UiT The Arctic University of Norway

Faculty of Health Sciences, Department of Community Medicine

# Economic aspects of the DHIS2 contact tracing system as part of the COVID-19 strategy in Tromsø municipality

Johanna Sanoja

Master's thesis in Public Health, HEL-3950, May 2022

*Supervisor: Torbjørn Wisløff*

*Co-supervisor: Einar Kristian Borud*

# Abstract

**Background:**

The corona virus pandemic caused by the SARS-CoV-2 virus begun in Norway in 2020. The Norwegian government decided that test-identify-trace-quarantine is the main national strategy fighting against the pandemic. From municipalities this required contact tracing actions to maintain the number of transmissions as low as possible. There was no earlier experience of contact tracing of this scale, nor knowledge of resources required from municipalities.

**Objective:**

The objective of this study was to estimate the resources needed for implementing and running a contact tracing function in a municipality, using Tromsø as an example. We aimed to describe a resource frame for contact tracing related to COVID-19.

**Data and methods:**

A mixed methods costing study was conducted, including COVID-19 index cases and close contacts registered on DHIS2 system used by Tromsø municipality, and cost related estimates from several sources. Probabilistic sensitivity analyses run as Monte Carlo simulation to cover the uncertainty in the data.

**Results:**

During 2020 in Tromsø municipality there were in the DHIS2 system registered 644 positive cases with SARS-CoV-2 virus, and 587 close contacts. With 95 percent uncertainty interval (NOK 557 149 – NOK 796 839), total cost of contact tracing was NOK 666 946 during 2020 for the municipality of Tromsø with population of 76 974 persons. Estimated costs for other hypothetical municipalities with populations of 1000 and 200 000 persons were NOK 60 003 and NOK 1 669 463, respectively.

**Conclusion:**

The cost of contact tracing facility in Tromsø was approximately NOK 670 000 during 2020, but the results are highly uncertain.



**Keywords:**

COVID-19, HMIS, TISK, contact tracing, uncertainty

# Acknowledgements

Being able to write about something so topical as COVID-19 and having a chance to deepen my knowledge of health economics has truly been the best imaginable end for this master's degree journey. I was truly fortunate with having Torbjørn Wisløff and Einar Borud as my supervisors; besides receiving appreciated support, you challenged and taught me loads. I also want to thank Jagrati Jani-Bølstad from Tromsø municipality for introducing me the data from the DHIS2 system.

Studying pandemic during a pandemic has definitely been an extraordinary experience. Along my family and friends in Finland; I want to thank to my fellow UiT students Laura Nevala and Mikaela Reinikainen, we all made it through, together. I am grateful to have had an exceptionally good studying environment at the harmonious housing provided by my dear neighbors and landlords, Borghild Richter-Hanssen and Jørgen Sundby. Yet most priceless has been the support from home, and I want to thank Krister Ekeroth for being the shoulder to cry on, an indomitable conversation partner, eternal optimist, and keeping my feet on ground.

# Table of Contents

# List of Tables



# List of Figures

# Abbreviations

| | |
|---|---|
| COVID-19 | Corona virus disease 2019 |
| ECDC | European Centre for Disease Prevention and Control |
| DHIS2 | District Health Information Software 2 |
| HMIS | Health Management Information System |
| KS | Norwegian Association of Local and Regional Authorities |
| MSIS | Norwegian Surveillance System for Communicable Diseases |
| NIPH | Norwegian Institute of Public Health |
| NOK | Norwegian krone |
| NSD | Norwegian Centre for Research Data |
| NSF | Norwegian Nurses Organization |
| PCR-test | Polymerase chain reaction -test |
| PSA | Probabilistic Sensitivity Analysis |
| SARS-CoV-2 | Severe Acute Respiratory Syndrome related Coronavirus |
| SE | Standard Error (of the mean) |
| USHT | Centre for Development of Institutional and Home Care Services |
| WHO | World Health Organization |

# 1 Introduction

On 30th of January 2020 the World Health Organization (WHO) declared that a respiratory virus that caused coronavirus disease and had spread rapidly globally since December 2019, was not only pandemic but also a Public Health Emergency of International Concern (PHEIC).(1) Norway's first positive COVID-19 case was detected in Tromsø, 26th of February 2020 (2, 3). In the early phase the Norwegian government made Test-Isolate-Trace-Quarantine (TISK) as their main strategy against the pandemic, following the WHO recommendation to set weight on aggressive testing and contact tracing.(4)

During the year 2020, the European Centre for Disease Prevention and Control (ECDC) listed four different virus variants of concern in Europe. Besides the original alfa, virus variants labelled beta, gamma and delta were also considered as variants to be seen in Norway.(5)

The process of developing a vaccine against COVID-19 started early, and the first vaccine against SARS-CoV2 was developed during 2020 in record time. The first vaccine being approved for use and distribution in Norway was Comirnaty mRNA vaccine from manufacturers BioNTech and Pfizer on 21st of December 2020.(6) Vaccinating the elderly and those in highest risk to become severely ill, begun in Norway from 27th December 2020 with the first doses. By the end of the year 2020, a total of 2402 first vaccine doses had been administered in Norway.(7) Therefore the vaccine introduction is likely to have had no impact on COVID-19 spread in the year 2020.

Tromsø is one of the 356 municipalities in Norway.(8) As the total population of Norway at the end of the first quarter of the year 2020 was 5 367 580 persons, the population of Tromsø represents approximately 1,43 percent of the total population of the country.(9) With a population of 76 974 persons (1st January 2020), Tromsø is commonly called the capital of the northern Norway. Tromsø is part of Troms and Finnmark county with major impact of travel through, cargo-, and transport movement.(10) The port of Tromsø is one of the biggest harbors in Norway. Even with reduced activity during year 2020, there was a total of 7939 docking calls in Tromsø harbor, 1619 of them being made by international and 6320 domestic ships.(11)

Keeling et. al., have discovered in their study in England that one positive SARS-CoV-2 virus carrier can spread the virus to approximately 36 other individuals as close contacts, while efficient contact tracing can reduce the spread of the virus (12).

With manual contact tracing, there is a risk that the contacted index case does not remember all the close contacts. If a close contact later is found to have a positive COVID-19 test, close contacts of this original contact is to be traced. It is necessary to be able to link these cases, and maintain a reliable data registry.(13) In some cases interpreter was needed, which made the contact tracing more challenging and time consuming [Personal communication: Laila Arnesdatter Hopstock, UiT The Arctic University of Tromsø].

Contact tracing following TISK was not going to be rapid and comprehensive enough by just pen and paper, therefore an electronic tool was needed for the process (14). Yet there were no direct guidelines on how to technically be prepared for the contact tracing, by which tools, and how much resources it would require.

Tools related to pandemic control can be divided into three groups focusing on either: *outbreak response*, *tracing proximity*, or *tracking symptoms*. The latter two requires mobile phone application or other Bluetooth- or location tracking and communicating device for the use of the public, and are to be used together with an outbreak response tool. Whereas plain outbreak response -tools are designed for healthcare personnel working with contact tracing.(13) During the COVID-19 pandemic in Norway, the national contact tracing mobile Smittestopp application was launched in December 2020 but it did not communicate with outbreak response -systems (15). The *outbreak response* tool called District Health Information Software -system (DHIS2), was chosen as a tool for COVID-19 contact tracing in Tromsø municipality. It rose then interest of how cost-efficient it was for Tromsø municipality to choose this precise tool, and how much staff resources the contact tracing would require while using this tool.

The objective of this study is to estimate the resources needed for implementing and running a contact tracing function in the municipality. The study aims to give a resource frame for future pandemic preparedness planning. This analysis covers the uncertainties in estimated resources used for COVID-19 contact tracing in Tromsø during year 2020, and projects the costs for smaller and larger municipalities than Tromsø.

This master's thesis is the final assignment of Master of Public Health -study programme, for HEL-3950 course at The Arctic University of Tromsø.

# 2 Background

## 2.1 DHIS2

District Health Information Software 2 (DHIS2) is an open-source health management information system (HMIS) platform, developed in Norway by a group of PhD students and faculty members of Department of Informatics at the University of Oslo. DHIS2 is one of the most chosen HMIS platforms, being now used in more than 100 countries.(16) The DHIS2 platform was originally created for the needs of low-income countries, and has been taken in use for several international organizations for their field data registering and reporting-tool (17). In January 2022, 42 countries were using DHIS2 based systems for Covid-19 close contact tracing, and 13 countries were in a development phase on implementing this contact tracing tool.(18) In 2021 at least 307 municipalities in Norway were using DHIS2 based systems for their contact tracing (14).

In several countries, contact tracing was combined with mobile phone app for public use (13). The DHIS2 contact tracing tool in Norway is for professional use only, to help contact tracers more systematically behold and share information and it is not connected with phone application for the general public.

In Norway, the DHIS2 -system for COVID-19 contact tracing, is linked under Norwegian Association of Local and Regional Authorities (KS) via their Fiks platform for digital solutions for municipalities. Via this connection, DHIS2 is linked with the National Population Register and data from the DHIS2 system can be extracted for reporting for example for NHIS. As the DHIS2 system is a cloud service, all the system updates are coordinated by KS.(19)

The process to scope and select a digital tool for contact tracing was launched from 23rd of March of 2020.(14) Actual use of DHIS2 -system for Covid-19 contact tracing begun in Tromsø municipality in June 2020. All data gathered prior to that was manually registered in the system afterwards. [Personal communication: Jagrati Jani-Bølstad, Tromsø Municipality]. The DHIS2 system has had several updates due to changes in national and local regulations for contact tracing. Due to the DHIS2 being a cloud service for all KS users, individual per municipality changes cannot be done as the program is equal for all users.(19)

## 2.2 Contact tracing

The Norwegian Institute of Public Health (NIPH) has created a guideline to municipalities for contact tracing. At the beginning of the pandemic, it was recommended that everyone who has respiratory symptoms must get tested.(4) Testing process and diagnostic laboratory procedures were established in January 23rd of 2020 (3). COVID-19 testing during the year 2020 were performed in the municipalities Covid-19 test centers, or in some cases via primary- or special health-care services (20).

After Tromsø had the first positive COVID-19 case in Norway on February 26th 2020 there was a need for rapid implementation of a contact tracing service. Contact tracers in Tromsø were primarily trained for the contact tracing task internally by the municipality. [Personal communication: Jagrati Jani-Bølstad, Tromsø Municipality]. In December 2020 a national online course for contact tracing was created by NIPH and Norwegian Directorate of Health. Health districts have several portals to enter to this course from. In Tromsø one could take this online course via the KS learning -portal, provided by KS.(21) Recruitment announcement from 2021 declares that all contact tracers in Tromsø municipality are to be over 18 years old, have good Norwegian- and English language skills, and have experience with using basic information communication technology (22).

Besides contacting the person found to be infected with the COVID-19 virus, and those being possibly close contacts for this person, contact tracing work included registering. In addition to DHIS2, each contact tracer registers data to Norwegian Surveillance System for Communicable Diseases (MSIS), and System-X patient journal system. [Personal communication: Laila Arnesdatter Hopstock, UiT The Arctic University of Tromsø].

### 2.2.1 Index case

A swab sample examined with a Polymerase Chain Reaction (PCR) -test method, is taken most commonly from the upper respiratory airways, nasopharynx.(23) A person who tested positive for SARS-Cov2 virus, is defined as an index case.(24) After a positive test result, the index case is contacted by the contact tracing team. Isolation is ordered and it is assessed who may be close contacts of the index case.

### 2.2.2 Close contact

NIPH defined in 2020 that those who have been in contact with someone to be confirmed having COVID-19 in the time window of 48 hours from the first symptoms, or time of testing for positive test result, are considered as close contacts. Close contact includes having had direct physical contact, being exposed to secretions of this person or being closer than 2 meters for more than 15 minutes.(24)

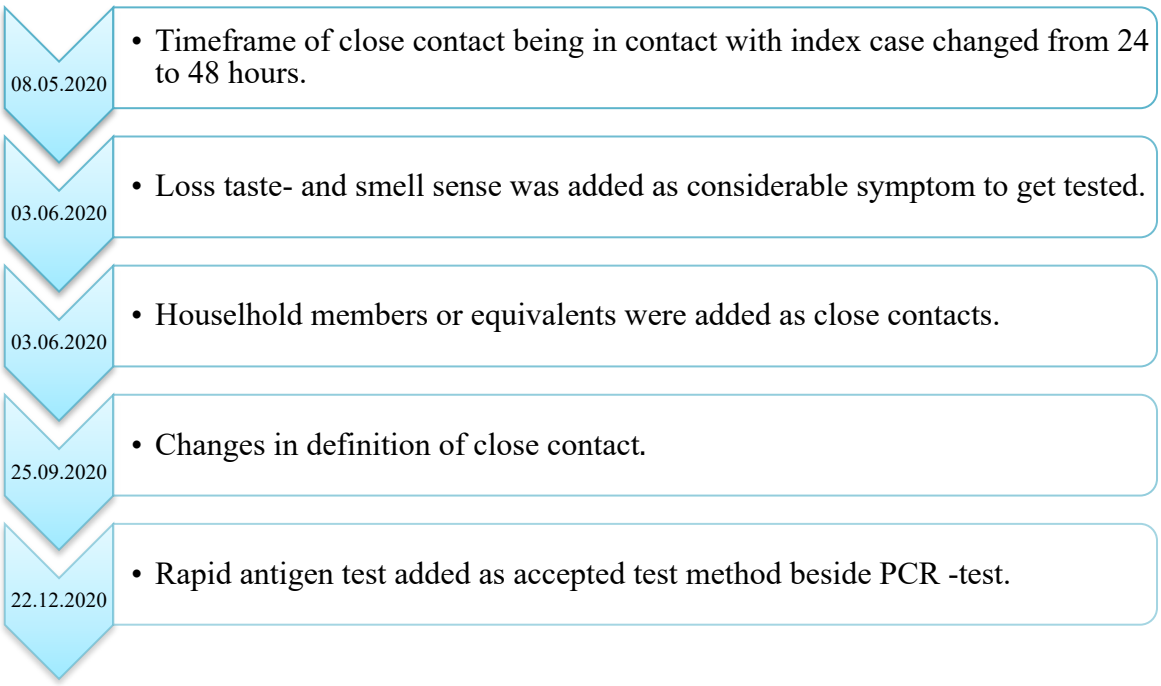


Figure 1. Some of the main changes in definitions during 2020 (24)

As continuously reported by NIPH, there were several changes of these definitions and regulations around who should get tested and how, and who is considered as close contact, during the year 2020 (24). Some of the most impactful are shown in Figure 3. Most importantly, the time window was primarily considered to be only 24 hours but extended to 48 hours on May 8th 2020. From 22nd of December 2020, confirmed index cases were also those who had received positive result from rapid antigen test.(24)

Close contacts are advised to take PCR-test soonest possible, and again after seven days. Close contacts are quarantined until the first PCR-test result is negative. Contact tracing team is also contacting others that have been in contact with the index case. They might be asked to test themselves and stay at home until test result is clear.(25)

## 2.3 Resource use

Staffing contact tracing (as seen in Figure 1.) during the year 2020 went through many changes. After the first cases, contact tracing responsibility lied under the Municipality Infection Control Chief Physician. From March 13th until end of April 2020, nurses and other health care professionals from Tromsø municipality Centre for Development of Institutional and Home Care Services (USHT) took responsibility of the contact tracing tasks. After May 2020 opened Tromsø municipality an official Corona Center and overtook contact tracing. [Personal communication: Øivind Benjaminsen, Tromsø Municipality].


Figure 2. Responsibility of contact tracing in Tromsø in 2020.

Contact tracers that have taken the national course, and passed a test afterwards, could register themselves in a national health personnel database as reserve staff for the municipality's needs.(26) In the early phase of the pandemic, municipalities were helping each other with sharing contact tracing resources – yet it is not documented how often this happened [Personal communication: Ragnhild Bassøe Gundersen, HISP Centre and Department of Informatics University of Oslo]. As shown later in this study, the need for labor resources varied according to the number of index cases and close contacts.

## 2.4 Corona center

During the summer 2020, Tromsø municipality launched a specified corona center to coordinate testing, contact tracing and vaccinating. Contact tracers have been working on three different locations inside the city of Tromsø; in Fiolveien, Kroken and Stakkevollveien. [Personal communication: Øivind Benjaminsen, Tromsø Municipality].

The contact tracers of Tromsø municipality were equipped with laptops, mobile phone and a headset. Mainly contact tracing was done at the office, but occasionally from home. If work was done from home, then some of the registering might have been done next possible time at

the office. [Personal communication: Laila Arnesdatter Hopstock, UiT The Arctic University of Tromsø].

## 2.5 Challenge

Municipalities followed the 1994 Act relating to control of communicable diseases § 7-1 (4) and the municipality head physician guidebook (27) and NIPH guidelines (28). Neither guidebook nor NIPH have directly assessed how much contact tracing resources each community would need, as this was left to the local municipalities to estimate [Personal communication: Emily MacDonald, Norwegian Institute of Public Health].

Little of the practicalities related to the pandemic was planned or prepared in forehand, and although municipalities were following orders and advise from the government, tools for example for contact tracing did not exist and there were no expertise to use them in the municipalities.(29) As due to different needs arising from municipalities resources and needs, several different HMIS systems have been in use in Norway, DHIS2 being one of the used contact tracing systems.(30)

## 2.6 Costing study

As contact tracing in this scale had not been performed before in Tromsø municipality, there was no certainty of how much resources the contact tracing would require.(29) Therefore this study aims to cover the economic evaluation in a form of analyzing the costs of contact tracing. Result of a costing study can then be used in a possible later cost-effectiveness analysis, and as a reference for targeting resources for contact tracing more efficiently.

Guidelines for costing studies as described by Hendriks. et. al.(31) were followed in this study. The study design is in depth explained further in the Study design -chapter.

## 2.7 Study aim, objective, and study question

This study aims to describe a resource frame of COVID-19 contact tracing, to be further used in pandemic preparedness planning for future, and efficiency estimation of contact tracing. Objective is to define the resource requirements for implementing and running contact tracing function.

The study question for this Master's thesis is:

*What are the cost implications of setting up and running COVID-19 contact tracing?*

# 3 Material and methods

## 3.1 Study design

A mixed methods costing study -design was chosen to be used for this work. Guidelines by Hendriks et. al. (31) was followed on the study structure. Data for the study was collected from multiple sources, and several of the cost data were unprecise estimates including uncertainty. To define the methodology for the costing study, accuracy and valuation of resources were first identified. With a bottom-up approach, the municipality utilization data is multiplied with unit prices to gain the cost estimate for the municipality.(31)

## 3.2 Population

The population in this study covers all those people who have received a positive test result for COVID-19, and are either living or currently staying in Tromsø, and their close contacts. This includes persons being tested either in Tromsø municipality test locations, test location of some other municipality (for example at the airport), and later in the year 2020 also tested by self-tests.

If a person was tested elsewhere, the laboratory analyzing the test or the doctor responsible for the treatment of this person, usually a general practitioner, then contacted the contact tracing team of the persons hometown. If a person was found to be close contact to someone elsewhere, the contact tracers could pass the information to the municipality of current residence so that they could locally maintain the contact for this close contact. Therefore, it is possible in the data to have close contacts even if there were no current local positive test results.

## 3.3 Ethical considerations

All used data is impersonal. There was no need for ethical approval from Regional Committees for Medical and Health Research Ethics (REC), or permit from Norwegian Centre for Research Data (NSD).

## 3.4 Data collection

### 3.4.1 Timeframe

Timeframe for collected data is set to be from 26th of February 2020 as then was the first index case detected in Tromsø.(2, 3) Endpoint for data timeframe is 31st of December 2020. Limiting the data sample to the end of the calendar year makes it more compliable with the municipality budget data. Even though there were only few index cases during early 2020, the costs of implementing contact tracing system, and resources for running the COVID-19 contact tracing activity were the main interest in this study.

### 3.4.2 Data

Data (by the plan in Table 1.) are received from several sources. Number of COVID-19 index cases and close contacts -data was extracted from the DHIS2 system by Tromsø municipality representant, advisor and epidemiologist Jagrati Jani-Bølstad. Exact data from Tromsø municipality regarding contact tracing, such as labor hours and other expenses were originally indicated to be made available for the present project. Despite numerous attempts, this proved unsuccessful, and the project is therefore based on best available costs estimates from a range of different sources. Salary is an average from Norwegian Nurses Organization (NSF), equipment is an estimate from The Arctic University of Tromsø (UiT), and cost of office space is an average from Norwegian classified advertisement web page FINN.no. More thorough explanation of the sources and variables further in the 3.5 cost estimates -chapter.

Table 1. Data variables and explanations

| Variable | Explanation | Source |
|---|---|---|
| Index cases | Daily number of index cases in Tromsø municipality 26.02.-31.12.2020 | DHIS2 |
| Close contacts | Daily number of close contacts in Tromsø municipality 26.02.-31.12.2020 | DHIS2 |
| Labor | Daily number of working hours used for COVID-19 contact tracing in Tromsø municipality 26.02.-31.12.2020 | Jagrati Jani-Bølstad |
| Salary | Average salary for nurse working for municipality in year 2020. | NSF |
| Equipment | Average cost for similar equipment package as used for contact tracing in municipality of Tromsø at year 2020. | UiT |
| Office space | Average office space cost for office space with similar location than Kroken corona center in Tromsø. | FINN.no |

## 3.5 Cost estimates

Following cost definitions defined by Drummond et.al., this study contains both fixed costs and variable costs. Fixed costs do not vary by the quantity of the output but rather by time. Variable costs on the other hand often varies by the output.(32)

In this thesis, cost estimates of rent and equipment are defined under the fixed costs category. Salary, as hours spent per index case and close contact vary by the daily amount of index cases and close contacts; is seen as variable cost. This division is made to make it easier for

municipalities to plan for future outbreaks of infectious diseases, since the variable costs are varying by the number of infections.

Methodology under mixed methods of costing study is explained (in Table 2.) below. In this study, all the costs are seen as *direct costs*.(31)

Table 2. Methodologies, data requirements and calculations to measure and value cost items for costing.

| Cost component | Methodology | Data requirements | Calculations |
|---|---|---|---|
| *Direct costs* | | | |
| Salary | Bottom-up micro costing | Staff salary for staff involved in contact tracing. Minutes spent per index case and close contact. | 1)Yearly average salary/yearly productive hours=staff cost per hour. 2)Minutes spent per index case and close contact. |
| DHIS2* | Top-down micro costing | Software price for municipality. | Software price for municipality per year/365 days=price per day |
| Equipment per set | Bottom-up gross costing | Purchasing value of equipment. | Equipment price per set. |
| Office space | Bottom-up gross costing | Total direct cost of rent. | Rent per used square meter per year/365days = rent per day |

*District Health Information Software 2

In this study, estimated salary covers the average salary for a nurse working for a municipality (municipalities outside of Oslo), without overtime or additional evening or weekend payments. This estimate is from Norwegian Nurses Association (NSF) statistical data, provided by the Norwegian Association of Local and Regional Authorities (KS).

Cost for the DHIS2 system for Tromsø municipality was based on the official cost information from the Norwegian Association of Local and Regional Authorities, that manages the cloud service for all municipalities. Cost of DHIS2 contains annual fixed costs and cost that varies by the number of persons in the municipality.(33) We estimated the cost of the DHIS2 system based on the given price per inhabitant and the given price with population of Tromsø municipality from first quarter of January, year 2020.

Actual equipment quantity and cost from Tromsø municipality was not available, which is why cost estimate for the equipment was based on one-time purchase price for equipment set used by the Arctic University of Norway. It did not include calculations of life expectancy (life years), telephone subscription, other software's, or possible maintenance of the equipment.

Actual expenditure on office space rent was not received, therefore estimate average rental cost of similar location from Tromsø was used. During implementation of corona center functions, location for contact tracing varied several times during year 2020. Therefore assumably similar office space was found from the Finn.no service and areal of 40m$^2$ was taken as an estimate for this calculation. Estimate of office space cost contains only rent, and does not cover electricity, internet-connection, water, or possible maintenance and is therefore likely to be a slight underestimate.

### 3.5.1 Time spent per index case and close contact

A crude estimate of the average required work time for contact tracing is about 110 minutes per index case, where 60 minutes is for the actual index case and 50 minutes for additional tasks; like registering data and being in contact with laboratory and doctors. Each close contact approximately requires 30 minutes of work time. During the year 2020, contact tracers had also other tasks for example giving COVID-19 related guidance, and other jobs, we therefore included only the time spent on the index and close contact in our calculations.

$$Labor\ time\ per\ index\ case = 110\ minutes = \ 1{,}83\ hours$$

$$Labor\ time\ per\ close\ contact = 30\ minutes = 0{,}5\ hours$$

### 3.5.2 DHIS2

For DHIS2 contact tracing system, municipalities pay a yearly fee of NOK 5 000 (Norwegian kroner) to implement and improve the cloud service for DHIS2 system. Additional to this, municipalities pay also another NOK 5 000, plus NOK 2 per inhabitant as a yearly fee. These payments go to KS.(33)

Each municipality pays the fee of system use to KS, and therefore the cost is maintained lower than it might be if each municipality bought the service direct. Following cost estimate for the year 2020 is calculated with the population of 76 974 persons (10). Even though the DHIS2

system was not taken in use before June, cost is for a full year. We calculated the cost per day and used this in the calculations for the whole year.

$$Per\ per\ year = (76974 \times 2\ NOK) + 5000\ NOK + 5000\ NOK = 163\ 948\ NOK$$

$$Per\ day = 163\ 948 \div 365 \approx 449{,}17\ NOK$$

### 3.5.3 Equipment

Fixed costs of contact tracing also contained physical equipment. Estimate of quantity of used equipment for COVID-19 contact tracing during year 2020 was five laptops, 5 headsets and 5 mobile phones. [Personal communication: Laila Arnesdatter Hopstock, UiT The Arctic University of Tromsø]. Estimate of cost for this equipment is from The Arctic University of Tromsø (UiT), as cost estimate from Tromsø municipality was not available. It was considered that purchase prices for University is likely to be close of the prices for municipality.

Data equipment package at UiT that is used as an example in this study; includes a laptop, headset, keyboard, mouse, laptop case, and docking station for laptop. Price for such package is NOK 13 000. [Personal communication: IT-service, UiT The Arctic University of Tromsø].

$$Data\ equipment\ per\ set = 13\ 000\ NOK$$

This cost estimate is equal to the one-time payment, which does not cover possible other software's, internet connection, telephone subscription and possible maintenance. Life years of the equipment is excluded from the cost, as this equipment must be acquired early in a crisis such as a pandemic, regardless of the potential duration of the pandemic.

### 3.5.4 Office space

COVID-19 contact tracing in Tromsø municipality was during 2020 performed from several locations. Occasionally contact tracers worked also from home, with the equipment provided by municipality. At least office spaces at Stakkevollveien, Fiolveien and Kroken were used. [Personal communication: Laila Arnesdatter Hopstock, UiT The Arctic University of Tromsø]. Office space in Kroken was also called the Tromsø municipality corona center.

As for this study the data of rent for this office space were not available, and therefore equivalent office space pricing was taken as example to calculate estimate of such office rental cost. It was also taken as example here that contact tracers would use 40m$^2$ of office space.

Office space used for example here is located at Skattørvegen 40, 9018 Tromsø. Although Kroken is located on mainland in Tromsø and this example is on the island, Skattørvegen 40 is further in north at the industrial side of Tromsø, hence possibly relatively close to the price in Kroken. Rental price in Skattørvegen 40 was by announcement in FINN.no NOK 900 per m$^2$ per year (34).

$$Office\ space\ rent = \frac{(40m^2 \times 900\ NOK)}{365\ days} = \frac{36000\ NOK}{365\ days} \approx 98{,}63\ NOK\ per\ day$$

### 3.5.5 Labor hour

During year 2020 professional background of those doing the contact tracing for Tromsø municipality varied. Salary of a registered nurse working for a municipality (municipalities in Norway, outside of Oslo) was used as an example for this cost estimate. Per month such salary was reported by Norwegian Nurses Organization (NSF) to be NOK 41 421 in year 2020.(35)

Contact tracers worked both morning and evening shifts, and during weekends, so they are by NSF considered to have a shift work. Shift work counts as 35,5 weekly hours of work per month. Monthly workload is divided to four weeks, meaning then 142 hours per month.(36) As this calculation is based on yearly average payment, overtime, or possible other additional payments are not included.

$$Salary = 41\ 421\ NOK\ per\ month \div 142\ hours \approx 291{,}7\ NOK\ per\ hour$$

## 3.6 Data analyses

This study is based on uncertainty analyses of the costs to get a comprehensive picture of the total cost of COVID-19 contact tracing for Tromsø municipality during the year 2020. Data includes both fixed and variable costs. Data from Tromsø was also used as a framework to calculate expected costs of COVID-19 contact tracing for smaller and larger municipalities.

### 3.6.1 Uncertainty

Specific cost estimate data for this study were not obtained due to inaccurate recording of resource data related to contact tracing. The necessary cost estimates were therefore not available, and an uncertainty analysis was therefore necessary.

Uncertainty is present at all estimates of cost.(37) Considerable for this study are uncertainties related to parameters and heterogeneity.(38) Probabilistic sensitivity analysis considers estimate with respect for the uncertainties.(39) Uncertainty coverage and the original assumption (in Table 3.) shown in table below.

Table 3. Parameter uncertainties, assumptions, and sensitivity analyses.

| Assumption | Alternative assumption | Sensitivity analysis |
|---|---|---|
| Number of hours required per index case | Hours required were less due to more efficient working practice. Hours required were more due to need for interpreter. | Vary estimate of index case contact tracing hours with ∓20% |
| Number of hours required per close contact | Hours required were less due to more efficient working practice. Hours required were more due to need for interpreter. | Vary estimate of close contact tracing hours with ∓20% |
| Salary of a contact tracer is equal to average municipality nurse salary. | Contact tracer has higher salary than municipality nurse. Contact tracer has lower salary than municipality nurse. | Vary estimate of salary per hour with ∓20% |
| Amount of equipment sets were five | More equipment or less equipment due to several offices spaces used in 2020 | Vary estimated equipment amount with ∓20% |
| Office space size | Office space need was less due to working from home. Office space need was larger due to big daily amounts of persons to be contacted. | Vary estimated square meter price with ∓20% |

### 3.6.2 Heterogeneity

Data from Tromsø municipality can be different from other municipalities for example due to population density, geographic location, or structure of the population. This can be seen as heterogeneity, as all municipalities are heterogenous.(38) To analyze heterogeneity we calculated also the estimated cost of COVID-19 contact tracing for municipalities with populations of 1000 and 200 000 persons, using the data from Tromsø as a frame. These analyses are created as examples, indicating costs to other municipalities implementing contact tracing systems.

### 3.6.3 Probabilistic Sensitivity analysis

Probabilistic sensitivity analysis (PSA) analyses all the possible variations of estimated baseline values of parameters simultaneously. This is done to provide information of possible variance caused by uncertainties. Electronically this analysis can be run by using Monte Carlo simulation. (39)

#### 3.6.3.1 Monte Carlo simulation

The methods of analyzing probabilistic sensitivity through Monte Carlo simulations is established as the recommended methods in health economic evaluations.(40) When there is uncertainty about the estimate, Monte Carlo simulation analyses all the possible variables so that an understanding of the uncertainty related to the main estimate can be made. For each variable, estimates of mean and standard error of the mean (SE) are used to approximate a probability distribution. For this study, to cover the uncertainties, per variable there were done 1000 iterations to simulate what the actual value could be. Combining these into 1000 potential estimates of the total costs provides an estimate of the uncertainty to accompany the actual estimate of cost. When extracting the $2.5^{th}$ and $97.5^{th}$ percentile from the resulting distribution of totals, this provides an estimate of a 95 percent confidence interval of the cost estimate.(39)

For to run the simulation we used gamma distributions for all variables, a probability distribution spanning the interval from 0 to positive infinity, that is recommended to represent the uncertainties in cost parameters.(40) In Excel software, gamma distribution can be viewed by methods of moments -approach as gamma ($\alpha\beta$). Formula for this can be described as following (40):

$$\bar{\mu} = \alpha\beta\ , \quad s^2 = \alpha\beta$$

$\theta \sim gamma(\alpha, \beta)$

$\mathrm{E}[\theta] = \alpha\beta$

$var[\theta] = a\beta^2$

For to be run in Excel, expressions need to be then rearranged, to solve two equations for the two unknowns simultaneously. Formula for rearranging can be described as (40):

$$\alpha = \frac{\bar{\mu}^2}{s^2}\ , \quad \beta = \frac{s^2}{\bar{\mu}}$$

In Excel the formula is called gamma.inv. First applied number defines probability, and thereafter comes alpha and beta. Each expression is separated with semicolon. When drawing random numbers from gamma distribution, random numbers from 0 to 1 were placed for probability, while placing alpha and beta converted from mean and standard error. In this study, we used the following Excel software formula: $= gamma.inv(rand(\,); alpha; beta)$, further details about the reasoning behind this process is available in the book by Briggs and colleagues (40).

### 3.6.4 Analyze software

Analyses were done by using Microsoft Excel for Mac, version 16.6.

### 3.6.5 Parameters and sources

Parameter and sources are described in table below (Table 4.).

Table 4. Parameters and source of data

| Parameter | Mean | SE | Source |
|---|---|---|---|
| Labor hours index case | 1,838325 | 0,186738125** | Jagrati Jani-Bølstad |
| Labor hours close contact | 0,5011468 | 0,051021346** | Jagrati Jani-Bølstad |
| Number of equipment sets | 4,9503161 | 1,275533642** | Laila Hopstock |
| **Costs** | | | |
| Salary per hour | 291,43998 | 29,76585308** | NSF |
| Equipment per set | 13061,156 | 1326,554988** | UiT |
| Rent per day | 99,172879 | 10,06447065** | FINN.no |
| DHIS2 per day* | 449,1726 | | KS |

*DHIS2 = District Health Information Software 2
**Mean varied by 20%

Labor hours are estimates of minutes spent per index case and close contact. Salary is a single hour cost. Number of equipment sets for Tromsø was estimated to be 5 during year 2020 by a contact tracer. Technical equipment set is a one-time payment of NOK 13 000. Rent is calculated for an estimate of 40$m^2$ of office space with average cost of NOK 900 per $m^2$. DHIS2 software is a yearly fixed cost based on population number of the municipality, which for Tromsø was 76 974 in 2020, cost for the program was received from KS. Approximated Standard Error (SE) is calculated with 20 percent variation of the Mean.

### 3.6.6 Extrapolation to other municipalities

To be able to compare data from Tromsø with other municipalities, extrapolative calculation was done in addition to the actual analyses to forecast the cost of COVID-19 contact tracing in varying sizes of municipalities. The existing parameters from Tromsø municipality were calculated for hypothetical municipalities with 1 000, 76 000, and 200 000 persons as exploratory analysis for other municipalities.

# 4 Results

## 4.1 Descriptive

Data from the DHIS2 -system used by Tromsø municipality shows that during the year 2020, 644 persons tested positive for the SARS-CoV-2 virus. They are called index cases in Figure 3. In the figure below we present also the close contacts registered in 2020. The distribution of covid index cases and close contacts appearance is shown here on the 53 calendar weeks of year 2020. While as first index case in Norway was found on 26th February, in the DHIS2 data the first positive case is registered on 21st of February, which is why the x-axis begins already from week number 8.

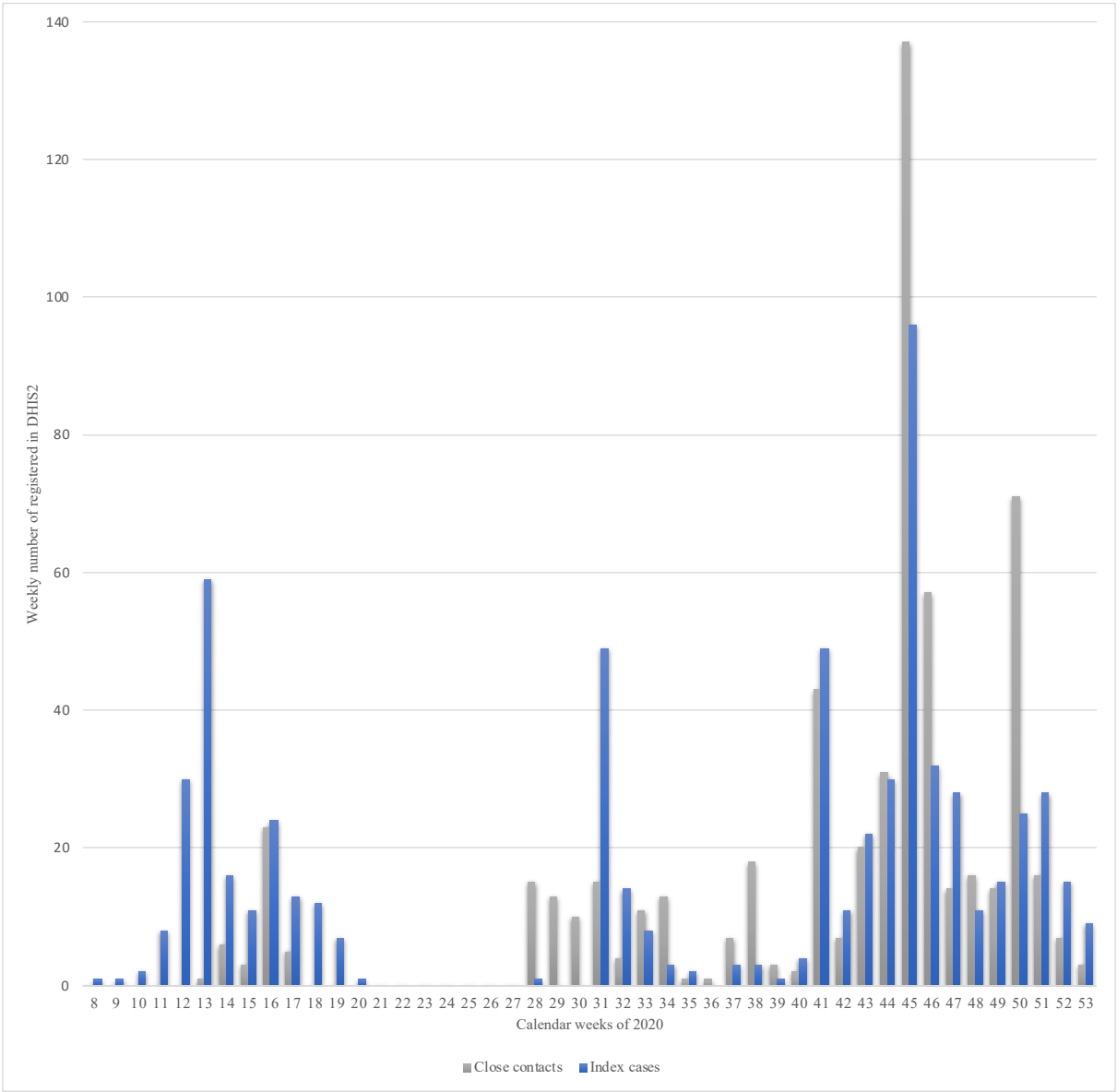


Figure 3. COVID-19 index cases and close contacts in Tromsø municipality, year 2020

From the DHIS2 data (in Figure 3.) it can be seen how the COVID-19 cases and close contacts are distributed for the year. Highest peak was during week 45, with 137 close contacts – which meant 68,5 hours of work for contact tracing. On the same week, 45, there were also 96 index cases which meant 175,68 hours of work. In total the work hours required for contact tracing during this one week were 244,18 hours.

Table 5. Calculation of labor hours for 2020

| Index cases | Total hours for index cases | Close contacts | Total hours for close contacts | Total labor hours |
|---|---|---|---|---|
| 644 | 1 178,52 | 587 | 293,50 | 1 472,02 |

Results above (in Table 5.) shows data from the DHIS2 system multiplied with the estimate of hours spent on contact tracing for index cases and close contacts. Number of registered index cases were 644 and close contacts 587. In total this gives the result of working hours spent on contact tracing in Tromsø municipality to be 1472,02 hours in the whole year of 2020. Total of 1178,52 hours of this labor was spent on index cases, and 293,50 on close contacts.

The parameter estimates (Table 6.) for number of hours, number of equipment and costs described below. Costs are presented in NOK.

Table 6. Estimates

| Parameter | Estimate | Minimum | Maximum |
|---|---|---|---|
| Labor hours per index case | 1,83 | 1,46 | 2,20 |
| Labor hours per close contact | 0,5 | 0,4 | 0,6 |
| Number of equipment sets | 5 | 1 | 6 |
| | | | |
| **Costs** | | | |
| Salary per hour | 291,70 | 233,36 | 350,04 |
| Equipment per set | 13 000,00 | 10 400,00 | 15 600,00 |
| Rent per day | 98,63 | 78,90 | 118,36 |
| DHIS2 per day | 449,17 | 449,17 | 449,17 |

## 4.2 Main results including tables / figures

Table 7. Main result of costs

| | Calculation | 95% Uncertainty interval (lower) | 95% Uncertainty interval (upper) |
|---|---|---|---|
| Variable costs | 429 388 | 329 269 | 552 683 |
| Fixed costs | 237 558 | 207 876 | 281 065 |
| Sum costs | 666 946 | 557 149 | 796 839 |

As shown above (in Table 7.), variable costs required for COVID-19 contact tracing for Tromsø municipality during year 2020 total of NOK 429 388. Covering the uncertainty, with 95 percent confidence interval the total costs estimate for labor are in the range between NOK 329 269 and NOK 552 683.

The fixed costs covering equipment, office space and the DHIS2 software, was by estimates total of NOK 237 558 for COVID-19 contact tracing during the year 2020 in Tromsø municipality. Covering the uncertainties, with 95 percent confidence interval was on range between NOK 207 876 and NOK 281 065.

Sum of total costs of COVID-19 contact tracing for Tromsø municipality was calculated by cost estimates to be NOK 669 946. Covering the uncertainties, with 95 percent confidence interval the range was between NOK 557 149 and NOK 796 839.

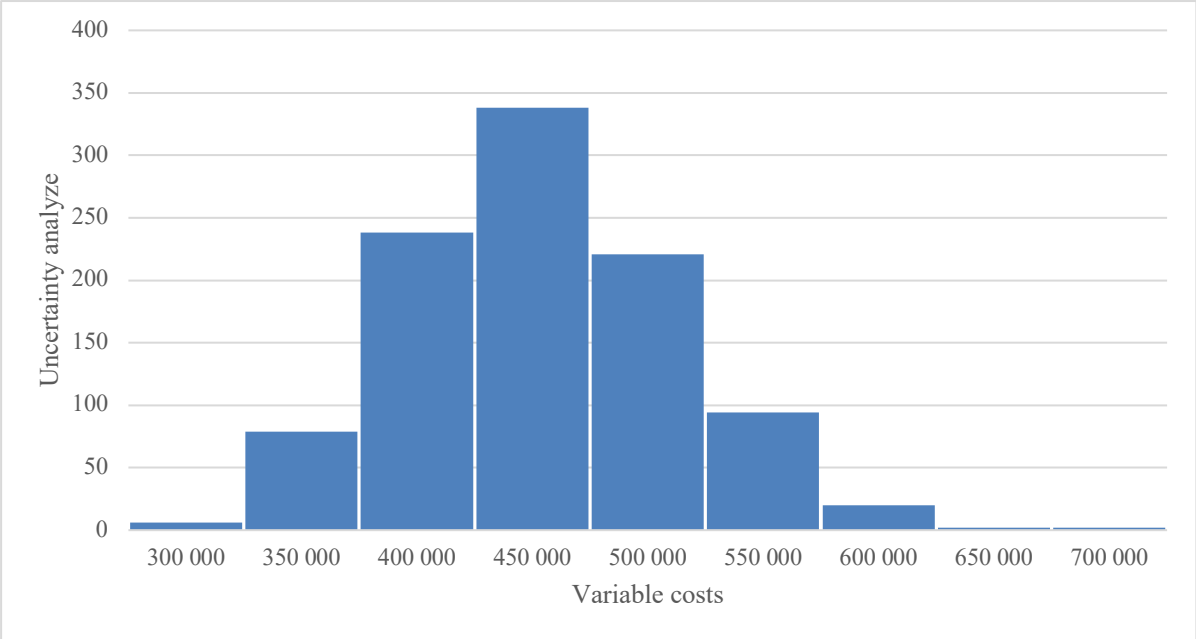


Figure 4. Histogram of variable costs (values on x-axis represent lower end of bin)

The histogram above (Figure 4.) shows the distribution of variable costs. On Y-axis is the distribution of uncertainty. X-axis demonstrates the variable costs, where the most likely is NOK 400 000 to NOK 450 000 shown in 338 Monte Carlo simulations.

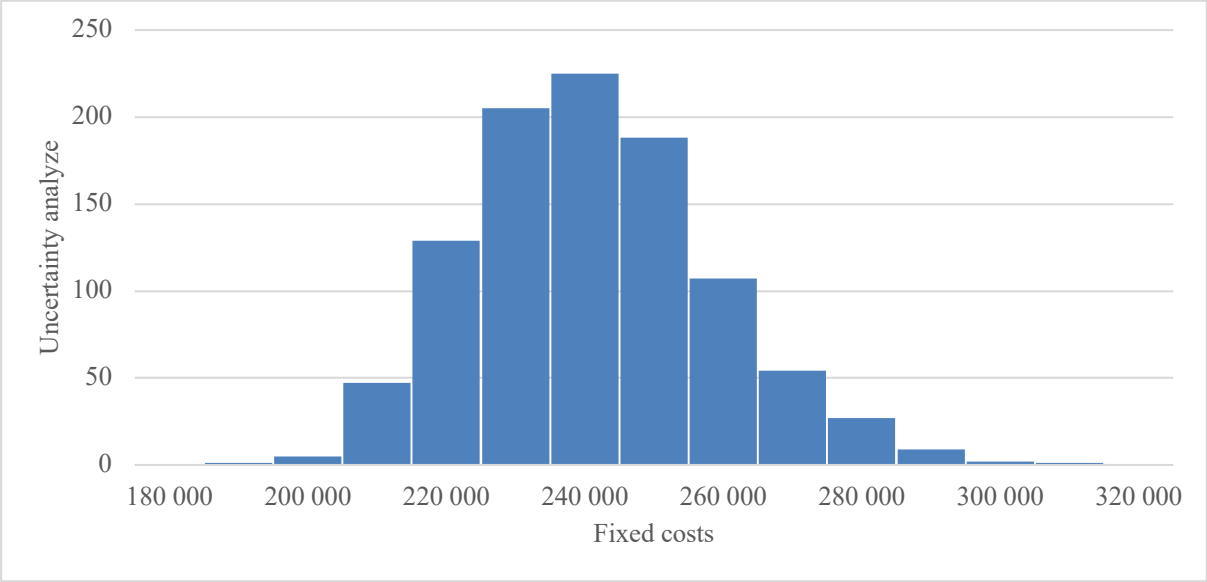


Figure 5. Histogram of fixed costs (values on x-axis represent lower end of bin)

Distribution of fixed costs can be seen in histogram above (Figure 5.). On Y-axis is the distribution of uncertainty. X-axis shows the variable costs, where the most likely is NOK 230 000 to NOK 240 000 by 225 Monte Carlo simulations.

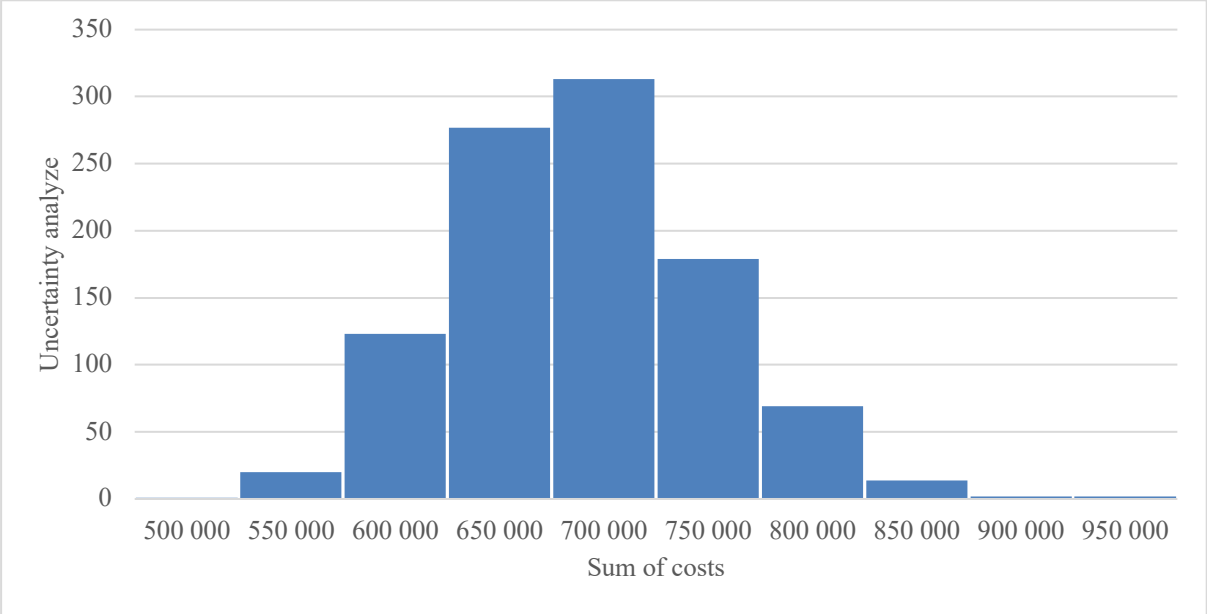


Figure 6. Histogram of sum of costs (values on x-axis represent lower end of bin)

Sum of total costs is distributed in histogram (Figure 6.). On Y-axis is the distribution of uncertainty. On X-axis can be seen the distribution of variable costs, where the most likely is NOK 650 000 to NOK 700 000 shown by 313 Monte Carlo simulations.

## 4.3 Sensitivity analysis

We also present the simulations more detailed, to provide further insights into potential uncertainty surrounding estimates. Actual estimates with simulated estimates (in Table 8.) from Monte Carlo simulation.

Table 8. Minimums and maximums of estimate from Monte Carlo simulation

| | **Estimate** | **Simulated minimum** | **Simulated maximum** |
|---|---|---|---|
| Labor hours index case | 1,83 | 1,8287829 | 2,5201428 |
| Labor hours close contact | 0,5 | 0,3546103 | 0,6796708 |
| Number of equipment sets | 5 | 1,7032003 | 9,728182 |
| | | | |
| **Costs** | | | |
| Salary per hour | 291,7 | 210,81444 | 394,68499 |
| Equipment per set | 13000 | 9034,4 | 17408,789 |
| Rent per day | 98,63 | 70,864607 | 134,08032 |
| DHIS2 per day | 449,17 | 449,17 | 449,17 |

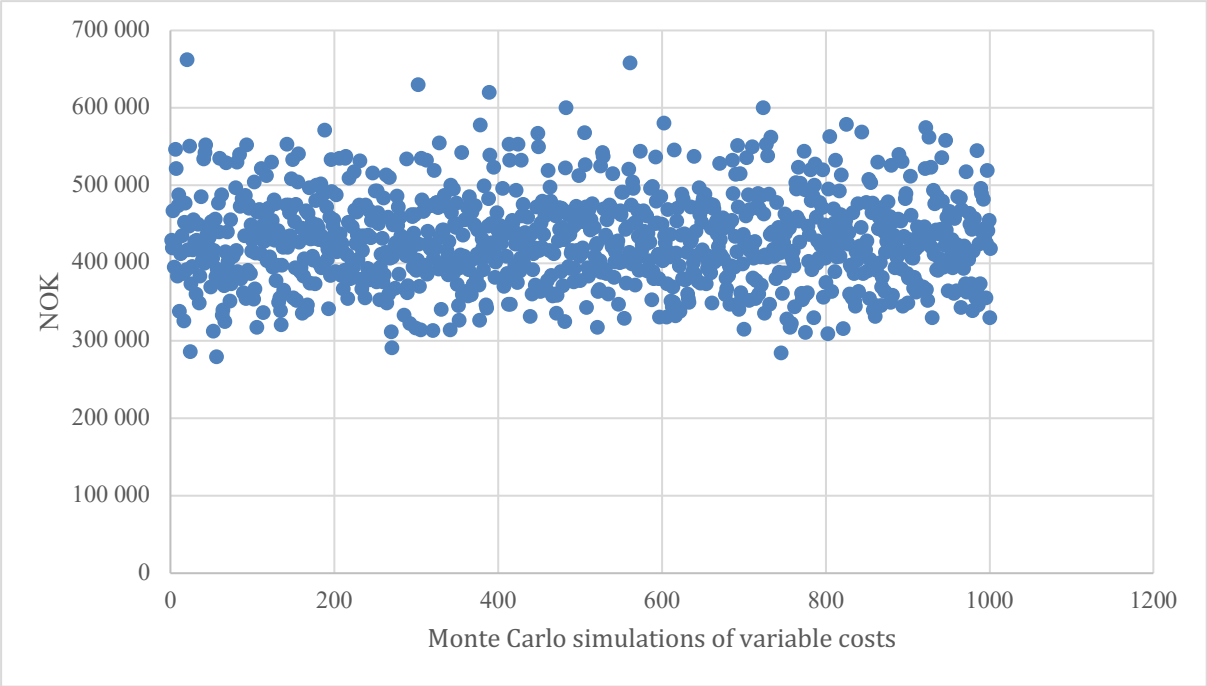


Figure 7. Monte Carlo simulation of variable costs

Distribution of Monte Carlo simulation results for variable costs (in Figure 7), reflects how scattered the cost estimation for variable costs are. Variable cost in this study is labor adjusted to amount of work hours related to COVID-19 contact tracing. X-axis shows the number of simulations, and Y-axis contains a cost scale of variable costs in Norwegian kroner (NOK).

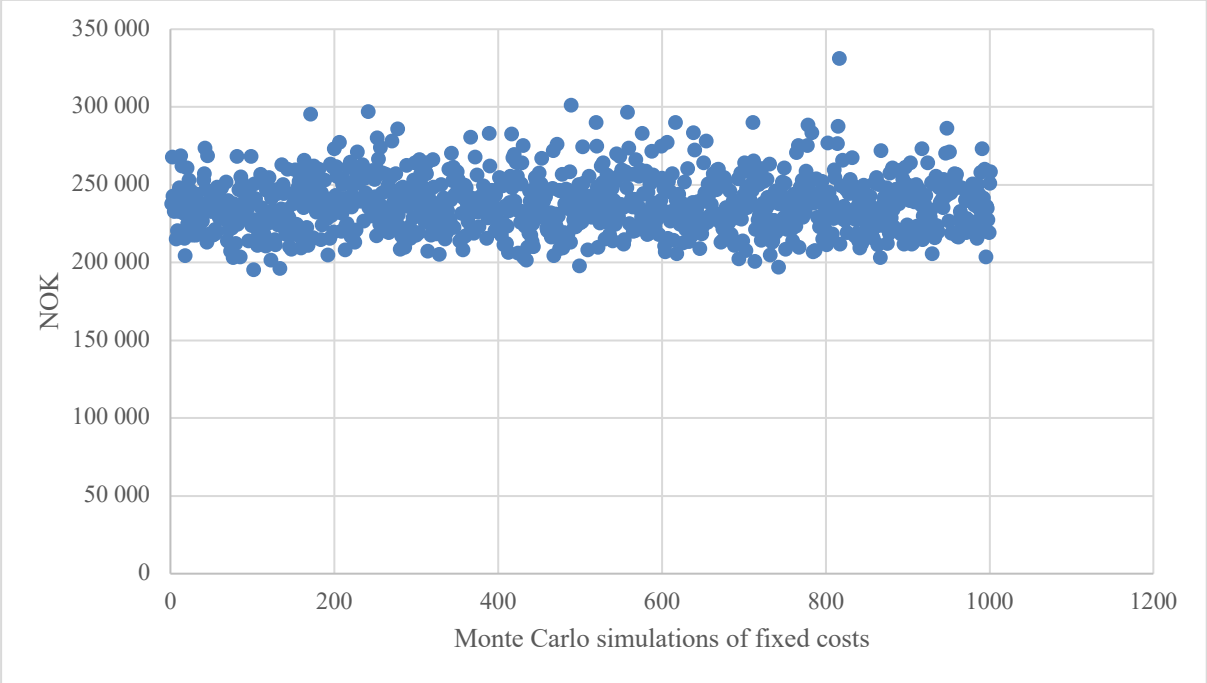


Figure 8. Monte Carlo simulation of fixed costs

Figure 8. presents the distribution of Fixed costs Monte Carlo simulation results in a scatter plot. Fixed costs contain the combined costs of equipment per day, rent per day, and DHIS2 software per day. X-axis shows the number of simulations, and Y-axis contains a cost scale of fixed costs in Norwegian kroner (NOK).

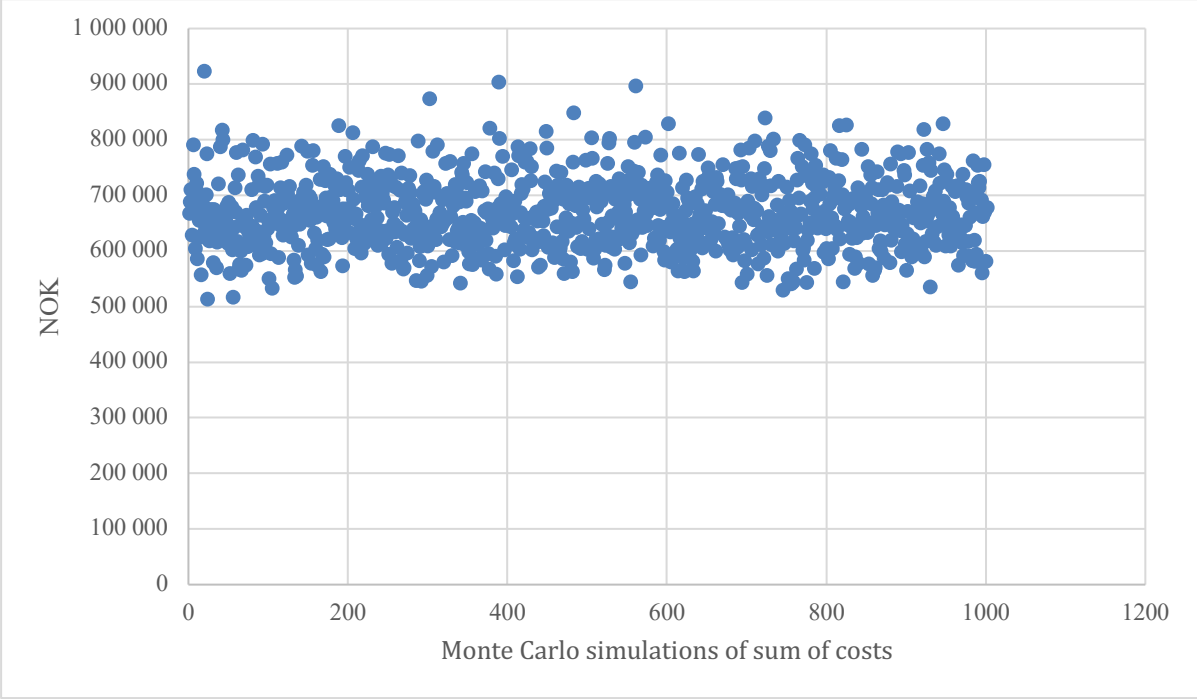


Figure 9. Monte Carlo simulation of sum of costs

When observing the total sum of costs (Figure 9.), in this scatter plot the Y-axis shows the total sum in Norwegian kroner (NOK), and X-axis tells the number of Monte Carlo simulations for the total cost.

## 4.4 Extrapolation for other municipalities

Tromsø were used as a frame to calculate the cost of contact tracing for hypothetic municipalities with a 1 000, 76 000 and 200 000 persons. Result of a deterministic analysis (Table 9.) describes the comparable costs for municipalities of different size.

Table 9. Calculations for other municipalities

| | **Tromsø municipality** | **Other, hypothetical municipalities** | | |
|---|---|---|---|---|
| Population | 76974 | 1 000 | 76 000 | 200 000 |
| | | | | |
| Labor hours index case | 1,83 | 1,83 | 1,83 | 1,83 |
| Labor hours close contact | 0,5 | 0,5 | 0,5 | 0,5 |
| Number of equipment sets | 5 | 1 | 5 | 12,99 |
| Total amount index cases | 644 | 8,37 | 635,85 | 1673,29 |
| Total amount close contacts | 587 | 7,63 | 579,57 | 1525,19 |
| | | | | |
| **Costs** | | | | |
| Salary per hour | 291,70 | 291,70 | 291,70 | 291,70 |
| Equipment per set | 13000 | 13000 | 13000 | 13000 |
| Rent per day | 98,63 | 98,63 | 98,63 | 98,63 |
| DHIS2 per day | 449,17 | 32,88 | 443,84 | 1123,29 |
| | | | | |
| **Calculation** | | | | |
| Variable costs | 429 388 | 5 578 | 423 955 | 1 115 671 |
| Fixed costs | 237 558 | 54 425 | 235 877 | 553 792 |
| Sum costs | 666 946 | 60 003 | 659 832 | 1 669 463 |

For municipality of 1000 persons we calculated to have 8,37 index cases and 7,63 close contacts during year 2020. It was also calculated that 1 equipment set would be used for contact tracing. For such municipality with population of 1000 persons, DHIS2 system would cost NOK 32,88 per day. Variable costs would be NOK 5 578 and fixed costs NOK 54 425. This leads to total costs of NOK 60 003.

As a comparison, a municipality of 76 000 persons would have 635,85 index cases, 579,57 close contacts and require 5 sets of equipment for COVID-19 contact tracing. This municipality would use NOK 443,84 per day for DHIS2 system. Variable costs would be NOK 423 955, fixed costs NOK 235 877 and total cost of COVID-19 contact tracing for the year 2020 being NOK 659 832.

Lastly a hypothetical municipality of 200 000 persons would have 1637,29 index cases and 1525,19 close contacts during year 2020. For their contact tracing work the municipality would need 13 sets of equipment and pay NOK 1123,29 per day for the use of DHIS2 system. This would show the variable costs being NOK 1 115 671, fixed costs NOK 553 792 and total cost of COVID-19 contact tracing for such municipality NOK 1 669 463 for the year 2020.

Table 10. Comparison of cost of DHIS2 per municipality

| | **Population of municipality** | | | |
|---|---|---|---|---|
| | **76 974** | **1 000** | **76 000** | **200 000** |
| DHIS2 | 163 947 | 12 001 | 162 001 | 410 037 |
| Total cost of contact tracing | 666 946 | 60 003 | 659 832 | 1 669 463 |
| Percentage of DHIS2 from total cost | 24,58 | 20,00 | 24,55 | 24,56 |

Above (in Table 10.) we have compared the price of the actual DHIS2 system. Price of tool varies per number of persons in the municipality. For municipality of 1000 person, the DHIS2 system total cost would have been NOK 12 001 for year 2020, whereas for municipality of 200 000 persons would the cost have been NOK 410 037.

# 5 Discussion

## 5.1 Main results summary

Objective for this research of defining the cost of COVID-19 contact tracing is tested by probabilistic and deterministic sensitivity analysis, covering the uncertainties related to the cost estimates of the parameters. COVID-19 register data of index cases and close contacts from DHIS2 tool was used for this study, along with cost estimates of costs of contact tracing. By our knowledge, this is the first study to evaluate the cost structure of the COVID-19 contact tracing in Tromsø.

The data contributes a clearer understanding of distribution of labor between index cases and close contacts. Of total labor of 1472 hours, 80 percent was spent on index cases and only 20 percent on close contact tracing. Cost of digital tool for contact tracing, in this case the DHIS2 system consists of 25 percent of the total costs of contact tracing; being NOK 163 948 for a whole year for Tromsø municipality.

In the histograms presenting cost estimates in uncertainty analyses, it is notable that the estimate is very uncertain, and that they are based on the uncertainty analysis. It is likely to assume that for variable costs, the costs are between approximately 350 000 and 550 000. These costs are dependent both on whether the estimates are correct, and that we have included a reasonable amount of uncertainty.

With a population of 76 974 inhabitants (in 2020), Tromsø can be seen as representing 1,43 percent of Norway. For comparison, we calculated the cost of contact tracing for hypothetical municipalities with populations of 1 000, 76 000 and 200 000 persons. For example, in a case of sudden spike in contact tracing smaller municipality could face problems of not having the resources available and borrowing contact tracing resources from neighboring municipalities might be necessary to cover the situation. Only for the municipality of 1 000 persons were fixed costs of contact tracing greater than variable costs. Daily cost of usage of the digital tool (DHIS2) was fairly low, being NOK 39 for the municipality of 1 000 persons, and NOK 1123 per day for the municipality with 200 000 persons.

The overall results indicate that variable costs contain the main part of total cost of COVID-19 contact tracing. During year 2020 for Tromsø municipality were total cost of contact tracing NOK 666 946 with 95 percent uncertainty interval.

## 5.2 Discussion of the results and findings related to existing knowledge

Plenty of studies related to COVID-19 contact tracing are made about app assisted contact tracing, but the actual professional HMIS tools for contact tracing have had lesser interest among researchers. Knowledge of costs and resource requirements has not been available to plan resource preparedness for pandemics of this size. Therefore these results should be considered when defining a frame for contact tracing for future pandemics and calculating cost-efficiency for contact tracing.

### 5.2.1 COVID-19 contact tracing in other (Nordic) countries

Before COVID-19, contact tracing has been used as one of the main tools to reduce the spread of infectious diseases. Contact tracing played a key role in efficiently managing and controlling the 2014 Ebola outbreak in Liberia, as Swanson et al. assessed (41). Rajan et. al. points out that contact tracing and control of infection is all about time and effectiveness to avoid more dramatic control means, like lockdowns (42). Armbruster and Brandeau studied cost-efficiency of contact tracing in general, finding that contacts traced in shorter time means less index cases in total (43).

Looking at the neighboring countries, principles of contact tracing differ. For example, in Finland the responsibility of contact tracing has been divided between regional and local authorities, and all the contact tracers have passed national online based contact tracing online course. There was also created a national staff-pool that could send resources to the areas that were having sudden peaks of index cases.(44) In Sweden the COVID-19 strategy did not focus on contact tracing, but instead aimed on flock immunity. Contact tracing was not performed in Sweden during the year 2020.(45)

Denmark's strategy focused on mass testing, and placed much more responsibility on individuals using the Smittestopp app. Close contact tracing, in focus to set them in quarantine just in case, went as far as close contacts of close contacts of the index case.(46) Yarmol-Matusiak et. al., compared epidemiological indicators of COVID-19 in these northern countries, pointing out that insufficient resources and inadequate health systems can be connected to the accumulation of COVID-19 cases (47).

### 5.2.2 Effect of harbor activity on COVID-19 contact tracing

Of the total of 7939 calls at the port of Tromsø during 2020, 3256 were made by fishing vessels, and the Norwegian cruise line Hurtigruten made 314 docking calls.(11) In the COVID-19 data of index cases and close contacts from DHSI2 system there is a dramatic spike on index cases on 31st of July. A total of 40 index cases and 7 close contacts were registered on that day. This can be explained with the spreading of SARS-CoV-2 virus at Hurtigruten cruise boat at the end of July 2020.

A study by Gravningen et. al. was made about the outbreak related to this cruise, where they found 37 positive cases traced back to the cruise ship, and noted that on the boat especially the crew had difficulty keeping their distance from others and avoiding the spread of the virus (48). This spike caused a rapid increase in the workload for the contact tracing team in Tromsø. Just for the 31st of July we calculated 76,7 hours of work needed for contact tracing.

## 5.3 Methodological discussion

The chosen model has limitations due to assumptions made. If we had data that allowed more precise estimates, we could have chosen a top-down costing study method. This might have had great difference on the results.

## 5.4 Strengths

Resource usage and costs of contact tracing related to COVID-19, has by our understanding not been researched earlier. This is the greatest strength of this study and can inspire for further and deeper studies about the theme.

By using the Monte Carlo simulation, we could estimate not just the cost but also indicate potential impact of our uncertain data sources. Providing estimates for municipalities of other sizes may prove useful in future planning for potential outbreak management.

## 5.5 Limitations

This study has several limitations. Reporting bias is also present in this study, firstly seen as the first COVID-19 cases in Norway was reportedly found in 26th of February – while as in the DHIS2 system used by Tromsø municipality, first index case is registered to have appeared already on 21st of February. This was re-checked from several sources. The municipality epidemiologist, and municipality head physician both confirmed this as likely erroneous registering in the system.

As in early 2020 contact tracing was not yet structured, and changes from national level came repeatedly. As contact tracing in the beginning of the pandemic during the spring 2020 was done in addition to other work tasks, there is no certainty of how much labor time resources were needed for the tracing. Fully functional version of DHIS2 was taken for use in Tromsø in June 2020, and all data prior to that was manually registered afterwards – this may have led to errors in registered numbers.

Changes and updates in DHIS2, which caused that some of the data we register now were not included in registering in the earlier versions. For example: status of COVID-19 vaccination. If the tracer had more time, they registered more and more defined details and in hurry just the most crucial ones.

The data gained for this study does not contain whether or not an interpreter was needed but given the assumed wide variation of origins among the tested people, there is likely also a considerable need for interpreter. Resources used for interpreter is not included, hence the actual resource use is likely higher than what is estimated.

When contact tracers were working from home office, they used their own Wi-Fi – which is hard to notice in the expenses. Also, if you worked in home office you could not manage to do all the required registering (System X, MSIS), which you only had access to at the office. Therefore, working at the home office meant that you had to re-register data the next time you got to the office. There is no log of when contact tracers were working from home, and when they were working in the office.

Estimated time spent on contact tracing per index case and close contact is based on estimates from the municipality's epidemiologist based on her observations of the work in an early phase of the pandemic. We do not have access to other data on actual time spent on the contact tracing work. This is a major weakness of the study.

There was unfortunately no available data of whether contact tracers were borrowed to or from Tromsø municipality. This could have made the resource estimates more accurate.

We assume that some confounding factors may remain in our study. When data relating to uncertainty in input is unavailable, assumptions has to be made to provide insights regarding overall uncertainty surrounding estimated costs. It is common in Monte Carlo simulations in health economic evaluations to assume either 10% or 20% on each side of the estimate as reasonable bounds for uncertainty. We chose the wider of these suggestions due to our considerable uncertainty related to inputs.

## 5.6 Future research

Further research is needed to establish a knowledge of efficiency of contact tracing HMIS systems that are not connected to mobile app for public use, as tools for contact tracing during pandemic.

It is considerable also to implement further study in a municipality that chose to use different contact tracing system during the COVID-19 pandemic, to get the true evidence of effect of using DHIS2 system as contact tracing tool. By this way could comprehensive data of the usability and resource requirements for contact tracing be gained while using this system.

# 6 Conclusion

Total cost of COVID-19 contact tracing in Tromsø municipality during year 2020, when calculating the cost estimates with uncertainty, was estimated to be NOK 666 946. Variable cost – in this case labor adjusted to the amount of work hours, constitutes the main part of costs. Fixed costs, especially cost of DHIS2 system usage as contact tracing tool, cost for Tromsø municipality only NOK 449,17 per day in year 2020. Electronic tool can be seen as economic solution for registering pandemic data, requiring approximately 20 – 25 percent of the annual total costs of contact tracing; yet further research and comparisons of cost-efficiency compared to other systems is required.

# Works cited


1. World Health Organization. COVID 19 Public Health Ermergency of International Concern (PHEIC) 12.02.2020 [cited 19.01.2022]. Available from: https://www.who.int/publications/m/item/covid-19-public-health-emergency-of-international-concern-(pheic)-global-research-and-innovation-forum.
2. Seppälä E, Tønnessen R, Veneti L, Paulsen TH, Steens A, Whittaker R, et al. COVID-19 cases reported to the Norwegian Institute of Public Health in the first six weeks of the epidemic. Tidsskr Nor Laegeforen. 2020;140(18).
3. NRK. Første tilfelle av koronasmitte i Norge. 27.02.2020 [cited 19.01.2022]. Available from: https://www.nrk.no/norge/forste-tilfelle-av-koronasmitte-i-norge-1.14920058.
4. Helsedirektoratet. Operasjonalisering av testing, isolering, smittesporing og karantene (TISK) ved covid-19 i kommunene. 03.07.2020 [cited 18.01.2022]. Available from: https://www.helsedirektoratet.no/tema/beredskap-og-krisehandtering/koronavirus/anbefalinger-og-beslutninger/Operasjonalisering%20av%20testing%20isolering%20smittesporing%20%20og%20karantene%20030720.pdf/_/attachment/inline/ee410417-4223-4843-8a3b-3e003d75fc3b:66a41c9a81a1ec49ce66b1450e3dd27ab9721545/Operasjonalisering%20av%20testing%20isolering%20smittesporing%20%20og%20karantene%20030720.pdf.
5. European Centre for Disease Prevention and Control. SARS-CoV-2 variants of concern as of 10 February 2022 Stockholm: ECDC; 2022 [cited 08.03.2022]. Available from: https://www.ecdc.europa.eu/en/covid-19/variants-concern.
6. Norwegian Institute of Public Health. Development and approval of coronavirus vaccine 2020 [cited 04.03.2022]. Available from: https://www.fhi.no/en/id/vaccines/coronavirus-immunisation-programme/development-of-covid-19-vaccine/.
7. Norwegian Institute of Public Health. Coronavirus vaccination - statistics 2021 [cited 08.03.2022]. Available from: https://www.fhi.no/en/id/vaccines/coronavirus-immunisation-programme/coronavirus-vaccination---statistic/.
8. Bolstad E. Kommuner i Norge i Store norske leksikon på snl.no [updated 16.11.2021. Available from: https://snl.no/kommuner_i_Norge.
9. SSB Statistics Norway. Population and changes during the quarter, by contents and quarter 2022 [cited 19.02.2022]. Available from: https://www.ssb.no/en/statbank/table/01222/tableViewLayout1/.
10. Thorsnæs G, Svendsen, Trond Olav,. Tromsø i Store norske leksikon på snl.no [cited 08.03.2022]. Available from: https://snl.no/Troms%C3%B8.
11. Tromsø Havn. Årsberetning 2020 [cited 10.04.2022]. Available from: https://tromso.havn.no/en/about-us/statistics/.
12. Keeling MJ, Hollingsworth TD, Read JM. Efficacy of contact tracing for the containment of the 2019 novel coronavirus (COVID-19). J Epidemiol Community Health. 2020;74(10):861-6.
13. World Health Organization. Digital tools for COVID-19 contact tracing: Annex: Contact tracing in the context of COVID-19. WHO White paper. 2020.
14. Gundersen RB, ; Utvik, Vetle Alvenes; Thorseng, Anne Asmyr; Sæbø, Johan Ivar; Nielsen, Petter. An Institutional Analysis of Digital Transformation of Covid-19 Contact Tracing During a Pandemic. Selected Papers of the IRIS. 2021(Issue Nr.12).
15. Mauroy C, Madslien EH, Meijerink H, Lunde CS, Johansen MK. Optimizing configurations for Smittestopp version 3.0. Norwegian Institute of Public Health

Division of Infection Control and Environmental Health, Department of infectious diseases and prevention; 2021. Report No.: 8284062496,9788284062495.
16. DHIS2. About DHIS2. Oslo [cited 21.01.2022]. Available from: https://dhis2.org/about/.
17. Celi LAG, Fraser HSF, Nikore V, Osorio JSn, Paik K. Global health informatics : principles of ehealth and mhealth to improve quality of care. Cambridge, Massachusetts: The MIT Press; 2017. xii, 451 pages p.
18. DHIS2. COVID-19 Surveillance, Response & Vaccine Delivery Toolkit. 2021 [cited 08.03.2022]. Available from: https://dhis2.org/covid-19/.
19. KS. Smittesporing ved bruk av DHIS2: Fiks dokumentasjon; [cited 08.03.2022]. Available from: https://ks-no.github.io/fiks-plattform/tjenester/dhis2/.
20. Legeforeningen. Informasjon til fastleger om koronavirus - SARS-CoV-2. Oslo. 2020 [cited 21.01.2022]. Available from: https://www.legeforeningen.no/foreningsledd/fagmed/norsk-forening-for-allmennmedisin/nyheter2/2020/informasjon-til-fastleger-om-koronavirus-sars-cov-2/.
21. KS. Smittesporing - Nasjonal læringsressurs med kunnskapstest 2021 [cited 19.02.2022]. Available from: https://www.kslaring.no/local/course_page/home_page.php?id=29922&start=0.
22. Tromsø municipality. Vill du jobbe med testing og sporing? Meld din interesse 2021 [cited 08.03.2022]. Available from: https://tromso.kommune.no/nyheter/2021/12/vil-du-jobbe-med-testing-og-sporing-meld-din-interesse.
23. CDC. Interim Guidelines for Collecting and Handling of Clinical Specimens for COVID-19 Testing [cited 05.02.2022]. Available from: https://www.cdc.gov/coronavirus/2019-nCoV/lab/guidelines-clinical-specimens.html.
24. Norwegian Institute of Public Health. Definitions. Coronavirus - facts, advice and measures 2020 [updated 14.03.2022]. Available from: https://www.fhi.no/en/op/novel-coronavirus-facts-advice/testing-and-follow-up/definitions-of-probable-and-confirmed-cases-of-coronavirus-covid-19-and-con/.
25. Norwegian Institute of Public Health. Intensivert testrategi [cited 17.02.2022]. Available from: https://www.fhi.no/nyheter/2021/intensivert-teststrategi/.
26. Helsedirektoratet. Registering av helsepersonell under covid-19 [cited 06.05.2022]. Available from: https://www.nasjonalthelsepersonell.no.
27. Norwegian Institute of Public Health. Håndbok for oppdaging, vurdering og håndtering av covid-19-utbrudd i kommunen [cited 10.01.2022]. Available from: https://www.fhi.no/nettpub/overvaking-vurdering-og-handtering-av-covid-19-epidemien-i-kommunen/.
28. Norwegian Institute of Public Health. Coronavirus - facts, advice and mesures [cited 16.05.2022]. Available from: https://www.fhi.no/en/op/novel-coronavirus-facts-advice/.
29. Koronakommisjonen. Myndighetenes håndtering av koronapandemien [Rapport]. Regjeringen.no; [cited 08.03.2022]. Available from: https://www.regjeringen.no/no/dokumenter/nou-2021-6/id2844388/.
30. Gundersen RB, Dynestøl EB, Nielsen P, Sæbø JI, Thorseng AA, Ulshagen A, et al. Digital Transformation under a pandemic: A case study of Covid-19 contact tracing in Norway. 2020.
31. Hendriks ME, Kundu P, Boers AC, Bolarinwa OA, te Pas MJ, Akande TM, et al. Step-by-step guideline for disease-specific costing studies in low- and middle-income countries: a mixed methodology. Glob Health Action. 2014;7(1):23573-.
32. Drummond MF, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press; 1987.

33. The Norwegian Association of Local and Regional Authorities (KS). Hva koster det å bruke Fiks smittesporing? 2020 [cited 01.03.2022]. Available from: https://www.ks.no/fagomrader/digitalisering/felleslosninger/fiks-smittesporing/hva-koster-det-a-bruke-fiks-smittesporing/.
34. Codex Advokat Tromsø AS. KONTORER/ LAGER SKATTØRA Tromsø FINN.no. 2022 [cited 30.04.2022]. Available from: https://www.finn.no/realestate/businessrent/ad.html?finnkode=243960728.
35. NSF. Lønn og tariff statistikk. Historikk fra 2002 til 2020 (PDF) 2020 [cited 30.04.2022]. Available from: https://www.nsf.no/lonn-og-tariff/statistikk.
36. NSF. Daglig/ukentlig arbeidstid og vaktordninger 2021 [cited Available from: https://www.nsf.no/arbeidsvilkar/dagligukentlig-arbeidstid-og-vaktordninger.
37. World Health Organization. Making choices in health : WHO guide to cost-effectiveness analysis. Geneva: World Health Organization; 2003.
38. Briggs AH, Weinstein MC, Fenwick EAL, Karnon J, Sculpher MJ, Paltiel AD. Model Parameter Estimation and Uncertainty Analysis: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force Working Group–6. Med Decis Making. 2012;32(5):722-32.
39. Doubilet P, Begg CB, Weinstein MC, Braun P, McNeil BJ. Probabilistic Sensitivity Analysis Using Monte Carlo Simulation: A Practical Approach. Med Decis Making. 1985;5(2):157-77.
40. Briggs A, Sculpher M, Claxton K. Decision Modelling for Health Economic Evaluation. Oxford: Oxford University Press; 2006.
41. Swanson KC, Altare C, Wesseh CS, Nyenswah T, Ahmed T, Eyal N, et al. Contact tracing performance during the Ebola epidemic in Liberia, 2014-2015. PLoS Negl Trop Dis. 2018;12(9):e0006762-e.
42. Rajan S, D. Cylus J, McKee M. What do countries need to do to implement effective 'find, test, trace, isolate and support' systems? J R Soc Med. 2020;113(7):245-50.
43. Armbruster B, Brandeau ML. Contact tracing to control infectious disease: when enough is enough. Health Care Manag Sci. 2007;10(4):341-55.
44. Tiirinki H, Tynkkynen L-K, Sovala M, Atkins S, Koivusalo M, Rautiainen P, et al. COVID-19 pandemic in Finland – Preliminary analysis on health system response and economic consequences. Health Policy Technol. 2020;9(4):649-62.
45. Pierre J. Nudges against pandemics: Sweden's COVID-19 containment strategy in perspective. Policy Soc. 2020;39(3):478-93.
46. Busk PK, Kristiansen TB, Engsig-Karup A. Assessment of the National Test Strategy on the Development of the COVID-19 Pandemic in Denmark. Epidemiologia. 2021;2(4):540-52.
47. Yarmol-Matusiak EA, Cipriano LE, Stranges S. A comparison of COVID-19 epidemiological indicators in Sweden, Norway, Denmark, and Finland. Scand J Public Health. 2021;49(1):69-78.
48. Gravningen K, Henriksen S, Hungnes O, Svendsen K, MacDonald E, Schirmer H, et al. Risk factors, immune response and whole‐genome sequencing of SARS‐CoV‐2 in a cruise ship outbreak in Norway. Int J Infect Dis. 2022;118:10-20.