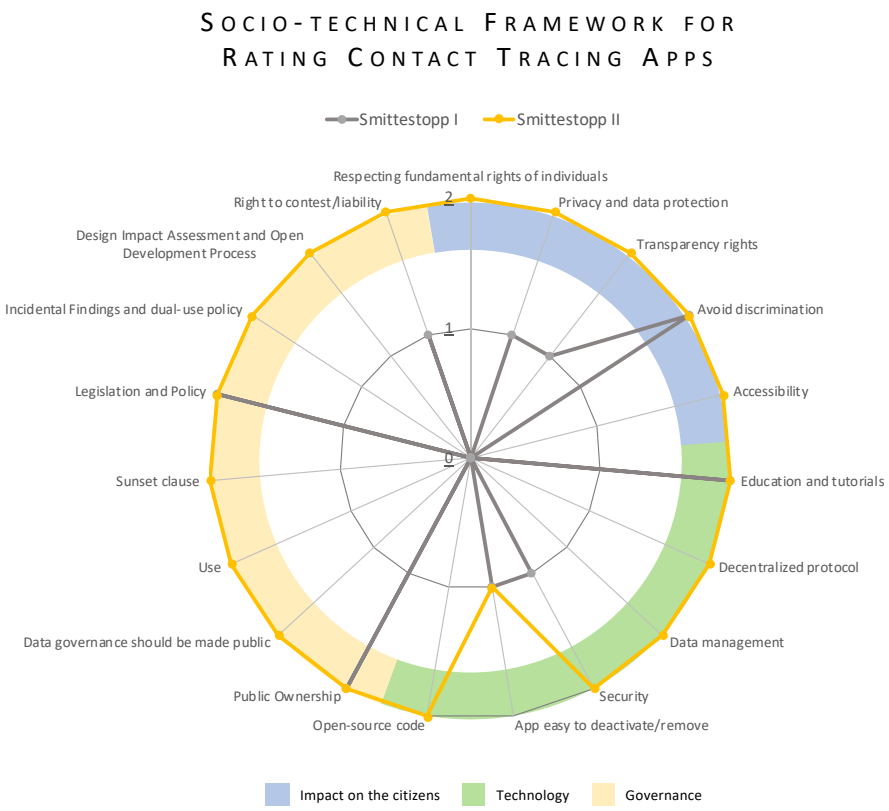

Figure 26: Results Smittestopp I and II - Socio-tech Framework for Rating Contact Tracing Apps (Vinuesa et al., 2020)

The overall impression is that Smittestopp version I had several deficiencies, and the deficiencies were at large mitigated in version II of the app.

Figure 26 above illustrates that Smittestopp had major issues related to all categories included in (Vinuesa et al., 2020):

- Impact on the citizen
- Technology
- Governance

Further detailed results shows that the most important issues in Smittestopp version I were related to *privacy, information security, data management, data governance, voluntary use, and data minimization*.

In addition, another interesting observation illustrated in Figure 26 above is that version II of Smittestopp has perfect rating according to the framework (Vinuesa et al., 2020). All criteria with low rating in Smittestopp I was corrected in the second version of the solution. Thus, the rating of Smittestopp II indicates that is has *little impact on the citizens, is based on sound technology and implement excellent governance*.

These initial findings were further elaborated in the successive Group Modelling sessions.

4.2.3.2 Socio-technical Root-cause brainstorming with Ishikawa diagrams

As described in chapter 2.2.4 above and illustrated in Figure 9, the major interacting categories of socio-technical components in this study is *Culture, Structure, Methods, and Machines (Kowalski, 1994a)*. As such, this study merges these socio-technical categories

with the root-cause brainstorming abilities provided by the nature of the Ishikawa diagram. The result of the merging is illustrated in Figure 13 above. This forms the basis for structuring the root-case brainstorming as illustrated in Figure 27 below.

The initial findings from scoring Smittestopp version I and II using the framework proposed by (Vinuesa et al., 2020) together with the the background material and data sources specified in chapter 4.2.3 above established a foundation for the socio-technical brainstorming.

As illustrated in Figure 27, the final effect of the Root-cause candidates is:

> *Norwegian Citizens reluctant to adopt second version of COVID-19 tracing app, Smittestopp II*

A challenge related the analysis was to simultaneously outline cause candidates related to both versions of the COVID-19 tracing app.

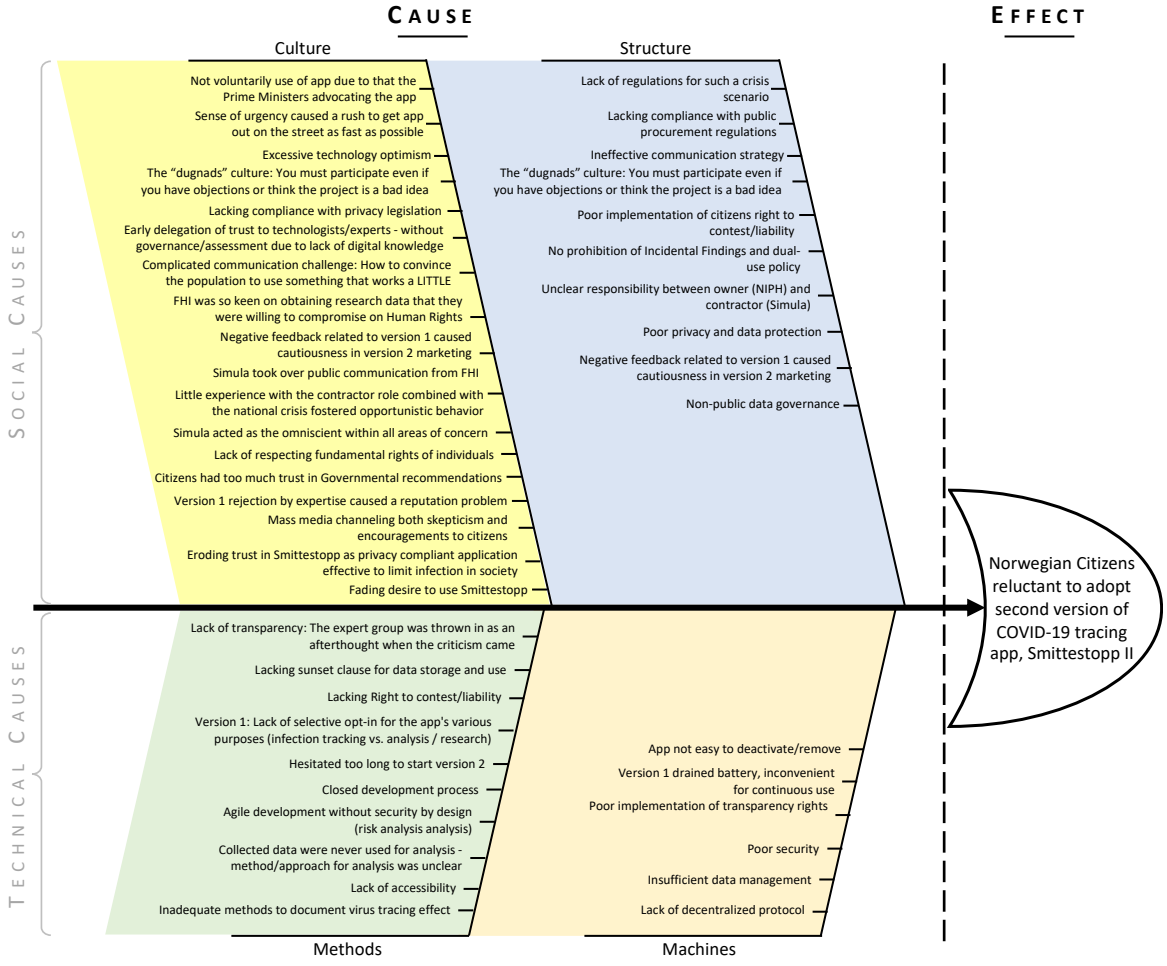

Figure 27: Ishikawa Diagram from Sociotechnical Brainstorming

As illustrated in Figure 27, a major part of the root-cause candidates is related to social causes. Many of these causes relates to the state of order characterizing the Norwegian society at the start on the COVID-19 pandemic and as well the initial phases of the Smittestopp app. As discussed in chapter 4.1.1 above, it is arguable that in the initial phases

of Smittestopp, the Norwegian public sector was operating in the *chaotic Cynefin domain (D. J. Snowden & Kurtz, 2003)*.

Further, the results related to Smittestopp from the session above by leveraging *A socio-technical framework for digital contact tracing (Vinuesa et al., 2020)* was rephrased and populated into the Ishikawa diagram. The candidate Root-causes were categorized according to socio-technical aspects specified above. Examples of such are.

- Lack of respecting fundamental rights of individuals
- Poor implementation of citizens right to contest/liability
- Lacking sunset clause for data storage and use
- Insufficient data management

Other candidate Root-causes found in the workshop session is related to the state of order existing in the initial phases of Smittestopp (chaotic Cynefin domain). Examples are:

- Sense of urgency caused a rush to publicly implement the app as quickly as possible.
- The "dugnads" culture: You must participate even if you have objections or believe the project is a bad idea
- Lack of regulations for such a crisis scenario
- Lacking compliance with public procurement regulations
- Lack of transparency: The expert group was thrown in as an patch when the criticism came

Summary of the social-technical brainstorming

Leveraging a socio-technical modification of the Ishikawa diagram worked well in the group session. It provided a good combination to allow both brainstorming ideas and the possibility to categorize Root-cause candidates into a socio-technical structure.

The list of cause candidates illustrated in Figure 27 above shows that there is a majority in the social cause category. There is a split between culture and structure categories, with the major causes represented in the culture category.

The results from the social-technical brainstorming shows that the nature of the cause candidates is oral in nature and is not necessarily related to facts retrieved from reports or articles. Although, the Root-cause candidates serve as a good foundation for the further process that address these issues.

4.2.3.3 Smittestopp overall socio-technical system

The second workshop involved discussion related to the socio-technical system related to the Smittestopp ecosystem. The discussion concluded with four major actors relevant to this study:

- *The Government of Norway*
- *The Bureaucracy* represented by the Norwegian Institute of Public Health (NIPH)
- *The Contractor*. This role is filled by two companies: Simula in Smittestopp I and Netcompany in version II
- *The Norwegian Citizen*

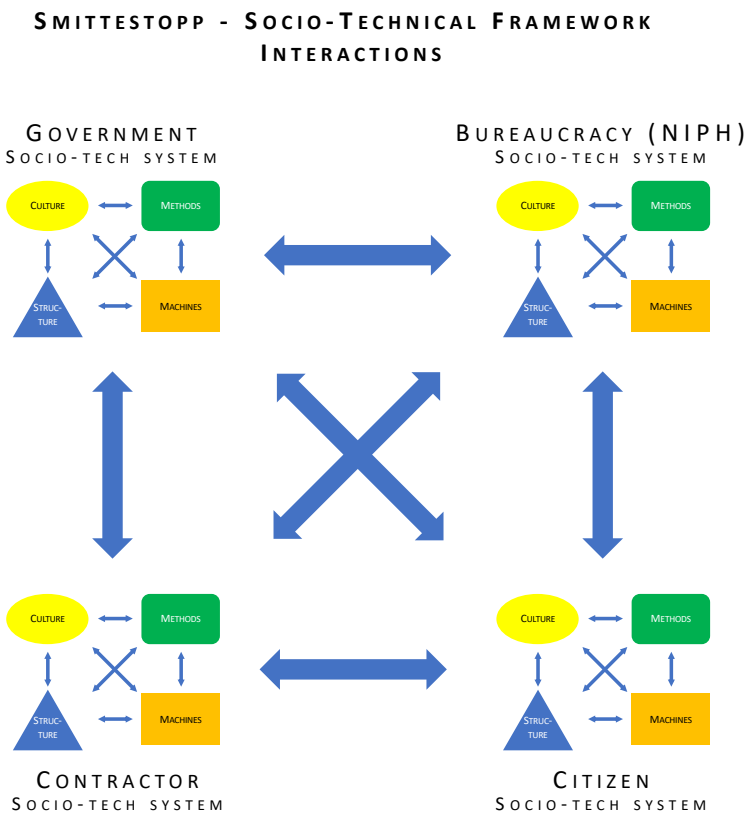

Figure 28: Socio-technical system related to Smittestopp

The socio-technical system related to these actors and their potential interactions is illustrated in Figure 28 above. Note that each actor can be viewed as a separate socio-technical system. This can also be viewed as interacting layers of socio-technical system, and this will be further elaborated below.

4.2.3.4 Smittestopp Root-cause analysis using socio-technical system

Based on the results from the socio-technical brainstorming described above and the overall socio-technical system illustrated in Figure 28 above, the Group Modelling session continued with populating the socio-technical system with the Root-cause candidates from the socio-technical Ishikawa diagram illustrated in Figure 27 above.

Further, to stay focus on when elaborating relevant causes, the investigated effect is as mentioned above:

> *Norwegian Citizens reluctant to adopt second version of COVID-19 tracing app, Smittestopp II*

As such, population of the socio-technical system with causes in Group Modelling session was conducted in an iterative manner outlining chain of causes, removing the redundancies and simplification of the model.

Figure 29, Figure 30, and Figure 31 below illustrates the refining and iterative process during the Group Modelling workshop ending up with final version of the social-technical system illustrated in Figure 31.

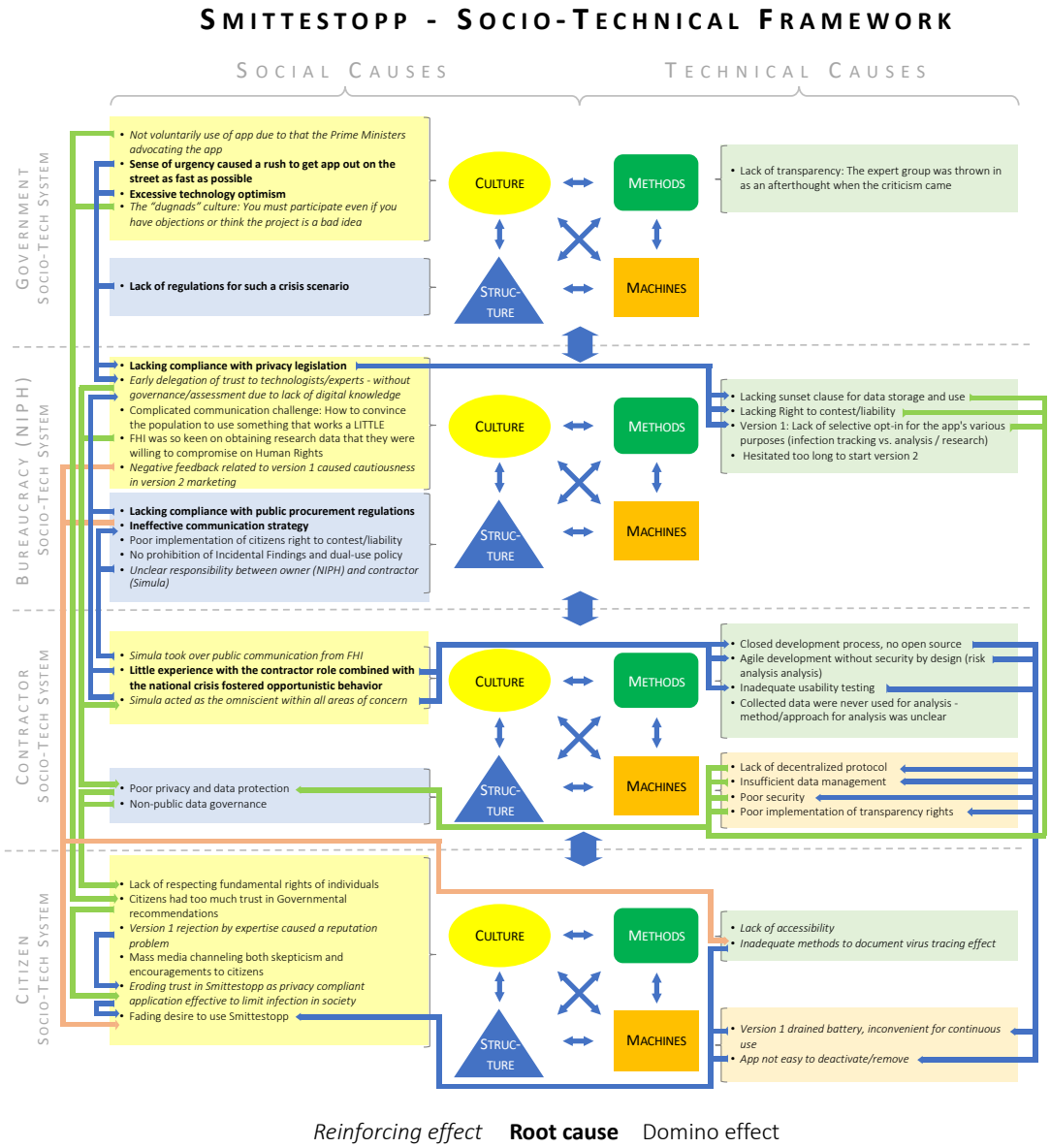

Figure 29: Smittestopp Socio-technical system – initial version

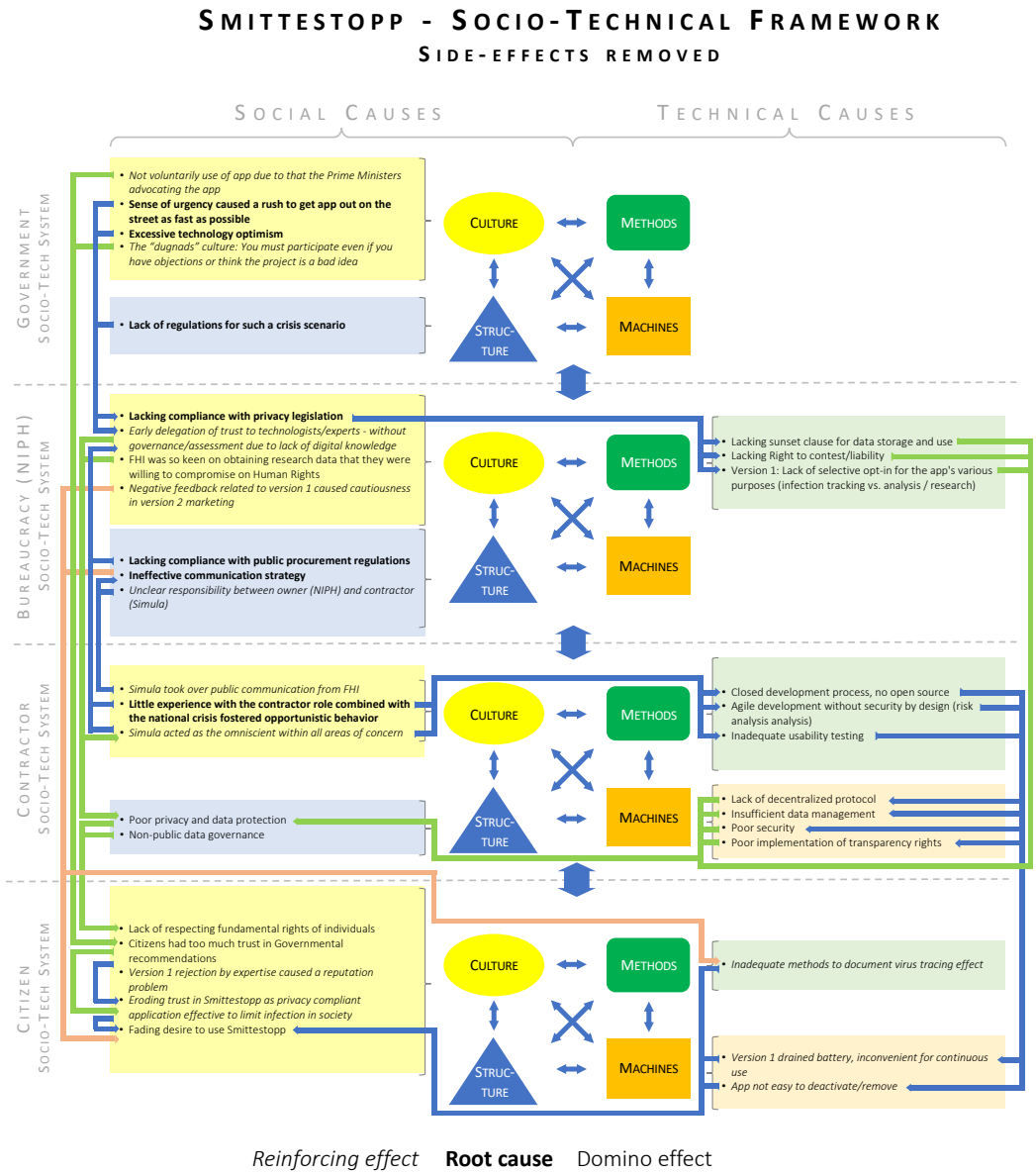

Figure 30: Smittestopp Socio-technical system - side effects removed

As mentioned above, the final and simplified version of the socio-technical system is illustrated in Figure 31 below. In this version of the socio-technical system redundant causes, causes expressed in orally forms, and causes considered as side effects, removed. The process of simplification was:

- The Group Modelling faciliatory created suggested simplified models
- The attendees reviewed, and eventually accepted the models

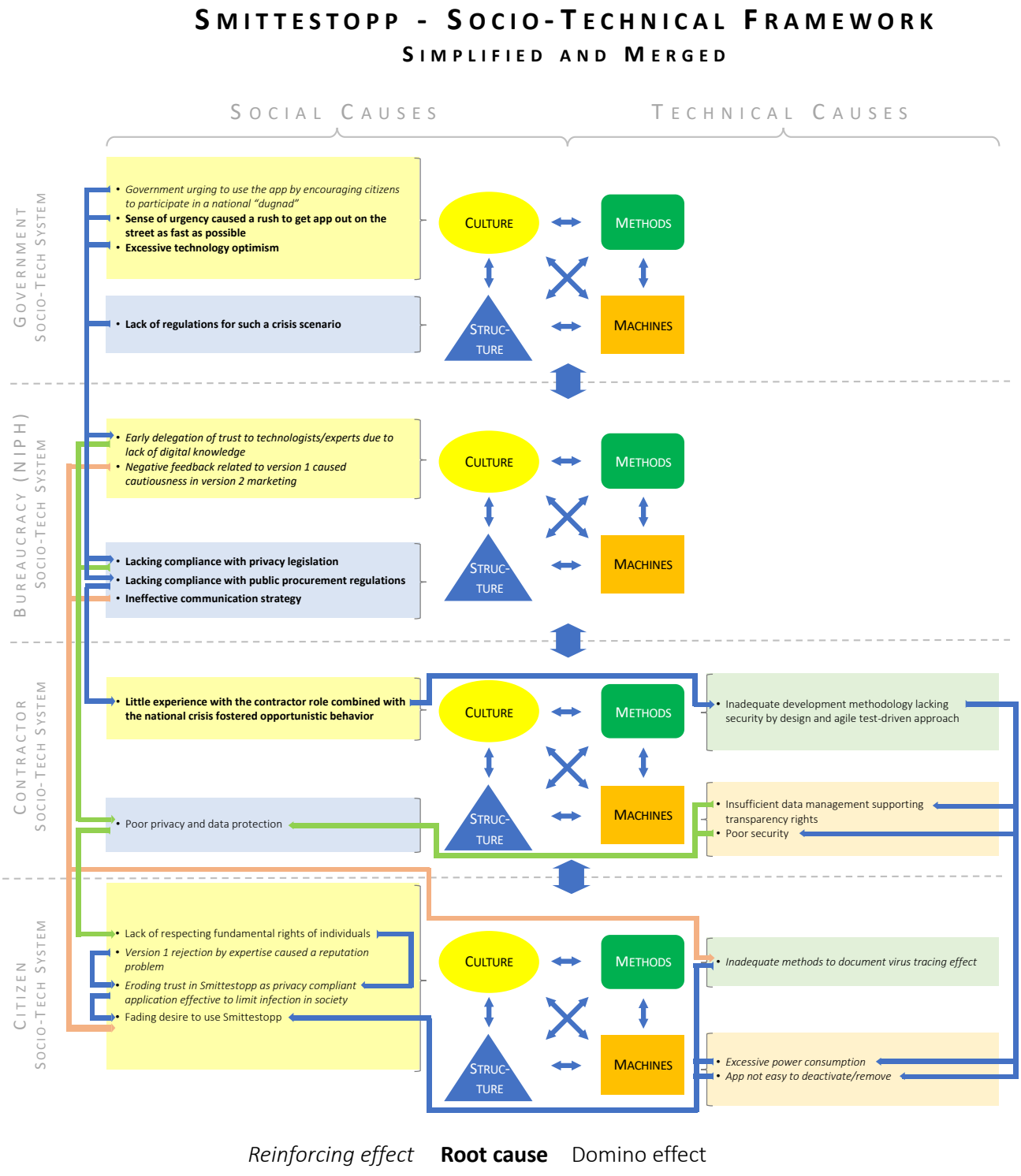

Figure 31: Smittestopp Socio-technical system - final model, simplified and merged

To sum up the Group Modelling session with iterative elaboration of the socio-technical system, the populated socio-technical system consists of

- *In total 21 Root-cause candidates*
- *4 Root-causes related to Governmental level*
- *5 Root-causes related to Bureaucracy level*
- *5 Root-causes related to Contractor level*
- *7 Root-causes related to Citizen level*

It should be noted that the identified causes are an aggregate related to both Smittestopp I and II. The further process described below separates the respective data from each version.

As illustrated in Figure 31, the domino effect of the causes was also identified and explained. They were named *Root-cause chains* and is illustrated as colored lines connection cause candidates. The modelling workshop identified 4 Root-cause chains. Figure 32 and Figure 33 below illustrates the Root-cause chains.

The Root-cause chains were further used in the SBC-modelling session below as a visual tool to elaborate interdependencies and mitigations that might break the chains.

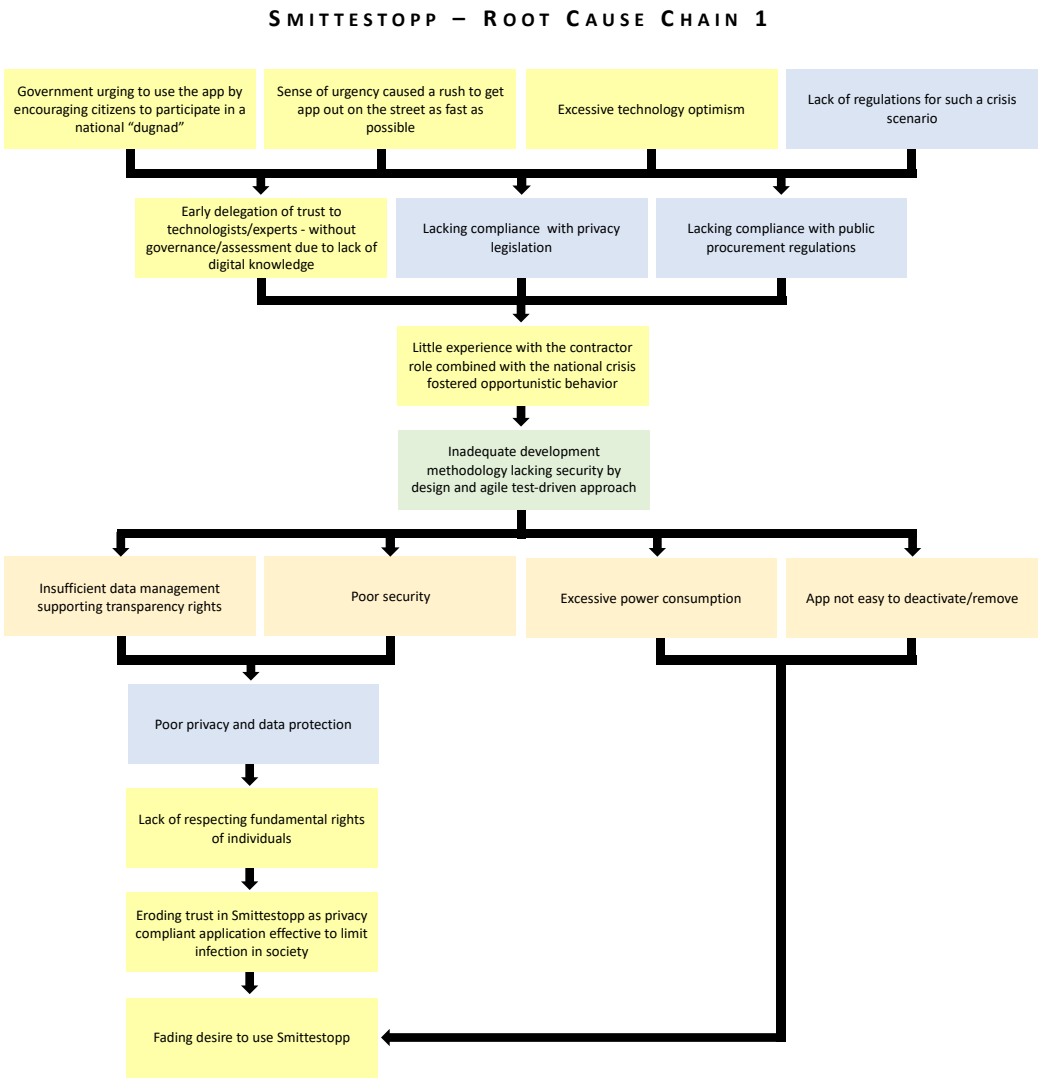

Figure 32: Smittestopp - Root Cause Chain no 1

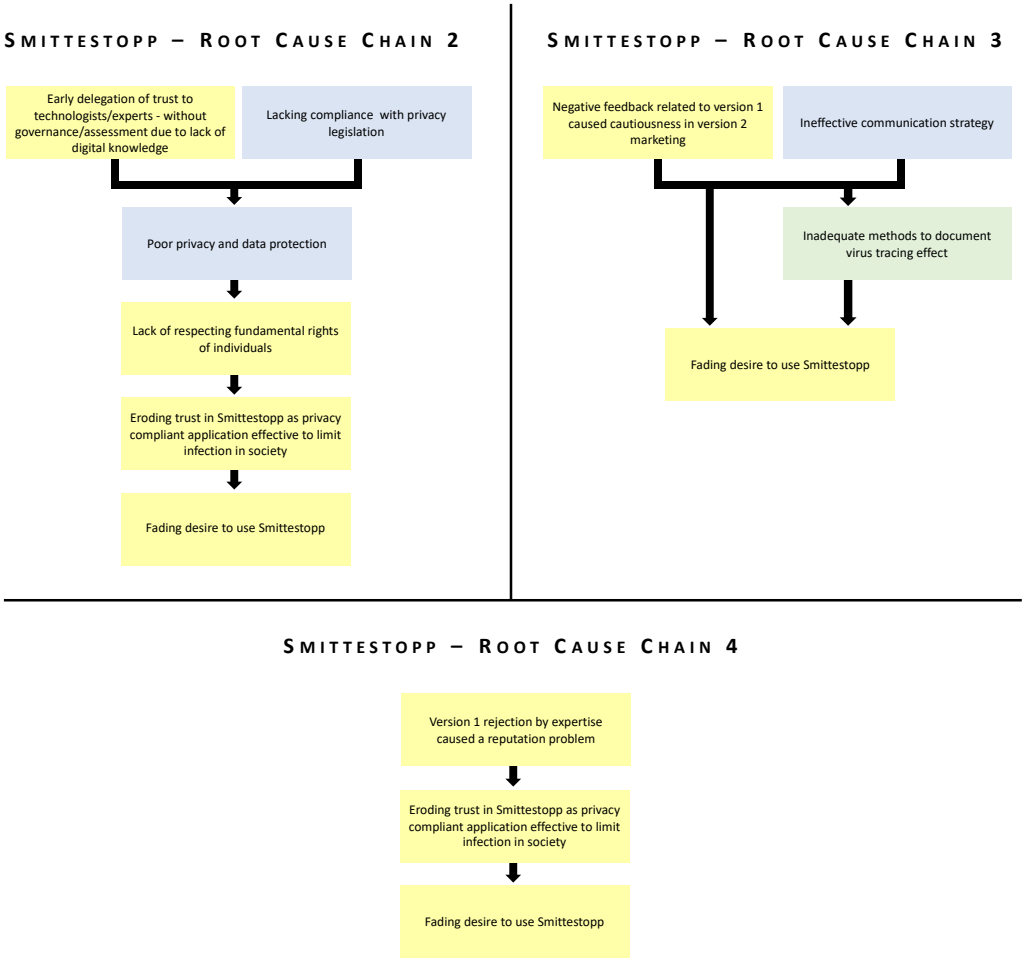

Figure 33: Smittestopp - Root Cause Chain no 2, 3 and 5

4.2.3.5 Smittestopp I – Root-cause of declining number of users

At this phase in the Root-cause analysis it was discussed the rapid decline in active users of Smittestopp I as shown in Figure 34 below. Thus, as mentioned in chapter 2.1.2 above and indicated in Figure 34 something caused users to delete the app quickly shortly after the launch of Smittestopp version I. Candidates for this behavior are *issues raised related to privacy, security, technical and user experience*. With all the focus on compliance related to privacy and information security (Lilleng et al., 2020; Moe, 2020; Norwegian DPA, 2020a, 2020b, 2020c; Sandvik, 2020a, 2020b), a plausible Root-cause was issues related to privacy and/or information security.

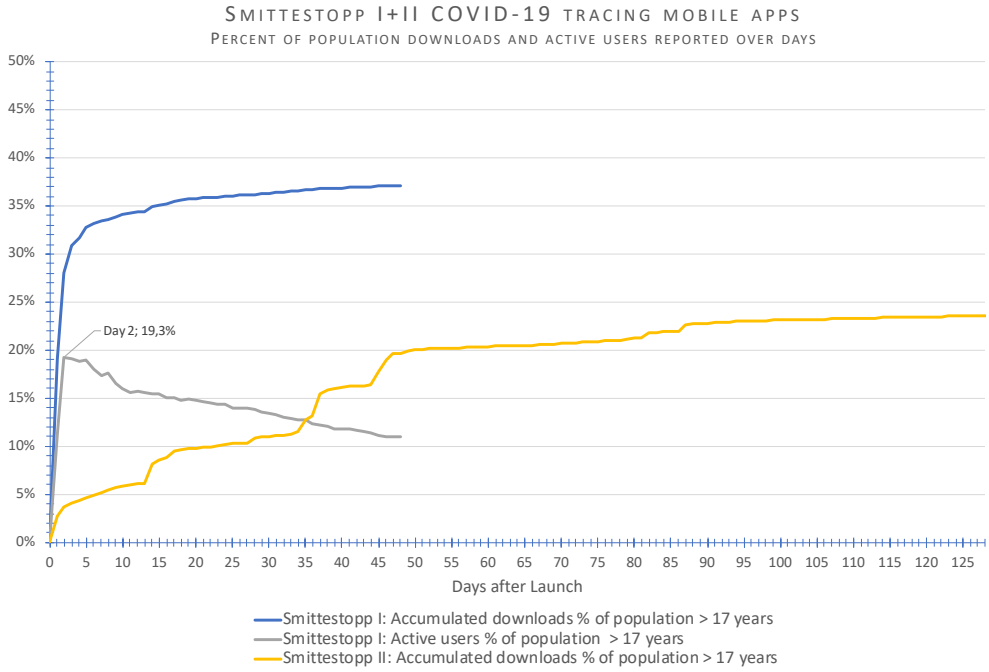

Figure 34: Downloads of Smittestopp version I and II

But, comparing the graph in Figure 34 with the timeline (see Figure 2 above and detailed timeline in Appendix 1 below) the public in general was not aware of privacy and security issues until weeks after launch of Smittestopp I. Thus, the hypothesis the declination of users was related to privacy/security issues does not align with the data showing a decrease in active users only two days after launch. Thus, it is plausible to assume that loss of Smittestopp I users was *not related to privacy or security issues*. *Rather technical or issues related to the user experience is more likely*. One known issue raised only one day after launch of Smittestopp was extensive power consumption (Plikk, 2020).

Thus, the plausible Root-cause for declining number of Smittestopp version I users was related to technical issues or user experience, and not issues related to privacy or information security. A prime suspect is extensive power consumption (Plikk, 2020).

4.2.4 Third session – SBC-modelling

The third workshop of Group Modelling was dedicated to elaborating measures mitigating the resulting challenges originated from the candidate Root-causes found in previous workshop. Security by Consensus (SBC) modelling (Kowalski, 1994a) was the chosen methodology for finding appropriate measures.

In addition, the Root-cause chains identified in the previous Group Modelling session (see Figure 32 and Figure 33 above) were used in the workshop to find measures that "breaks" the chains.

Thus, the expected outcome from the third Group Modelling session was:

- Overall SBC-model with causes and related measures
- SBC-models filtering out causes and irrelevant in Smittestopp version 2
- Revisited socio-technical model with remaining Smittestopp II causes and unimplemented measures

- Cause chain model with related measures

As mentioned previously, a challenge during the Group Modelling workshop was to simultaneously elaborate Root-causes related to shortcomings both in the first and second version of the Smittestopp application. Thus, the list Root-cause and measure candidates listed in Table 6 below may seem inconsistent due that is reflects two perspectives simultaneous. But this is a deliberate chosen approach to possible unwanted effect that Smittestopp II was not reluctantly adopted by the Norwegian population.

CAUSE CANDIDATES AND MEASURES RELATED THE SMITTESTOPP LIFECYCLE

		Measures \ Causes	Culture												Structure					Methods		Machines			
			Early delegation of trust to technologists/experts - without governance/assessment due to lack of digital k nowledge	Eroding trust in Smittestopp as privacy compliant application	Excessive technology optimism	Fading desire to use Smittestopp	Government urging to use the app by encouraging citizens to participate in a national "dugnad"	Lack of respecting fundamental rights of individuals	Little experience with the contractor role combined with the national crisis fostered opportunistic behavior	Negative feedback related to version 1 caused cautiousness in version 2 marketing	Sense of urgency caused a rush to get app out on the street as fast as possible	Version 1 rejection by expertise caused a reputation problem	Ineffective communication strategy	Lack of regulations for such a crisis scenario	Lacking compliance with privacy legislation	Lacking compliance with public procurement regulations	Poor privacy and data protection	Inadequate development methodology lacking security by design and agile test-driven approach	Inadequate methods to document virus tracing effect	App not easy to deactivate/remove	Excessive power consumption	Insufficient data management supporting transparency rights	Poor security
Social	Ethical-Cultural	Clear separation of responsibilities between customer and supplier							X															
		Communicate simple messages								X			X											
		Continue to comply with relevant procedures and regulations in times of crisis		X				X			X				X	X							
		Establish better understanding of technology	X		X																			
		Establish culture for building quality software																		X	X	X		
		Establish culture for effective cross-political contingency planning												X				X	X					
		Establish culture respecting citizens privacy						X											X					
		Establish good trust management		X			X																	
		Establish security culture																						X
		Establish situational awareness before acting					X																	
		Establish understanding of roles for both customer and supplier							X															
		Improve ability to receive criticism at Government and NIPH level			X					X			X											
		Improve awareness of current regulations						X							X	X	X							
		Improve communication skills (E.g. by using good communication consultants)								X			X											
		Promote what actually works								X			X											
		Respect the citizens' high trust in the government									X													
	Political-Legal-Contractual	Improve and professionalize the communication approach		X		X				X		X	X											
		Improve emergency training at Government level					X				X			X										
		Improve legal understanding and regulations					X				X			X										
		Improve public sector's ability to assess and manage offered technology solutions and propositions	X		X																			
		Improve readiness for pandemic					X				X			X										
		Improve understanding and documentation of proportionality in relation to privacy						X									X							
		Professionalize supplier-customer relationship							X															
		Use experienced vendors in software development																X						
	Administrative-Managerial	Apply agile test-driven, privacy and security focused approach to development methology. E.g DevOps, DevSecOps, Privacy by Design															X	X		X	X	X	X	
		Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers																	X					
		Utilize independent digital professional expertise	X		X																			
	Operational-Procedural	Ensure that measures have effect		X			X																	
		Improve consequence awareness for regulatory breaches						X							X	X	X							
		Implement Think Big, Start Small		X			X																	
		Improve methods for gaining experience and evaluation			X																			
		Improve rigging for the unforeseen (resillence)		X			X																	
Technical	Application	Adopt functional testing and user testing																X		X	X		X	
		Adopt security testing																X					X	
		Build according to Privacy by Design						X							X		X							
		Validate and test applied algorithms			X																			
	Operating System																							
	Hardware																							

Table 6: SBC - Measures and causes

The results in Table 6 above shows the result of the first iteration of SBC-modelling in the third Group Modelling session. Note that most of the measures in the table above mitigates several of Root-cause candidates.

Further, Table 6 visualizes that that major part of the Root-cause candidates (15 of 21 causes) relates to the *Culture* and *Structure* socio-technical categories. Both the categories Culture and Structure is part of the overall socio-technical group *Social*. The actual numbers per socio-technical category is:

Culture: 10 Root-cause candidates
Structure: 5 Root-cause candidates
Methods: 2 Root-cause candidates
Machines: 4 Root-cause candidates

Table 7 below focus on the measures found and their relevant category in the Security by Consensus (SBC) model (Kowalski, 1994a).

MEASURES RELATED THE SMITTESTOPP LIFECYCLE

		Measures	Applies to no of Causes	Total Causes Applied	Total Measures
Social	Ethical-Cultural	Clear separation of responsibilities between customer and supplier	1	35	16
		Communicate simple messages	2		
		Continue to comply with relevant procedures and regulations in times of crisis	5		
		Establish better understanding of technology	2		
		Establish culture for building quality software	3		
		Establish culture for effective cross-political contingency planning	3		
		Establish culture respecting citizens privacy	2		
		Establish good trust management	2		
		Establish security culture	1		
		Establish situational awareness before acting	1		
		Establish understanding of roles for both customer and supplier	1		
		Improve ability to receive criticism at Government and NIPH level	3		
		Improve awareness of current regulations	4		
		Improve communication skills (E.g. by using good communication consultants)	2		
		Promote what actually works	2		
		Respect the citizens' high trust in the government	1		
	Political-Legal-Contractual	Improve and professionalize the communication approach	5	20	8
		Improve emergency training at Government level	3		
		Improve legal understanding and regulations	3		
		Improve public sector's ability to assess and manage offered technology solutions and propositions	2		
		Improve readiness for pandemic	3		
		Improve understanding and documentation of proportionality in relation to privacy	2		
		Professionalize supplier-customer relationship	1		
		Use experienced vendors in software development	1		
	Administrative-Managerial	Apply agile test-driven, privacy and security focused approach to development methology. E.g DevOps, DevSecOps, Privacy by Design	6	9	3
		Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers	1		
		Utilize independent digital professional expertise	2		
	Operational-Procedural	Ensure that measures have effect	2	11	5
		Implement Think Big, Start Small	4		
		Improve consequence awareness for regulatory breaches	2		
		Improve methods for gaining experience and evaluation	1		
		Improve rigging for the unforeseen (resillence)	2		
Technical	Application	Adopt functional testing and user testing	4	10	4
		Adopt security testing	2		
		Build according to Privacy by Design	3		
		Validate and test applied algorithms	1		
	Operating System			0	0
	Hardware			0	0

Table 7: SBC-categories and related measures

The results from the SBC-modelling session shows of the 36 measures found, a major part of 32 relates the *Social* SBC-category and only 4 is in the *Technical* category. In more details the distribution of the SBC-categories is:

		Measures	Applies to Root-causes
Social	*Ethical-Cultural:*	16	35
	Political-Legal-Contractual:	8	20
	Administrative-Managerial:	3	9
	Operational-Procedural:	5	11
Technical	*Application:*	4	10
	Operating System:	0	
	Hardware:	0	

Whether or not some of the causes and measures found in the Group Modelling sessions are placed correctly can be a matter for discussion. But although some measures or Root-causes are categorized incorrectly, the result of the SBC-modelling aligns with the findings of the socio-technical models. *That is that the large part of the challenges related to Smittestopp was related to the Social socio-technical categories. Thus, the measures are also found in that category. Moreover, especially in the Ethical-Cultural SBC-category.*

This will be further discussed in chapter 5.

Existing measures applied to the SBC-models

As mentioned above the socio-technical and SBC-models have so far in the study included both Root-cause candidates and measures related to both versions of Smittestopp. This was done intentionally to include all relevant, and not prematurely reject candidate Root-causes or measures. Thus, both Figure 31, Table 6, and Table 7 above projects the combined causes and measures related to both Smittestopp version I and II.

But, as referred in chapter 4.1.2 above in the discussion of Cynefin domain related to the context of Smittestopp version II, the Norwegian public sector was in another state of order (moved from chaotic to complicated Cynefin domain). In addition study of the NIHP's web page documenting the progress of the Smittestopp II project (Norwegian Institute of Public Health, 2021b) gives clear indication that previous issues have resulted in an learning process.

In short, the procurement process was revised (Norwegian Institute of Public Health, 2020a), the previous issues related to privacy was mitigated (Norwegian Institute of Public Health, 2020b). Further reports from acceptance (Netcompany, 2020a) and performance testing (Netcompany, 2020b) indicates that findings in the expert group reviewing Smittestopp I has been addressed (Lilleng et al., 2020). In addition, as mentioned previously in chapter 4.1.2, issues related to risk management and information security was addressed (BDO, 2020; Norwegian Institute of Public Health, 2020d, 2020e).

Based the measures introduced because of the learning process combined with the ecosystem surrounding Smittestopp matured, it is natural to review the SBC-models in the context of

Norwegian Citizens reluctant to adopt second version of COVID-19 tracing app, Smittestopp II

As such, Table 8 below shows after the process of reviewing the measures found during the SBC-modelling and marking measures considered as either implemented during the Smittestopp II process of lost relevance due to gained maturity or regained general order in the Norwegian public sector

MEASURES RELATED THE SMITTESTOPP LIFECYCLE

		Measures
Social	Ethical-Cultural	Clear separation of responsibilities between customer and supplier
		Communicate simple messages
		Continue to comply with relevant procedures and regulations in times of crisis
		~~Establish better understanding of technology~~
		Establish culture for building quality software
		~~Establish culture for effective cross-political contingency planning~~
		Establish culture respecting citizens privacy
		Establish good trust management
		Establish security culture
		~~Establish situational awareness before acting~~
		Establish understanding of roles for both customer and supplier
		Improve ability to receive criticism at Government and NIPH level
		Improve awareness of current regulations
		Improve communication skills (E.g. by using good communication consultants)
		Promote what actually works
		Respect the citizens' high trust in the government
	Political-Legal-Contractual	Improve and professionalize the communication approach
		~~Improve emergency training at Government level~~
		Improve legal understanding and regulations
		Improve public sector's ability to assess and manage offered technology solutions and propositions
		~~Improve readiness for pandemic~~
		Improve understanding and documentation of proportionality in relation to privacy
		Professionalize supplier-customer relationship
		Use experienced vendors in software development
	Administrative-Managerial	Apply agile test-driven, privacy and security focused approach to development methology. E.g DevOps, DevSecOps, Privacy by Design
		Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers
		~~Utilize independent digital professional expertise~~
	Operational-Procedural	Ensure that measures have effect
		~~Implement Think Big, Start Small~~
		Improve consequence awareness for regulatory breaches
		Improve methods for gaining experience and evaluation
		~~Improve rigging for the unforeseen (resillence)~~
Technical	Application	Adopt functional testing and user testing
		Adopt security testing
		Build according to Privacy by Design
		Validate and test applied algorithms
	Operating System	
	Hardware	

Implemented in Smittestopp version 2

~~Lost relevance in Smittestopp version 2~~

Table 8: SBC-categories and related measures - Implemented and inrelevant in Smittestopp version 2

In Table 8 redundant measures are marked to illustrate the evolution from the Root-cause candidates elaborated from a holistic view of the Smittestopp lifecycle to the remaining

measures not resolved by the learning process mentioned above. The redundant measures marked "Implemented in Smittestopp 2" is found based on the information sources above (BDO, 2020; Lilleng et al., 2020; Netcompany, 2020a, 2020b; Norwegian Government, 2020; Norwegian Institute of Public Health, 2020a, 2020b, 2020d, 2020e, 2020f). Further, the measures marked "Lost relevance in Smittestopp" use the Cynefin analysis in chapter 4.1.2 above and the final report from the Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a, 2021b) as the main sources of information.

Thus, after redundant measures is removed, Table 9 below lists up the remaining measures not implemented and still considered as relevant.

UNIMPLEMENTED MEASURES SMITTESTOPP II

		Measures
Social	Ethical-Cultural	Communicate simple messages Establish good trust management Improve communication skills (E.g. by using good communication consultants) Promote what actually works Respect the citizens' high trust in the government
	Political-Legal-Contractual	Improve and professionalize the communication approach
	Administrative-Managerial	Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers
	Operational-Procedural	Ensure that measures have effect Improve methods for gaining experience and evaluation
Technical	Application	
	Operating System	
	Hardware	

Table 9: SBC-categories and measures not implemented in Smittestopp version 2

The remaining measures was then reverse-engineered into the overall SBC-model to reconnect to the associated Root-causes. The result is illustrated in Table 10 below.

		Measures	Causes: Culture – Eroding trust in Smittestopp as privacy compliant application effective to limit infection in society	Culture – Fading desire to use Smittestopp	Culture – Government urging to use the app by encouraging citizens to participate in a national "dugnad"	Culture – Negative feedback related to version 1 caused cautiousness in version 2 marketing	Culture – Sense of urgency caused a rush to get app out on the street as fast as possible	Culture – Version 1 rejection by expertise caused a reputation problem	Structure – Ineffective communication strategy	Methods – Inadequate methods to document virus tracing effect	Machines
Social	Ethical-Cultural	Communicate simple messages				X			X		
		Establish good trust management	X		X						
		Improve communication skills (E.g. by using good communication consultants)				X			X		
		Promote what actually works				X			X		
		Respect the citizens' high trust in the government					X				
	Political-Legal-Contractual	Improve and professionalize the communication approach	X	X		X		X	X		
	Administrative-Managerial	Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers								X	
	Operational-Procedural	Ensure that measures have effect	X		X						
		Improve methods for gaining experience and evaluation		X							
Technical	Application										
	Operating System										
	Hardware										

Table 10: SBC - Remaining measures and causes

From Table 10 the following distribution of the remaining socio-technical causes is extracted:

Culture: 6 Root-cause candidates
Structure: 1 Root-cause candidates
Methods: 1 Root-cause candidates
Machines: 0 Root-cause candidates

Further, the distribution of the measures in relevant SBC-categories related to the remaining Root-causes is:

		Measures	Applies to Root-causes
Social	*Ethical-Cultural:*	5	9
	Political-Legal-Contractual:	1	5
	Administrative-Managerial:	1	1
	Operational-Procedural:	2	3
Technical	*Application:*	0	0
	Operating System:	0	0
	Hardware:	0	0

As, such the reviewed SBC-models from the Group Modelling session indicates that Root-causes related to the unwanted effect that the Norwegian citizens was reluctant to adopt the second version of Smittestopp, is related to the *Social* socio-technical-category. More specifically related mainly of Cultural socio-technical characters.

As a natural consequence of the characteristics of the Root-causes, the SBC-model indicates that measures are in the *Social* category as well. More specifically they are mitigating deficiencies related to communication, trust management and respect, measurement mechanisms of app effectiveness, methodology for evaluation and gaining experience.

4.2.4.1 Revisiting Socio-technical system

After fulfilling the SBC-analysis it a natural step to revisit and update the model of socio-technical system based on the findings from the SBC-analysis.

This is illustrated in Figure 35 below where remaining Root-causes that leads to the unwanted effect that the Norwegian citizens was reluctant to adopt the second version of Smittestopp

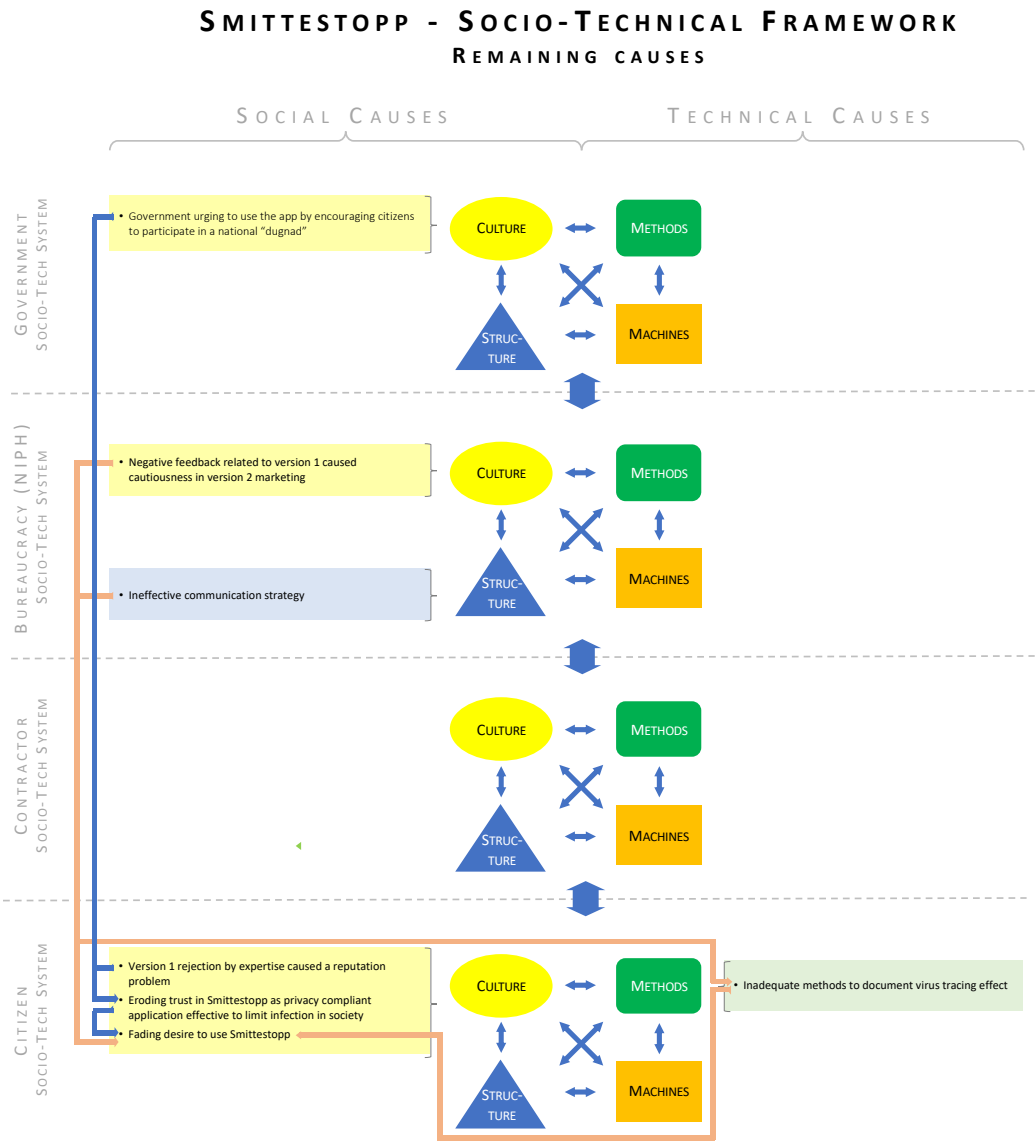

Figure 35: Smittestopp Socio-technical system - remaining causes

In the origin socio-technical system, four Root-cause chains was identified (see Figure 32 and Figure 33 above). As illustrated in Figure 36 below only two Root-cause chains are identified related to the remaining causes.

In addition, Figure 36 list up the remaining measures with numbering. Further, it illustrates how the remaining unimplemented measures "breaks" the Root-cause chains marked with red "X" and numbers referring to the relevant measures.

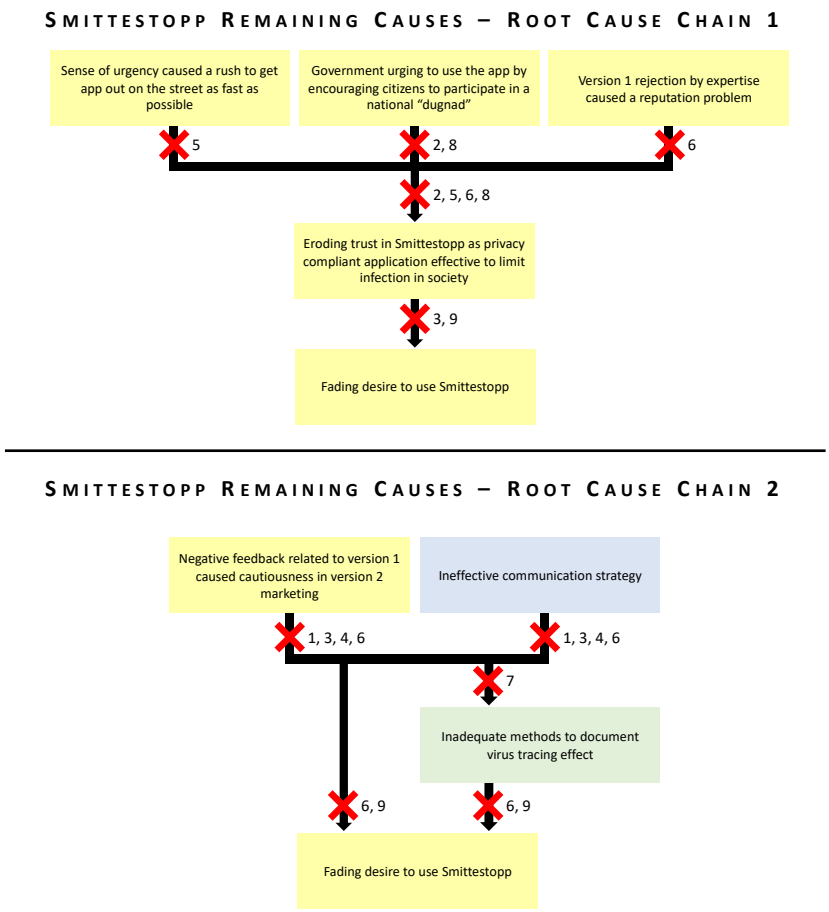

Figure 36: Remaining measures and causes - Root Cause Chain no 1 and 2

4.2.5 Fourth session – System Dynamics

The fourth and last group modeling workshop was dedicated to System Dynamic Modelling. Although the workshop attendees had received relevant introduction material describing system dynamics (Goodman, 1991; D. H. Kim, 1999) and system dynamics archetypes (D. H. Kim, 1992, 2000a, 2000b), this topic was the most challenging topic for the group to establish sufficient understanding of the concepts. Thus, this session involved most guiding and instructions from the workshop facilitator.

The expected outcome from the fourth Group Modelling session was:

- Simplified system dynamic model showing the actual dynamics in both Smittestopp I and II with respect to user adoption
- Simplified system dynamic model showing the dynamics in Smittestopp II with respect to user adoption and mitigated challenges

As, such the systems dynamic models illustrated in Figure 37 and Figure 38 below is quite simple but is still an essential contribution to the modelling process due to the addition of the dynamic point of view compared to the previous more static models.

The archetype "Limits to Success" (D. H. Kim, 1992) is chosen as base for the models (see Figure 11 above). The basic dynamics of this archetype fits well with the dynamics of the Norwegian citizen adoption rate of Smittestopp. That is a wanted reenforcing loop that drives the growth of users combined with an unforeseen balancing loop that slows or reverse the user growths of users.

As discussed in chapter 4.2.3.5 above *the plausible Root-cause for declining number of Smittestopp version I users was related to technical issues or user experience. One prime suspect is the extensive power consumption (Plikk, 2020).*

The argumentation above gives a basic understand of the dynamics the models in Figure 37 and Figure 38 below is trying to simulate, although simplified. As such, the systems dynamic models' intention is not to mirror the real-world. It is extremely difficult to create a system dynamic model that behaves correctly given the real-world's complexity and exceptions. Rather, the models illustrated in Figure 37 and Figure 38 below contribute as a thinking tools adding the dynamic aspect to Root-cause analysis.

Figure 37 shows the experienced dynamics of the Smittestopp socio-technical system. As mentioned above, the models are based on the system dynamic archetype "Limits to Success" (D. H. Kim, 1992). Thus, the main drivers of the dynamics in this model in a reenforcing loop, R1 "User growth", and a balancing loop, B2 "Quality limitation".

4.2.5.1 Smittestopp version I – System dynamics

Wanted R1-loop dynamics

- The general *trust* in authorities Norway is ***high***
- This generates a ***high*** *desire to use the app*
- High desire generates ***many*** *downloads*
- Many downloads lead to ***many*** *active users*
- Many active users ***increase*** the *virus tracing capability*
- High virus tracing capability creates an even ***higher*** *desire to use the app*

Unforeseen B2-loop dynamics

- Many downloads ***decrease*** the *support capacity*
- Decreased support capacity eventually leads to ***less*** *technical quality*
- Fewer technical quality leads to ***less*** *active users*
- Fewer active users ***decrease*** the virus tracing capability
- Less virus tracing capability ***decrease*** the desire to use the app

Long term effects of privacy and security compliance

- Smittestopp I was associated with issues related to privacy and security compliance
- Over time this eroded the citizen's trust (Note the delay between privacy compliance, security compliance and the impact on the citizen trust

The end state of the socio-technical system after Smittestopp I

As the data in Figure 34 above shows, Smittestopp I was withdrawn after only 48 days with continuous declining number of active users. Although the debate of lacking privacy and security compliance was still going on. Several reports and articles were supporting the issues raised (Lilleng et al., 2020; Norwegian DPA, 2020b; Sandvik, 2020a, 2020b). Thus, as the system dynamic model in Figure 37 suggests, it is plausible that the value of citizen trust regarding a Smittestopp app was eroded to a minimum.

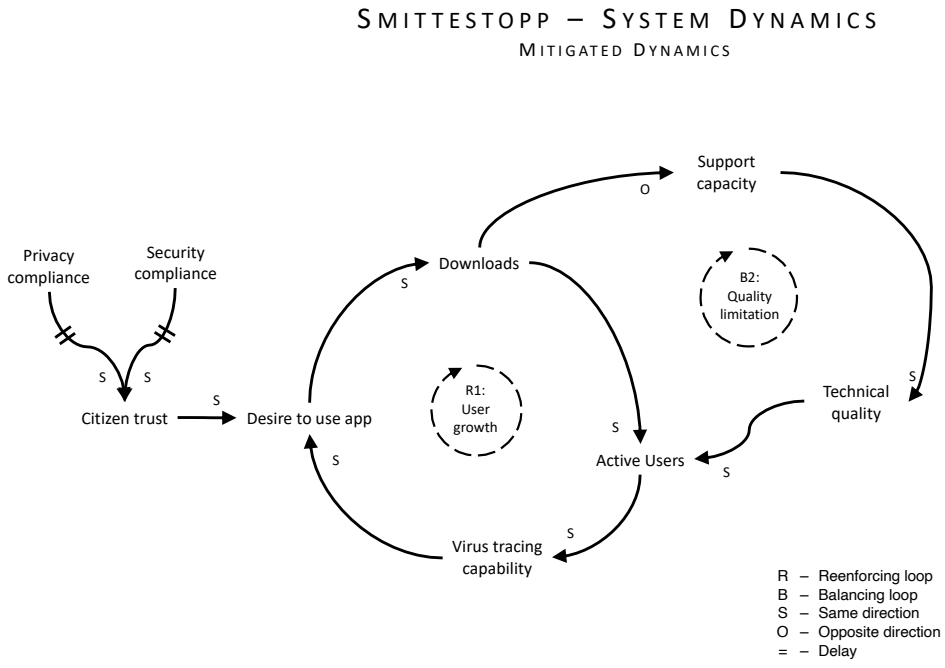

Figure 37: Smittestopp System Dynamics - Actual dynamics

4.2.5.2 Smittestopp version II – System dynamics

As discussed above, it is plausible the systems dynamics of Smittestopp I depleted the trust related to virus tracing application at a minimum. This has an impact on the rate of user growth as described below.

R1-loop dynamics

- The citizen *trust* in virus Smittestopp applications is ***low***
- This generates a ***low*** *desire to use the app*
- Low desire generates ***few*** *downloads*
- Few downloads lead to ***few*** *active users*
- Few active users ***decrease*** the *virus tracing capability*
- High virus tracing capability creates an even higher *desire to use the app*

B2-loop dynamics

- Fewer downloads ***increase*** the *support capacity*
- Increased support capacity increase capacity to handle *technical quality* issues
- Good technical quality leads to ***more*** *active users*
- More active users increase the virus tracing capability
- More virus tracing capability increase the desire to use the app

The challenge in this system dynamics is that it requires efforts to reestablish the citizen trust. As long there are no measures to mitigate this, a low citizen trust will efficiently slow down the whole user growth process. Thus, this aligns with the graph showing the accumulated download of Smittestopp version II in Figure 34 above

4.2.5.3 Smittestopp II with measures – System dynamics

The measures to mitigate the issues related to Smittestopp is outlined in Table 10. It is mainly related to improving communication, trust management and measurement of virus tracing effect. Figure 38 below illustrates some of these implemented in the system dynamic model. Note that all aspects are not implemented in the model. Examples of such are dynamics to handle changes in privacy and security compliance.

As mentioned above, Smittestopp II inherited an eroded citizen trust. In addition, the dynamics above reveals a possible issue related to support capacity. To address these issues three loops is added to the system dynamic model shown below in Figure 38. They are coloured in blue.

As explained in chapter 4.2.3.5 above the issues related to privacy (Norwegian Institute of Public Health, 2020b), security compliance (BDO, 2020; Norwegian Institute of Public Health, 2020d, 2020e) and technical quality (Netcompany, 2020a, 2020b) was resolved in the second version of Smittestopp. Although, note the delay in the dynamic relation between privacy, security compliance, and citizen trust in Figure 38. Thus, improved privacy and security does not have an immediate effect on citizen trust. This justifies the reenforcing loop *R4: Communicate good news* and the balancing loop *B3: Usage monitoring*. Although Smittestopp II did not have issues related to quality or technique, the balancing loop *B5: Support staffing* is added to ensure adequate support capacity.

The loops addressing the shortcomings of the first dynamic model illustrated in Figure 37 above is further elaborated below.

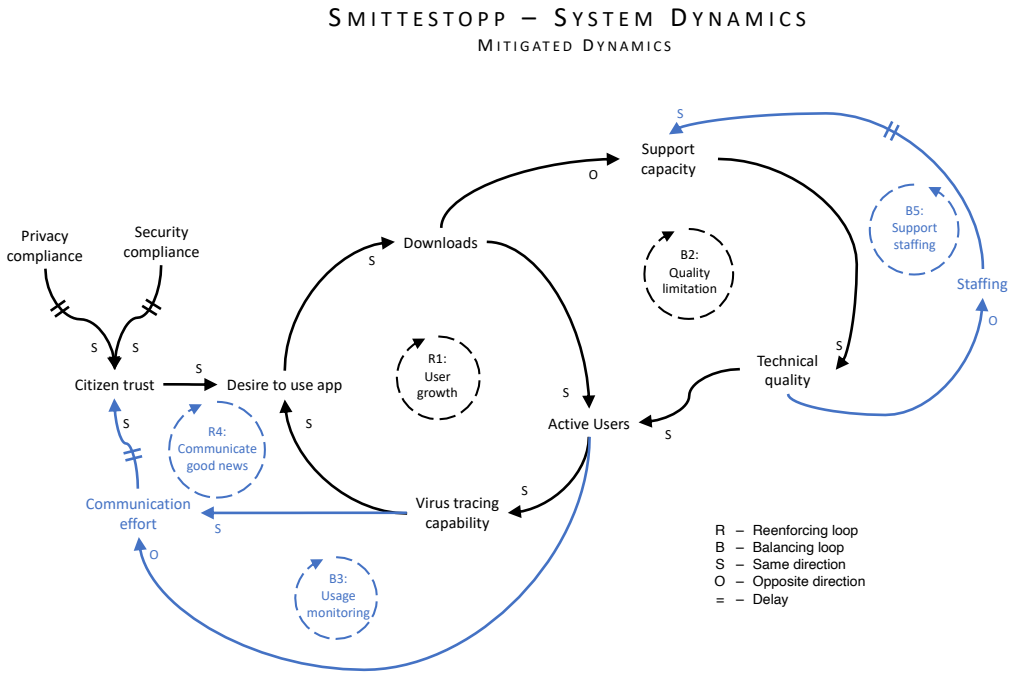

Figure 38: Smittestopp System Dynamics - Mitigated dynamics

B3: Usage monitoring - loop dynamics

- The low citizen trust generates a ***low*** *desire to use the app*
- Low desire to use the app causes ***low*** *downloads*
- Low downloads cause ***low*** numbers of *active users*
- Few active users initiate ***more*** *communication* efforts
- More communication efforts cause eventually ***increased*** *citizen trust*
- Increased citizen trust generates ***higher*** *desire to use the app*
- Higher desire to use the ap generates ***more*** *downloads*
- (and so forth recursively reenforce downloads and citizen trust)

R4: Communicate good news - loop dynamics

- The increased citizen trust generates an ***increased*** *desire to use the app*
- Increased desire to use the app causes ***higher*** *downloads*
- Higher downloads cause ***higher*** numbers of *active users*
- Higher numbers of active users cause ***more*** *virus tracing capability*
- More virus tracing capability cause ***more*** *communication effort* to communicate good news
- More communication effort cause eventually ***increased*** *citizen trust*
- Increased citizen trust generates ***higher*** *desire to use the app*
- Higher desire to use the ap generates ***more*** *downloads*
- (and so forth recursively reenforce downloads and citizen trust)

Although technical quality was not an issue in Smittestopp, the balancing loop *B5: Support staffing* is added to the model as a safety valve.

B5: Support staffing - loop dynamics

- High downloads ***deteriorate*** *support capacity*
- Deteriorated support capacity potentially ***deteriorates*** *technical quality*
- Deteriorated technical quality leads to ***increased*** *staffing*
- Increased staffing ***increases*** *the support capacity* with some delay
- Increased support capacity enables ***higher*** *technical quality*
- (And so forth, balance support capacity and staffing based on technical quality)

4.2.5.4 Summary - Smittestopp Dynamics

As mentioned above, the intention of the system dynamic models presented in this chapter is not to project real-world scenarios, but rather to serve as thinking tools to add a dynamic perspective to the root-cause analysis.

Experience from the Group Modelling session shows that system dynamics is a rather difficult concept to comprehend and requires more training and guiding compared to the other methodologies applied in the other modelling sessions.

Although the concept can be mentally challenging, it useful to add a non-statical viewpoint to root-cause analysis. Applying system dynamic modeling, forces a shift from viewing effects only as the result of a direct cause, but also includes causes that influences gradually over time.

Smittestopp I dynamics illustrated in chapter 4.2.5.1, reflect issues related to the chaotic state of order the Norwegian public sector was in the start of Smittestopp I. Thus, the challenges related to the first version of Smittestopp could probably been avoided by slowing the process of creating the first version of the virus tracing app

As illustrated in Figure 37 above, the system dynamics focus on issues to related to technical issues that caused a loss of active users and slowed down the app download rate. In addition, the effects of the focus on issues related to privacy and security compliance that over time had a negative impact on the citizens trust related to Smittestopp applications in general. As the dynamics shows at this state, low citizen trust and low desire to use Smittestopp was left as a heritage to the next version of Smittestopp.

Further, as in Figure 38 above, the system dynamics implements key mitigating measures elaborated in the SBC-modelling (see chapter 4.2.3.5 and Figure 36 above) that removes the legacy from Smittestopp I. These measures are related to ensuring good trust management, ensure good communication skills, establish measurement of the virus tracing effect, and ensure adequate support capacity.

4.3 Summary – Social-technical Root-cause analysis

The chapter above elaborated the results from the Social-technical Root-cause analysis implementing the proposed research process illustrated in Figure 19 above. As such, this includes literature studies, Cynefin analysis, Group model building and result analysis.

The outcome of this process is related to the unwanted effect studied:

> *Norwegian Citizens reluctant to adopt second version of COVID-19 tracing app, Smittestopp II*

To find the root cause of this unwanted the effect the process applied the analysis on the complete lifeline of both versions of Smittestopp.

Summary of discussion of Cynefin Domains related to Smittestopp

> *The Norwegian public sector, including the Norwegian Directorate of Health and the National Institute of Public Health (NIPH) moved from Simple to Chaotic Cynefin domain when the pandemic emerged.*

The main reason for this insufficient national contingency plans to handle pandemic crisis. In addition, the situation was further complicated that the operating pattern of behavior was unable to handle a chaotic working environment. Thus, in addition the general state of chaos in Norwegian public also affected the pattern of behavior related to Smittestopp's emergence and early production phase.

The Norwegian public sector regained more control during the first three quarters 2020. Thus, the operating Cynefin domain moved out from Chaotic. Further, the many of the issues and criticism related to the first version of Smittestopp was addressed. Still the Autumn 2020 was still in a state of uncertainty and turbulence, and the Smittestopp II sociotechnical system was presumably affected by this turbulence.

> *As such it is reasonable to conclude that the relevant Cynefin domain is Complicated and not Simple in the early days of Smittestopp II at Autumn 2020.*

Summary of Group modelling sessions

A socio-technical framework for digital contact tracing (Vinuesa et al., 2020) was used to rate used to rate Smittestopp version I and II. The overall impression is that:

> *Smittestopp version I had several deficiencies related to technology, privacy, information security, data management, data governance, voluntary use, and data minimization, and the deficiencies were at large mitigated in version II.*

These initial findings were further elaborated in the successive Group Modelling sessions.

The cause candidates listed the Ishikawa diagram illustrated in Figure 27 above shows many social causes with the culture category most frequently populated. The Root-cause candidates serve as a good foundation for the further process that address these issues.

Iterative population of the socio-technical system with Root-cause candidates for the sum of Smittestopp I and II.

- *In total 21 Root-cause candidates*
- *4 Root-causes related to Governmental level*
- *5 Root-causes related to Bureaucracy level*
- *5 Root-causes related to Contractor level*

- *7 Root-causes related to Citizen level*

As illustrated in Figure 31, the domino effect of the causes was named *Root-cause chains* and illustrated as colored lines. The *four identified Root-cause chains* are illustrated in Figure 32 and Figure 33 above. The Root-cause chains were further used in the SBC-modelling session below as a visual tool to elaborate interdependencies and mitigations that might break the chains.

At this phase in the Root-cause analysis it was discussed the rapid decline in active users of Smittestopp I as shown in Figure 34 above. Candidates for this behavior are *issues raised related to privacy, security, technical and user experience*. With all the focus on compliance related to privacy and information security (Lilleng et al., 2020; Moe, 2020; Norwegian DPA, 2020a, 2020b, 2020c; Sandvik, 2020a, 2020b), a plausible Root-cause was issues related to privacy and/or information security. But, this does not align when comparing the graph in Figure 34 with the timeline (see Figure 2 above)showing that the public was not aware of privacy and security issues until weeks after launch of Smittestopp version I.

> *Thus, the plausible Root-cause for declining number of Smittestopp version I users was related to technical issues or user experience, and not issues related to privacy or information security. A prime suspect is extensive power consumption (Plikk, 2020).*

Further, results from the SBC-modelling session shows of the 36 measures found, 32 relates the *Social* SBC-category and only 4 is in the *Technical* category. This aligns with the findings from the socio-technical models:

> *Challenges related to Smittestopp was mainly related to the Social socio-technical categories, and the measures are also in the same category. Moreover, especially the Ethical-Cultural SBC-category.*

To find the Root-causes related to the unwanted effect of reluctance to adopt Smittestopp II, the further process eliminated already implemented measures in reviewed SBC-models. The reviewed SBC-models shown in Table 9 and Table 10 above indicates that Root-causes related to the unwanted effect is in the *Social* socio-technical-category, mainly of *Cultural* character as shown below in Table 11:

CATEGORIES	CAUSES
Culture	Eroding trust in Smittestopp as privacy compliant application effective to limit infection in society
	Fading desire to use Smittestopp
	Government urging to use the app by encouraging citizens to participate in a national "dugnad"
	Negative feedback related to version 1 caused cautiousness in version 2 marketing
	Sense of urgency caused a rush to get app out on the street as fast as possible
	Version 1 rejection by expertise caused a reputation problem
Structure	Ineffective communication strategy
Methods	Inadequate methods to document virus tracing effect

Table 11: Reluctance to adopt Smittestopp II – Root-causes

> This sums up: *legacy from issues related to the first version like; the Government urge to use the app, a rush to launch the app, negative feedback causing bad reputation, rejection by expertise, was inherited by version two causing erosion of citizens trust, and further a reluctance to adopt Smittestopp II.*

The SBC-model shows that measures are in the *Social* categories as shown in Table 12 below.

		MEASURE
Social	Ethical-Cultural	Communicate simple messages
		Establish good trust management
		Improve communication skills (E.g. by using good communication consultants)
		Promote what actually works
		Respect the citizens' high trust in the government
	Political-Legal-Contractual	Improve and professionalize the communication approach
	Administrative-Managerial	Establish measurement of app effectiveness e.g by asking COVID-19 tested if allerted by Smittestopp at COVID-19 test centers
	Operational-Procedural	Ensure that measures have effect
		Improve methods for gaining experience and evaluation

Table 12: Reluctance to adopt Smittestopp II – Measures

> *More specifically the measures mitigating the reluctance to adopt Smittestopp are related to communication, trust management and respect, measurement mechanisms of app effectiveness, methodology for evaluation and gaining experience.*

The System dynamic model before mitigations as illustrated in Figure 37 above, focus on issues to related to technical issues that caused a loss of active users and slowed down the app download rate. As such:

> *Issues related to privacy and security compliance had over time a negative impact on the citizen's trust. Low citizen trust and low desire to use Smittestopp was left as a heritage to the next version of Smittestopp.*

Figure 38 above illustrates the System dynamic model implementing key mitigating measures removes legacy from Smittestopp I. Thus:

> *Measures are related to ensure good trust management and good communication skills, establish measurement of the virus tracing effect, and ensure adequate support capacity.*

4.4 Application of the Socio-technical Research Process

As part of this research questions in study, the one focus was improvement of root-cause analysis from a socio-technical perspective:

RQ4: How can socio-technical Root-cause analysis processes be improved by combining existing well-known methodologies?

This research question further resulted in the proposition:

PR4: *Applying existing socio-technical methodologies to root-cause analysis processes improves the insight of causes related to interdependent socio-technical systems*

Further this led to the main theoretical contribution of this study:

CO4: *The theoretical contribution this study is a research process combining known methodologies and modelling techniques known from socio-technical systems (Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Goodman, 1991; D. H. Kim, 1999; Richardson, 2013, 2020; Richardson & Andersen, 1995), and lean quality thinking (Ishikawa, 1985; Renee & James, 2010; Womack & Jones, 1996), and sensemaking in complex and complicated contexts (David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)*

To accommodate this the process illustrated in Figure 19 above was applied. Main components in methodology are:

- *Literature and data collection*
- *Analysis of state of order by applying the Cynefin framework*
- *Group model building*
- *Analysis of the results*

Further the group model building was conducted by completing four workshops with the topics

1. *Establish common understanding*
2. *Cause and socio-technical brainstorming using Ishikawa and socio-technical models*
3. *Cause and measure elaboration by SBC-modelling*
4. *Exploring dynamical socio-technical cause and effect relationship through system dynamic modelling*

A challenge during research is that the events and activities related to Smittestopp and the COVID-19 pandemic, were still playing out while the study was conducted. This challenged the research process, and a revision introduced an iterative approach as illustrated in Figure 19 above.

This introduced more stress and workload for the facilitator. An example of this is that one major source of information, the report Norwegian Coronavirus Commission (Norwegian Coronavirus Commission, 2021a, 2021b), was published very late in the research period.

On the other hand, the report did not introduce a great number of new topics, but rather confirmed or refuted existing hypothesis. Especially (Norwegian Coronavirus Commission, 2021a, 2021b) was a valuable source for the analysis of the state of order in public sector using the Cynefin framework (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003).

The chosen research process illustrated in Figure 19 above is mainly a multi-perspective root-cause analysis driven by qualitative data. The quantitative data was, as mentioned above, mainly used to confirm or refute findings or candidate hypothesis developed during the process.

The literature studies supporting the research process can separated in two areas:

- Literature of related work of methodologies applied in the research process
- Literature describing documenting the lifespan of the Smittestopp solution, related events, and activities

Experience of the first, was that it was less effort to find relevant literature supporting applied methodologies due to the static nature of the task. Conversely, the latter methodology was more challenging due to the continuous evolvement of the Smittestopp eco system. During the research period (May 2020 – June 2021) there was a continuous flow of new literature documenting events and activities. This introduced the need for agile support in the research process as illustrated in Figure 19 above.

Some parts of the study were conducted by the researcher alone. This is according to the selected *inductive research process* (see discussion chapter 3.1.2) where the researcher becomes part of the research process. Thus, the planning, literature study, data collection, Cynefin analysis, and result analysis was conducted by the researcher.

The Cynefin framework (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) was applied to analyze the state of order in the Norwegian public sector at two periods of time; the early days of Smittestopp (1st and 2nd quarter 2020) and the introduction of Smittestopp version II (3rd and 4th quarter 2020). The result of the Cynefin analysis served as a useful backdrop for the activities in the latter Group Modelling workshops.

Further, EUs publication of a field guide for managing complexity in times of crisis (Dave Snowden & Rancati, 2021) strengthened the argumentation that the Cynefin framework as a useful tool to find state of order related to socio-technical systems.

The Group Modelling sessions were originally planned as a workshop series in person utilizing whiteboards and sticky notes. Due to the COVID-19 pandemic 1st half of conducting workshops in person was note recommendable. Thus, Miro, an online whiteboard & visual collaboration platform was chosen (Miro, 2021). This required more preparation efforts from the researcher. On the other hand, the online collaboration utilizing simultaneously video meeting and Miro worked even better than expected. The experience was that using the Miro-platform benefitted the interaction.

Further, the modelling session applied several socio-technical modelling techniques to elaborate causes and effects related to Smittestopp ecosystem. The experience was that there was an increasing level of difficulty related to the understanding and application of the modelling techniques. This required more effort from the researcher in preparation before and assisting during the model building. Relevant learning material was sent to the

group prior the workshop to address this, but the effect was limited. Thus, this a learning point that could be implemented in an improved research process.

Group model building as described in chapter 2.2.5 above requires 5 roles. This was a limiting factor since the researcher had to implement all five roles. Thus, more assistance during the modelling sessions would be helpful.

Although these limiting factors, the outcome from the modelling sessions was very useful and resulted in the socio-technical models illustrated and described in chapter 0 above.

I retrospect the chosen research process has similarities with the Double Diamond Design Thinking methodology (Design Council, 2015; Stackowiak & Kelly, 2020). The Double Diamond is a process concept of diverging-converging-diverging-converging as illustrated in Figure 39 with the outcomes of the Group Modelling process populated in the illustration.

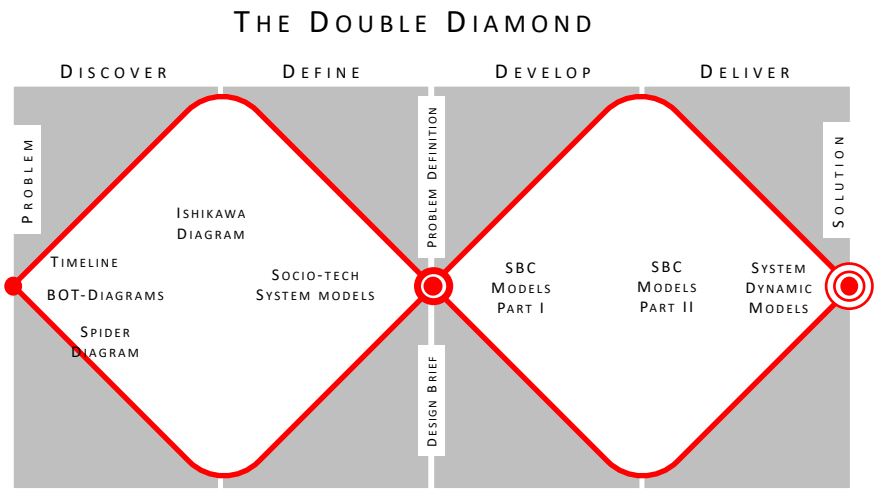

Figure 39: Double Diamond Design Thinking methodology (Design Council, 2015; Stackowiak & Kelly, 2020)

An improvement of the research process in this study could be to enrich the process by apply of methodologies from the area of Design Thinking like the Double Diamond.

To sum up the experience gained from applying the research process designed for this study, the relevant research question, proposition, and contribution is revisited:

RQ4: How can socio-technical Root-cause analysis processes be improved by combining existing well-known methodologies?

The research process designed for this study show that it is plausible to improve existing socio-technical Root-cause analysis (Huynen & Lenzini, 2018; Wangen et al., 2018) by both combining known socio-technical methodologies, and apply both qualitative and quantitative approaches.

PR4: Applying existing socio-technical methodologies to root-cause analysis processes improves the insight of causes related to interdependent socio-technical systems

Further the socio-technical systems developed (see chapter 4.2.3.3 and 4.2.3.4) visualizes the interdependencies between four socio-technical systems. The visualization and work with the models provided insight of both insight of the interdependencies and chain of interacting causes between the ecosystem of interacting socio-technical systems.

The theoretical contribution of this research was:

CO4: *The theoretical contribution this study is a research process combining known methodologies and modelling techniques known from socio-technical systems (Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Goodman, 1991; D. H. Kim, 1999; Richardson, 2013, 2020; Richardson & Andersen, 1995), and lean quality thinking (Ishikawa, 1985; Renee & James, 2010; Womack & Jones, 1996), and sensemaking in complex and complicated contexts (David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)*

As elaborated above, the research process applied in this study have shortcomings and room for improvements. Although, this research has contributed with a research process or methodology that utilize a combination of existing methodologies in a new concept that provides value in socio-technical root-cause analysis.

5 Discussion

This chapter discuss this research with respect of the research questions, propositions, and contribution unfolded from this study's problem description in chapter 1.3 above.

As such, during the reach both related to the socio-technical Root-cause analysis of Smittestopp and the theoretical contribution manifested in the socio-technical methodology applied in the research, there have been a continuous balance between time, available, resources available and the scope of the study. Thus, er this chapter will reflect on the results of this research and enlighten the choices and considerations done in the study.

The topics of the discussion in this chapter is:

RQ1, PR1, CO1: Smittestopp – Socio-technical systems

RQ2, PR2, CO2: Smittestopp – Citizen's privacy during a crisis

RQ3, PR3, CO3: Smittestopp II – Citizen's reluctance to adopt

RQ4, PR4, CO4: Proposed socio-technical Root-cause analysis methodology

5.1 Smittestopp – Socio-technical systems

The research question, proposition and contribution related to the socio-technical perspective of the virus tracing Smittestopp is:

RQ1: Seeing the Smittestopp app from a socio-technical system perspective. What are the key components in this socio technical system, and how do they interact?

PR1: The Smittestopp software solution is part of a multitude of interacting socio-technical systems.

CO1: The study will provide socio-technical and systems dynamic models identifying key components and interrelationship in the Smittestopp socio-technical system.

The study has identified four interacting socio-technical systems as part of the study as illustrated in Figure 28 above:

- The Norwegian Government
- The Norwegian bureaucracy represented by NIPH
- The contractor of Smittestopp
- The Norwegian citizen

As such, the study results have answered RQ1 by identifying four key socio-technical systems in the Smittestopp ecosystem. Further, the research results confirm PR1 that the Smittestopp software solution is part of a multitude of interacting socio-technical systems.

On the other hand, the study has not identified, nor included, *all* socio-technical affecting or influencing the Smittestopp ecosystems. Example of such is the Norwegian DPA, the software developers, and a more granular representation of the Norwegian Government.

Figure 28 illustrates the overall socio-technical model but does not detail the interaction between the socio-technical systems. The interaction is a consequence of elaborated Root-cause candidates influencing each other. Thus, Figure 31 above details the socio-technical systems and the interaction between the Root-cause candidates. The interactions between

Root-cause candidates are further illustrated by *Root-cause Chains* in Figure 32 and Figure 33 above.

Since the elaborated Root-cause candidates and interdependencies are a result of brainstorming and workshops not supported by statistical methodologies, the study cannot claim causality between cause and effect. That will require further research involving studies like surveys, interviews, and relevant quantitative data.

Further, proposed system dynamic models are illustrated in Figure 37, Figure 38, and Figure 38 above. These models illustrate interaction od socio-technical variables across identified socio-technical systems. But as stated in chapter 4.2.5, the models do not implement all aspects of the Root-cause analysis, and their primarily function to serve as a thinking tool.

By this, the study has met contribution CO1 by providing requested socio-technical and systems dynamic models. Thus, *this study has identified four central interacting socio-technical systems, their key components, and central system dynamics but does not claim to identify all*. Neither the total interaction between all possible socio-technical systems and their individual components.

Despite the limitation discussed above, the resulting models contribute with essential perspectives to the overall results of interacting socio technical systems and their system dynamics.

5.2 Smittestopp – Citizen's privacy during a crisis

The lawfulness and compliance to existing regulations is often under stress when a crisis emerge. This is the foundation for this research question, proposition and contribution related to this topic:

RQ2: *How are citizens lawful rights to privacy balanced against the societies need for virus tracing during a national crisis?*

PR2: *In chaotic situation invoked by a national crisis like the COVID-19 pandemic, citizens privacy stated by law is violated and restricted.*

CO2: *This study will analyze the balance between violating citizens' lawful rights to privacy and a mean necessary to support a crisis related to the Smittestopp ecosystem.*

The answer to RQ2 mist be seen from both the perspectives of Smittestopp version I and version II. In first version Smittestopp the Norwegian DPA considered the violation of privacy not to be proportional with respect to the sensitivity of the data collected (Norwegian DPA, 2020a, 2020b, 2020c). As such, according to the Norwegian DPA the citizens lawful rights were violated in Smittestopp version I.

Further, with respect to the second version of Smittestopp, relevant reports (Netcompany, 2020a; Norwegian Institute of Public Health, 2020b, 2020d, 2020e) indicates the solution complies to the citizens lawful rights to privacy.

Thus, there virus tracing application was *not compliant* to privacy regulations in its *first version*, but *compliant in the second version*. To explain this shift, the state of order existing in the Norwegian public sector during the days of the two versions was analyzed using the

Cynefin framework (see chapter 0 above). As the analysis propose there existed a state of chaos in the Norwegian public sector during the early days of Smittestopp version I. But, later during the release of Smittestopp version the Norwegian public sector had regained more order.

Although the Cynefin analysis is based on qualitative literature, it is plausible to state that there existed as state of chaos in the early days of the COVID-19 pandemic in the Norwegian public. Thus, also in the early days of Smittestopp version I.

As such, there is a plausible explanation that the state of chaos in the Norwegian public caused a neglection of the citizens privacy motivated by the need of introducing effective countermeasures to fight the COVID-19 pandemic.

Even the Cynefin analysis concludes that the Norwegian public sector has regained more order in the period Smittestopp version II, but this alone is not a plausible explanation. There are reasons to believe that all the negative attention related to violated privacy (Moe, 2020; Norwegian DPA, 2020c; Sandvik, 2020a, 2020b) had in impact to improve privacy compliance in Smittestopp version II.

As such, PR2 statement that citizens privacy stated by law is violated under a chaotic situation invoked by a national crisis, is correct for the early days of the Norwegian COVID-19 pandemic. But also, this study confirms that when order is regained, the compliance to privacy regulation is given more attention.

The measures to keep focus on compliance during crisis was elaborated during SBC-analysis during the Group-modelling workshop. Two of the measures suggested was the ability to comply to with relevant procedures and regulation in times of crisis and establishing a culture for respecting privacy.

As such, this study fulfills CO2 with providing an analysis of the balance between violating citizens' lawful rights to privacy and means necessary to support a crisis related to the Smittestopp ecosystem.

5.3 Smittestopp II – Citizen's reluctance to adopt

As shown in Behavior-Over-Time diagram in Figure 1, Figure 3, and Figure 4 above, the adoption rate of the two versions of the virus tracing application, Smittestopp, differs. The adoption rate of the 2nd version is significantly lower than the 1st version. This is the background for the third research question, proposition, and contribution:

RQ3: Why was Norwegian Citizens reluctant to adopt the second version of COVID-19 tracing app, Smittestopp II?

PR3: *The citizens reluctance to adopt Smittestopp version II was related to multiple factors like previous experience, technical problems, privacy issues, and eroded citizen trust and goodwill.*

CO3: *This study will analyze main cause of actions leading up the reluctance of adopting Smittestopp by utilizing socio-technical (Kowalski, 1994a) and system dynamic modelling (Kim, 1999; Wolstenholme, 2003).*

RQ3 aligns well with the *effect* the Root-case analysis in this study is investigating:

Norwegian Citizens reluctant to adopt second version of COVID-19 tracing app, Smittestopp II

Thus, answering RQ3 is the foundation for the outcome of the Group modelling sessions. But, since the Root-cause analysis conducted in this study shows that effects are a result of chains of interacting events (se cause chain illustrated in Figure 32 and Figure 33 above), the Root-cause of the failure of Smittestopp should be visited. As discussed in chapter 4.2.3.5 and 4.2.5.4 above, without quantitative data supporting the research it would be natural to assume the major Root-cause of declining number of Smittestopp version I users was either/or compliance issues related to privacy or security. The quantitative data refuted this hypothesis, and a more plausible hypothesis supported by the data was:

> *The plausible Root-cause for declining number of Smittestopp version I users was related to technical issues or user experience, and not issues related to privacy or information security. A prime suspect is extensive power consumption (Plikk, 2020)*

This shows both the weakness and the strength of the research process in this study. The weakness is that relying on qualitative data only can lead to wrong conclusions, but the strength of the research process is availability of quantitative data to either confirm or refute candidate theories and hypothesis.

Further, this was not the only deficiency related to the first version of Smittestopp, the Group modelling building concluded that:

> *Smittestopp version I had several deficiencies related to technology, privacy, information security, data management, data governance, voluntary use, and data minimization, and the deficiencies were at large mitigated in version II.*

As, such the sum of issues related to Smittestopp version I elaborated above, created a legacy of negative impression that was inherited by the 2nd version of Smittestopp. As such the plausible Root-cause of RQ3 is:

> *Legacy from issues related to the first version was inherited by version two causing erosion of citizens trust, and further a reluctance to adopt Smittestopp II.*

The Group modelling sessions further elaborated possible measure to remove the legacy inherited from Smittestopp I:

> *Measures are related to ensure good trust management and good communication skills, establish measurement of the virus tracing effect, and ensure adequate support capacity.*

Since the results these results are based on discussions in the Group modeling sessions, they must be considered as only plausible. Although the results are supported by quantitative data and documented events, further research like surveys and data analysis is needed to confirm the results.

As discussed above the proposition:

PR3: *The citizens reluctance to adopt Smittestopp version II was related to multiple factors like previous experience, technical problems, privacy issues, and eroded citizen trust and goodwill.*

Thus, PR3 is considered confirmed by this study to the extent of the discussed limitations of the research process, supporting qualitative and quantitative data.

Further the contribution:

CO3: *This study will analyze main cause of actions leading up the reluctance of adopting Smittestopp by utilizing socio-technical (Kowalski, 1994a) and system dynamic modelling (Kim, 1999; Wolstenholme, 2003).*

CO3 is considered fulfilled with implemented methodologies and applied in this study.

5.4 Proposed socio-technical Root-cause analysis methodology

As the review of the related work in chapter 2.2.1 sums up that all reviewed Root-cause analysis included socio-technical elements in the research. But none of them includes socio-technical and system dynamic analysis that emphases interaction and interdependencies between multiple socio-technical systems. Thus, they did not fulfill the requirements of the Root-cause analysis in this research: the perspectives of multi-layer socio-technical systems and systems dynamics. This rationalizes the following research question, proposition, and contribution:

RQ4: *How can socio-technical Root-cause analysis processes be improved by combining existing well-known methodologies?*

PR4: *Applying existing socio-technical methodologies to root-cause analysis processes improves the insight of causes related to interdependent socio-technical systems*

CO4: *The theoretical contribution this study is a research process combining known methodologies and modelling techniques known from socio-technical systems (Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Goodman, 1991; D. H. Kim, 1999; Richardson, 2013, 2020; Richardson & Andersen, 1995), and lean quality thinking (Ishikawa, 1985; Renee & James, 2010; Womack & Jones, 1996), and sensemaking in complex and complicated contexts (David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)*

Although the review of other related Root-cause analysis (RCA) methods concluded that the did not fulfill the requirements for this research, it may be relevant RCA-methodologies in other subject areas than reviewed. The reviewed RCAs are in the information security area, and there could be in other subject areas like aviation, energy sector, health, and insurance. This is scoped out of this research an considered to be a candidate for further studies.

Proposed RCA-process is illustrated in Figure 19 above and the results of the implementation in the research is discussed in chapter 3.2 0 above.

The general idea of the proposed RCA-methodology is to combine existing well-known methodologies and apply them in a new context. As such, like a set of Lego-blocks that can be reassembled and create new structures. Thus, it can be argued that this study has have a significant theoretical contribution. On the other hand, by already applying already existing work in this manner, it creates a solid foundation for proposed RCA-methodology.

To confirm the results research question, proposition and planned contribution is elaborated and discussed.

RQ4: How can socio-technical Root-cause analysis processes be improved by combining existing well-known methodologies?

The research process designed for this study show that it is plausible to improve existing socio-technical Root-cause analysis by both combining known socio-technical methodologies, and apply both qualitative and quantitative approaches.

PR4: *Applying existing socio-technical methodologies to root-cause analysis processes improves the insight of causes related to interdependent socio-technical systems*

The socio-technical systems developed (see chapter 4.2.3.3 and 4.2.3.4) visualizes the interdependencies between four socio-technical systems. The visualization and work with the models provided insight of both insight of the interdependencies and chain of interacting causes between the ecosystem of interacting socio-technical systems.

Theoretical contribution of this research was:

CO4: *The theoretical contribution this study is a research process combining known methodologies and modelling techniques known from socio-technical systems (Kowalski, 1994a; Mwakalinga & Kowalski, 2011), system dynamics (Goodman, 1991; D. H. Kim, 1999; Richardson, 2013, 2020; Richardson & Andersen, 1995), and lean quality thinking (Ishikawa, 1985; Renee & James, 2010; Womack & Jones, 1996), and sensemaking in complex and complicated contexts (David J. Snowden, 2010; David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003)*

As elaborated in chapter 4.3, the research process applied in this study have shortcomings and room for improvements. The identified shortcomings and potential improvements are:

- Facilitation of Group modelling sessions required more resources than anticipated
- Some of the material required substantial training, and requires more efforts to apply in workshops
- The data could be improved by applying statically sound surveys
- The process can be improved by applying even more qualitative data

Although the identified shortcomings and improvement potential, this research has contributed with a research process or methodology that utilize a combination of existing methodologies in a new concept that provides value in socio-technical root-cause analysis.

The Cynefin framework (David J. Snowden & Boone, 2007; D. J. Snowden & Kurtz, 2003) was applied to analyze the state of order in the Norwegian public sector at two periods of time.

This analysis was conducted by the researcher alone and not discussed in the group. A potential weakness is that the researcher's subjective opinions was influencing the analysis. But, the analysis applied the findings from (Norwegian Coronavirus Commission, 2021a) as the main source. This adds a degree of objectivity to the results. As such, the result of the Cynefin analysis served as a useful backdrop for the activities in the latter Group Modelling workshops

I retrospect, the chosen research process has similarities with the Double Diamond Design Thinking methodology (Design Council, 2015; Stackowiak & Kelly, 2020). As such,

implementing the Double Design methodology in the proposed research process is a candidate for future studies

Although, the proposed research process, or Root-cause analysis (RCS), has the discussed weaknesses, the results from this study has contributed with a methodology that

> *Combines known methodologies and modelling techniques known from socio-technical systems, system dynamics, lean quality thinking, and sensemaking in complex and complicated contexts.*

And, as such

> *Improved socio-technical Root-cause analysis processes by combining existing well-known methodologies.*

Further

> *By applying existing socio-technical methodologies to root-cause analysis processes improved the insight of causes related to interdependent socio-technical systems*

6 Conclusion and Future Work

Due to the COVID-19 crisis the Norwegian government introduced the Smittestopp digital solution as a mean to trace the spread of the corona infection in the Norwegian population.

The Smittestopp COVID-19 virus tracing application was introduced in two versions. The 1st version was released in April 2020, the 2nd in December 2020. Compared to the targets of user adoption, the applications had limited success. In addition, especially the first version was getting negative attention related to technical issues and lacking privacy and information security compliance. These issues were corrected in version two of Smittestopp, but still the Norwegian citizens remained reluctant to adopt the virus tracing application.

This motivated this research to conduct a multi-perspective socio-technical Root-cause analysis elaborating the socio-technical systems involved their interdependencies and interactions.

The socio-technical ecosystem Smittestopp is a part of involves 4 relevant socio-technical systems:

- The Norwegian Government
- The Norwegian bureaucracy represented by NIPH
- The contractor of Smittestopp
- The Norwegian citizen

These socio-technical systems have a rather complicated interaction as illustrated in Figure 31 above.

The COVID-19 pandemic was still emerging in the early days of Smittestopp version I, and Norway was in the middle of a national crisis. To determine the state of order the Norwegian public sector was in this period of time, the research conducted a analysis by applying the Cynefin framework (D. J. Snowden & Kurtz, 2003). The result of the Cynefin analysis showed that Norwegian public sector was operating in the *Chaotic Cynefin domain*. This a possible part of the explanation why the Smittestopp I process characterized by haste and the citizen lawful rights to privacy was ignored.

A Cynefin analysis was also applied to the period time of the 2nd version of Smittestopp. The analysis shown the Norwegian public sector has regained a state of more order having moved out from the *Chaotic* to the *Complicated Cynefin domain*.

Further the study shows that the failure of Smittestopp I has at least two perspectives: *the users' rejection of the application* and the *lack of privacy compliance*.

Data illustrating numbers of downloads and active users (see Figure 4 above) regarding the first perspective shows that a plausible Root-cause for declining number of Smittestopp version I users was related to technical issues or user experience, and not issues related to privacy or information security. A prime suspect is extensive power consumption (Plikk, 2020)

Regarding, the second perspective that gained more negative attention throughout Smittestopp I was related to privacy and security compliance. This caused the action from the Norwegian DPA to temporarily stop collection data (Norwegian DPA, 2020b) and further the Norwegian Institute of Public Health (NIPH) to cancel Smittestopp version I.

The Root-causes resulting in Smittestopp version I cancellation was several deficiencies related to technology, privacy, information security, data management, data governance, voluntary use, and data minimization, and the deficiencies were at large mitigated in version II.

As, such the sum of issues related to Smittestopp version I elaborated above, created a legacy of negative impression that was inherited by the 2nd version of Smittestopp. Thus, the legacy inherited by version two caused an erosion of citizens trust, and further a reluctance to adopt Smittestopp II. In addition, the study reveals that improved communication the Norwegian public sector strategy would contribute positively.

This research suggests measures that could remove legacy inherited from Smittestopp I *are implementing improved trust management, improved communication skills, establish measurement of the virus tracing effect, and ensure adequate support capacity to mitigate technical issues*.

Further the study finds that under a chaotic situation invoked by a national crisis, the citizens privacy stated by law is in risk of violation. This was the situation in the early days of the Norwegian COVID-19 pandemic. But also, this study confirms that when order is regained, compliance of privacy regulations is given more attention.

To enable the research to conduct a multi-perspective socio-technical Root-cause analysis, an improvement of known existing Root-cause analysis (RCA) was applied as part of the research process. The general idea of the proposed RCA-methodology is to combine existing well-known RCA and Socio-technical methodologies and apply them in a new context. As such, like a set of Lego-blocks that can be reassembled and create new structures. Thus, the research process (or RCA-methodology) combines well-known methodologies and modelling techniques known from socio-technical systems, system dynamics, lean quality thinking, and sensemaking in complex and complicated contexts.

Further, the proposed improved socio-technical Root-cause analysis provided an improved insight of causes related to interdependent socio-technical systems

6.1 Future work

Due to limitations related to available resources, time, and capacity there are topics not covered by this study. Thus, there are several areal suggested for future work.

As, discussed in the discussion chapter above, the results related to research questions RQ1-RQ3 is a subject for a validity discussion. Thus, a suggestion to confirm or refute these results is to conduct a quantitative research with questionaries to a statically representative population of Smittestopp users. The survey should investigate the causes related to both adoption and rejection of Smittestopp I, and the potential reluctance to adopt Smittestopp II.

Another suggestion is to conduct a literature survey of RCAs from a socio-technical perspective including application not only in information security but other subject areas as well. For example, the energy sector, aviation, and insurance. The literature survey should have the focus on application of methodologies applied in this study such as socio-technical system modelling, system dynamics, SBC-modelling, and the Cynefin framework

Further, a suggested future work is to research the possible application of the proposed socio-technical Root-cause methodologies on other case studies. As, such the proposed methodology is reviewed, tested, a probably further improved.

In retrospect, the research recognized elements of Design Thinking (Design Council, 2015; Stackowiak & Kelly, 2020) in the proposed methodology. Thus, a proposed future work is to implement Design Thinking elements like Double Dimond into the proposed sociotechnical Root-cause analysis.

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Appendix 1 Detailed Timeline Smittestopp I+II

Table 13: Detailed Timeline - Smittestopp I+II

Date	Topic	Event	Link/reference
11.03.2020	Smittestopp I	Simula CEO Aslak Tveito writes to the NIPH Director General Camilla Stoltenberg to offer services with respect to data analysis and management	Sandvik, K. B. (2020). "Smittestopp": If you want your freedom back, download now. Big Data & Society, 7(2), 2053951720939985. doi:10.1177/2053951720939985
12.03.2020	Smittestopp I	The Norwegian government shuts down Norway due to the COVOD-19 crisis	https://www.regjeringen.no/no/aktuelt/nye-tiltak/id2693327/
12.03.2020	Smittestopp I	The Norwegian government shuts down Norway due to the COVOD-19 crisis	https://www.regjeringen.no/no/aktuelt/pressekonferanse-om-nye-tiltak-for-a-bekjempe-koronaviruset/id2693286/
13.03.2020	Smittestopp I	Development of Smittestopp started	Sandvik, K. B. (2020). "Smittestopp": If you want your freedom back, download now. Big Data & Society, 7(2), 2053951720939985. doi:10.1177/2053951720939985
14.03.2020	Smittestopp I	Simula linked up with UK partners and other government entities	Sandvik, K. B. (2020). "Smittestopp": If you want your freedom back, download now. Big Data & Society, 7(2), 2053951720939985. doi:10.1177/2053951720939985
02.04.2020	Smittestopp I	Massive criticism of corona-app	https://www.dagensmedisin.no/artikler/2020/04/02/massiv-kritikk-mot-korona-app/
04.04.2020	Smittestopp I	Expert group appointed by the Ministry of Health and Care Services	https://www.fhi.no/nyheter/2020/appen-smittestopp-skal-bli-trygg-i-bruk/
08.04.2020	Smittestopp I	Development contract between NIPH and Smittestopp signed	Sandvik, K. B. (2020). "Smittestopp": If you want your freedom back, download now. Big Data & Society, 7(2), 2053951720939985. doi:10.1177/2053951720939985
08.04.2020	Smittestopp I	New app for virus tracing to be reviewed by expert group	https://www.regjeringen.no/no/aktuelt/ekspertgruppe/id2697068/
16.04.2020	Smittestopp I	Contract for operation and maintenance signed	Sandvik, K. B. (2020). "Smittestopp": If you want your freedom back, download now. Big Data & Society, 7(2), 2053951720939985. doi:10.1177/2053951720939985
16.04.2020	Smittestopp I	Release of Smittestopp	https://www.fhi.no/nyheter/2020/ny-app-fra-folkehelseinstituttet/
17.04.2020	Smittestopp I	FFI encourages downloading Smittestopp	https://www.ffo.no/aktuelt/2020/last-ned-smittestopp-appen/
24.04.2020	Smittestopp I	Norwegian Data Protection Authority starts control of NIPH's Smittestopp app	https://www.datatilsynet.no/aktuelt/aktuelle-nyheter-2020/starter-kontroll-av-smittestopp/
05.05.2020	Smittestopp I	Expert group gets access to source code	https://www.fhi.no/nyheter/2020/appen-smittestopp-skal-bli-trygg-i-bruk/
07.05.2020	Smittestopp I	Almost 900,000 (899,142) Smittestopp users and 20.5 percent of the population.	https://www.fhi.no/nyheter/2020/vi-trenger-flere-smittestopp-brukere/
12.05.2020	Smittestopp I	Norwegian Data Protection Authority gives notice of orders to Smittestopp	https://www.datatilsynet.no/aktuelt/aktuelle-nyheter-2020/varsel-om-palegg-til-smittestopp/
18.05.2020	Smittestopp I	Final report for source code review of solution for digital infection detection of coronavirus	https://www.regjeringen.no/no/dokumenter/endelig-rapport-for-kildekodegjennomgang-av-losning-for-digital-smittesporing-av-koronaviruset/id2703467/
19.05.2020	Smittestopp I	300 experts sign Joint statement on contact tracing for Norway	https://medium.com/@jointstatementnorway/joint-statement-on-contact-tracing-for-norway-331ee49fc6f6
20.05.2020	Smittestopp I	The expert group delivers its report to NIPH	https://www.fhi.no/nyheter/2020/fhi-har-mottatt-rapport-fra-ekspertgruppen-om-smittestopp/
20.05.2020	Smittestopp I	The Norwegian Data Protection Authority requests more information regarding Smittestopp	https://www.datatilsynet.no/aktuelt/aktuelle-nyheter-2020/etterspor-mer-informasjon-om-smittestopp/
20.05.2020	Smittestopp I	Expert group suggests improvements in Smittestopp app	https://www.regjeringen.no/no/aktuelt/ekspertgruppe-foreslar-forbedringer-i-smittestopp-appen/id2703470/
01.06.2020	Smittestopp I	NIPH reports that no data is analyzed so far	https://www.bt.no/nyheter/i/qL0MBO/faerre-enn-ti-har-faatt-varsel-fraa-smittestopp-appen
03.06.2020	Smittestopp I	The number of active users as of 3 June 2020 is 592 924.	https://www.fhi.no/sv/smittsomme-sykdommer/corona/nokkeltall-fra-smittestopp/
15.06.2020	Smittestopp I	NIPH stops all data collection	https://www.fhi.no/nyheter/2020/fhi-stopper-all-innsamling-av-data-i-smittestopp/

Date	Topic	Event	Link/reference
15.06.2020	Smittestopp I	The Norwegian Data Protection Authority imposes a temporary ban on processing personal data in Smittestopp	https://www.datatilsynet.no/aktuelt/aktuelle-nyheter-2020/midlertidig-stans-av-appen-smittestopp/
16.06.2020	Smittestopp I	Amnesty International: Bahrain, Kuwait and Norway contact tracing apps among most dangerous for privacy	https://www.amnesty.org/en/latest/news/2020/06/bahrain-kuwait-norway-contact-tracing-apps-danger-for-privacy
16.06.2020	Smittestopp I	The Smittestopp app is divided into two with two different consents	https://www.aftenposten.no/norge/politikk/i/vQaqvm/smittestopp-appen-deles-i-to-med-to-ulike-samtykker
28.09.2020	Smittestopp II	NIIHP decides to acquire a new app for virus tracking	https://www.fhi.no/nyheter/2020/starter-arbeid-med-ny-losning-for-digital-smittesporing/
07.10.2020	Smittestopp II	Tender documents for Smittestopp II released	https://www.fhi.no/om/smittestopp/digital_smittesporing/
15.10.2020	COVID-19 progression	Violent increase of infection in Europe.	https://www.tv2.no/a/11711746/
23.10.2020	COVID-19 progression	City council leader in Oslo municipality greatly concerned about the import of infection from Poland and Lithuania	https://www.aftenposten.no/oslo/i/X8gGgx/sterkt-bekymret-over-importsmitte-fra-polen-og-litauen-oensker-stans-i
20.20.2020	Smittestopp II	Netcompany awarded contract to develop of Smittestopp II	https://www.fhi.no/contentassets/93841455d6554ccb869f3a2fe362b9f6/vedlegg/presentasjoner/pdfer/20-02511-meddelelsesbrev--netcompany.pdf
05.11.2020	COVID-19 progression	The Norwegian Government warns of 2nd wave of the COVID-19 pandemic	https://www.regjeringen.no/no/aktuelt/-hold-dere-hjemme-ha-minst-mulig-sosial-kontakt/id2783763/
21.12.2021	Smittestopp II	New Smittestopp-app ready for download	https://www.fhi.no/nyheter/2020/ny-smittestopp-app-klar-for-nedlasting/
21.12.2021	Smittestopp II	The new Smittestopp-app is far more trustworthy	https://www.tek.no/nyheter/guide/i/lEMB4L/den-nye-smittestopp-appen-er-langt-mer-tillitvekkende
03.01.2021	Smittestopp II	Minister of Children and Families Kjell Ingolf Ropstad encourages use of Smittestopp II	https://www.regjeringen.no/no/aktuelt/innforer-flere-nasjonale-smitteverntiltak/id2826466/
04.01.2021	Smittestopp II	The number of downloads accelerated after the Minister for Children and Families Kjell Ingolf Ropstad (KrF) on Sunday called for the app to be used.	https://kampanje.com/tech/2021/01/den-nye-smittestopp-appen-narmer-seg-350.000-nedlastinger/
21.01.2021	Smittestopp II	4 out of 10 Norwegians say that they want to use the new Smittestopp app, figures from Opinion/Norsk koronamonitor.	https://www.nrk.no/nyheter/4-av-10-vil-bruke-smittestopp-app-1.15337389
22.01.2021	Mutated COVID-19 virus	Mutated virus outbreak in Northern Follo: Asking people not to leave the municipality	https://www.vg.no/nyheter/i/eK5aAy/virusutbruddet-i-nordre-follo-ber-folk-om-ikke-aa-forlate-kommunen
26.01.2021	Smittestopp II	SMS from Norwegian Institute of Public Health encourages downloading Smittestopp II	
27.01.2021	Mutated COVID-19 virus	Fears of mutated virus: Checks 13 samples	https://www.dagbladet.no/nyheter/frykter-mutert-virus-sjekker-13-prover/73337986
28.01.2021	Mutated COVID-19 virus	16 close contacts related to mutated virus: - Very unfortunate	https://translate.google.no/?sl=no&tl=en&text=16%20n%C3%A6rkontakter%20knyttet%20til%20mutert%20virus%3A%20%E2%88%92%20Sv%C3%A6rt%20uheldig&op=translate
02.02.2021	Mutated COVID-19 virus	Mutated virus detected in Ulvik	
28.02.2021	Mutated COVID-19 virus	Oslo municipality hardening infection control measures	https://www.nrk.no/nyheter/byradet-om-koronatiltak-i-oslo-1.15395434
09.03.2021	Mutated COVID-19 virus	Kindergartens and schools in Oslo move to red level	https://www.nrk.no/osloogviken/byradet-strammer-inn-i-oslo-1.15408836
15.03.2021	Mutated COVID-19 virus	Teaching will be digital in Oslo. Prohibition on more than two visitors	https://www.nrk.no/nyheter/blir-digital-undervisning-i-oslo-1.15418816 https://www.nrk.no/nyheter/forbud-mot-mer-enn-to-besokende-1.15418825

Appendix 2 Smittestopp I – Data – number of Downloads and Active Users

Norwegian Population >= 17 years: 4 250 291

Table 14: Smittestopp I – Data – number of Downloads and Active Users

Date	Daily downloads	Daily new active users	Accumulated downloads	Active users	Accumulated downloads % of population	Active users % of population
16.04.2020	810690	476030	810690	476030	19%	11%
17.04.2020	379121	343279	1189811	819309	28%	19%
18.04.2020	120443	-8462	1310254	810847	31%	19%
19.04.2020	38141	-10811	1348395	800036	32%	19%
20.04.2020	45768	9117	1394163	809153	33%	19%
21.04.2020	16416	-41585	1410579	767568	33%	18%
22.04.2020	10097	-29346	1420676	738222	33%	17%
23.04.2020	9445	8451	1430121	746673	34%	18%
24.04.2020	9858	-45452	1439979	701221	34%	16%
25.04.2020	9945	-20410	1449924	680811	34%	16%
26.04.2020	5148	-17940	1455072	662871	34%	16%
27.04.2020	4144	6732	1459216	669603	34%	16%
28.04.2020	5411	-8402	1464627	661201	34%	16%
29.04.2020	19770	-3971	1484397	657230	35%	15%
30.04.2020	4042	-2067	1488439	655163	35%	15%
01.05.2020	10674	-17564	1499113	637599	35%	15%
02.05.2020	9468	2484	1508581	640083	35%	15%
03.05.2020	4775	-11986	1513356	628097	36%	15%
04.05.2020	6295	3972	1519651	632069	36%	15%
05.05.2020	1997	-5483	1521648	626586	36%	15%
06.05.2020	2510	-6007	1524158	620579	36%	15%
07.05.2020	2019	-3063	1526177	617516	36%	15%
08.05.2020	1422	-4928	1527599	612588	36%	14%
09.05.2020	2087	-4479	1529686	608109	36%	14%
10.05.2020	2382	-16386	1532068	591723	36%	14%
11.05.2020	5104	2913	1537172	594636	36%	14%
12.05.2020	1216	-3546	1538388	591090	36%	14%
13.05.2020	633	-5266	1539021	585824	36%	14%
14.05.2020	1562	-7496	1540583	578328	36%	14%
15.05.2020	4413	-6196	1544996	572132	36%	13%
16.05.2020	2809	-9946	1547805	562186	36%	13%
17.05.2020	1901	-10969	1549706	551217	36%	13%
18.05.2020	2390	-2094	1552096	549123	37%	13%
19.05.2020	2524	-4351	1554620	544772	37%	13%
20.05.2020	4169	-3287	1558789	541485	37%	13%
21.05.2020	1907	-18739	1560696	522746	37%	12%
22.05.2020	2055	-3067	1562751	519679	37%	12%
23.05.2020	1649	-8773	1564400	510906	37%	12%
24.05.2020	1592	-8400	1565992	502506	37%	12%
25.05.2020	1623	322	1567615	502828	37%	12%
26.05.2020	1882	-1575	1569497	501253	37%	12%
27.05.2020	1631	-4256	1571128	496997	37%	12%
28.05.2020	1405	-4474	1572533	492523	37%	12%
29.05.2020	1231	-5533	1573764	486990	37%	11%
30.05.2020	796	-11399	1574560	475591	37%	11%
31.05.2020	925	-6604	1575485	468987	37%	11%
01.06.2020	1067	-2314	1576552	466673	37%	11%
02.06.2020	942	-931	1577494	465742	37%	11%

Appendix 3 Smittestopp II – Data – number of Downloads

Norwegian Population >= 17 years: 4 250 291

Table 15: Smittestopp II – Data – number of Downloads

Date	Downloads	Smittestopp II: Accumulated downloads	Smittestopp II: Accumulated downloads % of population > 17 years
20.12.20	0	0	0,0%
21.12.20	117700	117700	2,8%
22.12.20	41000	158700	3,7%
23.12.20	15600	174300	4,1%
24.12.20	9500	183800	4,3%
25.12.20	10900	194700	4,6%
26.12.20	12500	207200	4,9%
27.12.20	10200	217400	5,1%
28.12.20	13800	231200	5,4%
29.12.20	10500	241700	5,7%
30.12.20	7300	249000	5,9%
31.12.20	6800	255800	6,0%
01.01.21	3200	259000	6,1%
02.01.21	3900	262900	6,2%
03.01.21	82100	345000	8,1%
04.01.21	21300	366300	8,6%
05.01.21	8300	374600	8,8%
06.01.21	27400	402000	9,5%
07.01.21	6000	408000	9,6%
08.01.21	4600	412600	9,7%
09.01.21	3300	415900	9,8%
10.01.21	3700	419600	9,9%
11.01.21	3400	423000	10,0%
12.01.21	2200	425200	10,0%
13.01.21	10100	435300	10,2%
14.01.21	2700	438000	10,3%
15.01.21	1800	439800	10,3%
16.01.21	1300	441100	10,4%
17.01.21	19700	460800	10,8%
18.01.21	4400	465200	10,9%
19.01.21	3000	468200	11,0%
20.01.21	3600	471800	11,1%
21.01.21	2500	474300	11,2%
22.01.21	3200	477500	11,2%
23.01.21	10600	488100	11,5%
24.01.21	55300	543400	12,8%
25.01.21	18600	562000	13,2%
26.01.21	96300	658300	15,5%
27.01.21	17400	675700	15,9%
28.01.21	6700	682400	16,1%
29.01.21	4200	686600	16,2%
30.01.21	3800	690400	16,2%
31.01.21	2000	692400	16,3%
01.02.21	700	693100	16,3%
02.02.21	2500	695600	16,4%
03.02.21	58100	753700	17,7%
04.02.21	54600	808300	19,0%
05.02.21	26200	834500	19,6%
06.02.21	3000	837500	19,7%
07.02.21	9600	847100	19,9%
08.02.21	4800	851900	20,0%
09.02.21	2100	854000	20,1%

Date	Downloads	Smittestopp II: Accumulated downloads	Smittestopp II: Accumulated downloads % of population > 17 years
10.02.21	1700	855700	20,1%
11.02.21	1600	857300	20,2%
12.02.21	1500	858800	20,2%
13.02.21	400	859200	20,2%
14.02.21	1400	860600	20,2%
15.02.21	1500	862100	20,3%
16.02.21	1300	863400	20,3%
17.02.21	1900	865300	20,4%
18.02.21	400	865700	20,4%
19.02.21	1500	867200	20,4%
20.02.21	1400	868600	20,4%
21.02.21	200	868800	20,4%
22.02.21	1400	870200	20,5%
23.02.21	1500	871700	20,5%
24.02.21	400	872100	20,5%
25.02.21	1500	873600	20,6%
26.02.21	700	874300	20,6%
27.02.21	500	874800	20,6%
28.02.21	4500	879300	20,7%
01.03.21	600	879900	20,7%
02.03.21	4000	883900	20,8%
03.03.21	1700	885600	20,8%
04.03.21	1600	887200	20,9%
05.03.21	1400	888600	20,9%
06.03.21	1400	890000	20,9%
07.03.21	1400	891400	21,0%
08.03.21	3100	894500	21,0%
09.03.21	5700	900200	21,2%
10.03.21	3000	903200	21,3%
11.03.21	1900	905100	21,3%
12.03.21	19600	924700	21,8%
13.03.21	900	925600	21,8%
14.03.21	4900	930500	21,9%
15.03.21	3000	933500	22,0%
16.03.21	1000	934500	22,0%
17.03.21	30100	964600	22,7%
18.03.21	2800	967400	22,8%
19.03.21	1500	968900	22,8%
20.03.21	1400	970300	22,8%
21.03.21	1500	971800	22,9%
22.03.21	1600	973400	22,9%
23.03.21	1500	974900	22,9%
24.03.21	1700	976600	23,0%
25.03.21	1000	977600	23,0%
26.03.21	2400	980000	23,1%
27.03.21	1400	981400	23,1%
28.03.21	300	981700	23,1%
29.03.21	1300	983000	23,1%
30.03.21	200	983200	23,1%
31.03.21	1400	984600	23,2%
01.04.21	200	984800	23,2%
02.04.21	100	984900	23,2%
03.04.21	1200	986100	23,2%
04.04.21	200	986300	23,2%
05.04.21	1200	987500	23,2%
06.04.21	200	987700	23,2%
07.04.21	1100	988800	23,3%
08.04.21	0	988800	23,3%
09.04.21	500	989300	23,3%
10.04.21	1200	990500	23,3%

Date	Downloads	Smittestopp II: Accumulated downloads	Smittestopp II: Accumulated downloads % of population > 17 years
11.04.21	100	990600	23,3%
12.04.21	200	990800	23,3%
13.04.21	5400	996200	23,4%
14.04.21	400	996600	23,4%
15.04.21	130	996730	23,5%
16.04.21	300	997030	23,5%
17.04.21	1100	998130	23,5%
18.04.21	100	998230	23,5%
19.04.21	200	998430	23,5%
20.04.21	200	998630	23,5%
21.04.21	200	998830	23,5%
22.04.21	1400	1000230	23,5%
23.04.21	300	1000530	23,5%
24.04.21	100	1000630	23,5%
25.04.21	1200	1001830	23,6%
26.04.21	1300	1003130	23,6%
27.04.21	200	1003330	23,6%

Appendix 4 Detailed results - Rating Socio-technical framework for digital contact tracing

Table 16: Detailed results - Rating Smittestopp Socio-technical Framework for Contact Tracing Apps

Nbr	Category	Criteria	Score guide	Smittestopp I	Smittestopp II
1	Impact on the citizens	Respecting fundamental rights of individuals	This includes the rights to safety, health, non- discrimination and freedom of association (2). Unclear information/only partially respecting these rights (1), or not respecting them (0) are not adequate	0	2
2	Impact on the citizens	Privacy and data protection	Data collection should be compliant with the General Data Protection Regulation (GDPR) [6] and respect the privacy of the individual. A Data Protection Impact Assessment (DPIA) must be carried out before the deployment of any contact-tracing system. The purpose of the app and the mechanisms to assess its usage need to be clearly defined. All these requirements should be fulfilled (2), whereas fulfilling them only partially (1) or not at all (0) are not adequate	1	2
3	Impact on the citizens	Transparency rights	They include the right of users to be notified, to control their own data, transparency regarding which personal data are collected, and of explanation of app-produced output. The app should be auditable. Fulfillment of all requirements (2) is suitable, whereas fulfilling them only partially (1) or not at all (0) are not adequate	1	2
5	Impact on the citizens	Accessibility	Possibility to be used by all regardless of demographics, language, disability, digital literacy, and financial accessibility. All these requirements should be fulfilled (2), whereas addressing them only partially (1) or not at all (0) are not adequate	0	2
7	Technology	Decentralized protocol	E.g. use of the Decentralized Privacy-Preserving Proximity Tracing (DP-3T) architecture. Furthermore, the app needs to allow interoperability. Bluetooth is preferred over GPS. A fully decentralized protocol is best (2), whereas mixed (1) or completely centralized approaches are not adequate (0).	0	2
8	Technology	Data management	Ensure data-minimization principle, i.e., usage of local and temporary storage, and encryption, based on principles of data protection by design. Ensure that only data strictly necessary are processed. All these requirements are needed (2), whereas unclear documentation (1) or lack of compliance with all of them (0) are not adequate	0	2
9	Technology	Security	User authentication to prevent risks such as access, modification, or disclosure of the data. Use unique and pseudo-random identifiers, renewed regularly and cryptographically strong. Compliance with these requirements is needed (2), whereas unclear (1) or lack of compliance (0) are not adequate	1	2
10	Technology	App easy to deactivate/remove	Either through clear instructions or automatically by sunset clause (2). Unclear (1) or difficulties for removing the app and the data (0) are not adequate	1	1
11	Technology	Open-source code	Participatory and multidisciplinary development, access to the code and methods used for adaptation to new knowledge on the virus (2).	0	2

Nbr	Category	Criteria	Score guide	Smittestopp I	Smittestopp II
			Open-source code without the possibility of contributing (1) is not recommended, and non open-source code is undesirable (0)		
13	Governance	Data governance should be made public	Open data governance is preferable (2), while intermediate (1) or private/opaque settings (0) are not suitable	0	2
14	Governance	Use	Downloading the app needs to be voluntary (2). Furthermore, the use of the app cannot be mandatory to access certain places (1) or otherwise be legally enforced (0)	0	2
15	Governance	Sunset clause	This needs to be clearly specified with a clear date and procedure (2), while unclear information (1) or the lack of such a clause (0) are not adequate	0	2
17	Governance	Incidental Findings and dual-use policy	Purposes beyond contact tracing (e.g. placing people into crime scenes, identification of behaviour patterns) are strictly prohibited (2). If not, at least a policy stating what are the other potential uses of the data collected (1) needs to be in place	0	2
18	Governance	Design Impact Assessment and Open Development Process	Explicit design process, including clear description about aims and motivation, stakeholders, public consultation process and impact assessment (2). Unclear information (1) or the lack of such an assessment (0) are not adequate	0	2
19	Governance	Right to contest/liability	Users need to be able to contest decisions or demand human intervention (2). Partial/unclear compliance (1) or the lack of this feature (0) are not adequate	1	2

Appendix 5 Survey Forms Education, Experience and Competence levels

Below are the forms used to survey the Group Modelling sessions atendees education, experience, and competence levels

Table 17: Survey form education and experience

Education and experience The purpose of this section in the survey is to document the education level and experience of the respondents
Highest level of education ○ High school (videregående) ○ Bachelor ○ Master ○ PhD
Type of education ☐ Computer Science ☐ Mathematics ☐ Social Science ☐ Engineering ☐ Other
Working experience - length ○ 1-3 years ○ 4-6 years ○ 7-10 years ○ more than 10 years
Working experience - Professions ☐ IT Consulting ☐ Management consulting ☐ Software development ☐ Project managing ☐ Enterprise architecture ☐ Privacy ☐ Information security ☐ Other
Working experience - sectors ☐ Private sector ☐ Public sector ☐ Health ☐ Education ☐ Finance ☐ Politics ☐ Aviation ☐ Energy sector ☐ Retail ☐ Other

Table 18: Survey form competence areas

Knowledge of competence areas used in Group Model Building workshops

The purpose of this section in the survey is to document of the level of competence related to the areas applied in Group Modelling sessions using Bloom's Taxonomy of Educational Objectives (See figure below).
As the figure describes, Bloom's taxonomy consists of 6 levels with level 1 as the most basic level. The figure below with the accompanying descriptions serves as guidance when setting relevant competance level in the survey questions.

Are you familiar with the Norwegian virus-tracing app, Smittestopp, related events and activities?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Do you know Ishikawa (Fishbone) diagrams?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Are you familiar with the term "socio-technical systems"?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Are you familiar with Security by Consensus (SBC) models and modelling?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Are you familiar with System Dynamic Models and modelling?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Are you familiar with Root-cause analysis?

Rate 0-6 according to Bloom taxonomy

0	1	2	3	4	5	6
○	○	○	○	○	○	○

Appendix 6 Survey Results Education, Experience and Competence levels

Survey results Education and Experience

Highest level of education	Percent	Answers
High school (videregående)	0%	0
Bachelor	25%	1
Master	75%	3
PhD	0%	0

Type of education	Percent	Answers
Computer Science	100%	4
Mathematics	25%	1
Social Science	0%	0
Engineering	0%	0

Working experience - length	Percent	Answers
1-3 years	0%	0
4-6 years	0%	0
7-10 years	0%	0
more than 10 years	100%	4

Working experience - profession	Percent	Answers
IT Consulting	100%	4
Management consulting	25%	1
Software development	75%	3
Project managing	100%	4
Enterprise architecture	100%	4
Privacy	25%	1
Information security	0%	0

Working experience - sectors	Percent	Answers
Private sector	75%	3
Public sector	75%	3
Health	50%	2
Education	50%	2
Finance	25%	1
Politics	0%	0
Aviation	0%	0
Energy sector	50%	2
Retail	50%	2

Table 19: Survey results Education and Experience

Survey results Competence Levels

Before Group Modelling sessions

	Ishikawa diagrams	Root cause analysis	Security by Consensus (SBC) modelling	Socio-technical systems	System Dynamic modelling	Familiar with Smittestopp, related events and activities
	1	3	0	2	1	5
	0	5	0	2	0	3
	2	2	0	0	0	2
	3	3	0	0	0	6
	0	1	0	2	0	2
Min	0	1	0	0	0	2
Q1	0	2	0	0	0	2
Median	1	3	0	2	0	3
Q3	2	3	0	2	0	5
Max	3	5	0	2	1	6

Table 20: Survey results Competence Levels - Before Group Modelling sessions

After Group Modelling sessions

	Ishikawa diagrams	Root cause analysis	Security by Consensus (SBC) modelling	Socio-technical systems	System Dynamic modelling	Familiar with Smittestopp, related events and activities
	3	5	2	6	5	5
	3	3	0	5	3	5
	2	5	0	3	4	2
	0	3	0	0	0	5
Min	0	3	0	0	0	2
Q1	1,5	3	0	2,25	2,25	4,25
Median	2,5	4	0	4	3,5	5
Q3	3	5	0,5	5,25	4,25	5
Max	3	5	2	6	5	5

Table 21: Survey results Competence Levels - After Group Modelling sessions

Rune Schumann

The Norwegian Infection-Tracing App analyzed from a Socio-technical Perspective

NTNU
Norwegian University of
Science and Technology