Master's degree thesis

LOG950 Logistics

Visualization of the distribution of COVID-19 vaccines in Norway

Manru Xue

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Preface

This article is about studying the distribution of COVID-19 vaccine in Norway through visualization technology. One of the reasons why I chose visualization as a tool for writing my thesis is that the school designated the course IDA730 - Visual Analytics - as part of the Master of Science studies in Logistics. After I took this course, I became very interested in visualization, and I became aware of that visualization technology has penetrated various fields, including logistics. The second reason is that the development trend of modern logistics has changed from traditional forms to intelligent logistics, and it is accelerating. Better application of visualization technology to the logistics field is an indispensable skill for logistics workers. Another reason is that under the current severe situation of the new coronavirus pneumonia, the logistics and transportation of vaccines are a huge challenge for all countries. So, I want to find the best visualization type through the research on the distribution of vaccines and use it to get valuable information from the research results, hoping to make some constructive suggestions for the COVID-19 immunization plan.

The basis for this thesis can be found on the website: *https://manru-web.web.app*.

I can complete my graduation thesis, and I need to thank many people.

First, I would like to thank my two supervisors, Arild Hoff and Kristoffer Singstad. Without their dedicated help, I would not be able to successfully complete the thesis. In the discussion meeting every week, Arild patiently guided and gave a lot of valuable comments, and carefully corrected every draft I updated. Kristoffer not only provided me with strong technical support but also sacrificed his rest time to help me, and often working late into midnight. Thousands of words cannot express my gratitude to them, and I will remember everything they have done for me in my whole life.

Next, I want to thank my dear parents for their tremendous spiritual support, they are my strong backing. I also want to thank my friends, thank them for their company, and alleviate my homesickness. Especially Even Molland and Veranika Salashenka, their positive attitude towards learning and their spirit of delving deeply infected me. Without their help and encouragement, I would not be able to successfully complete my study. Grateful to meet. And wish everyone the best.

Molde May 25, 2021

Manru Xue

Abstract

With the rapid spread and expansion of the COVID-19 pandemic, the entire world has entered a state of extreme tension. In order to effectively control the epidemic, the World Health Organization (WHO) and its member states have stepped up the research and development of a variety of vaccines, and they have started to distribute them. This is great news for the people of the world. However, although the vaccine has been successfully developed, there are many constraints and challenges when distributing it to the population. It has very high requirements for temperature and environment and requires that the vaccinations must be completed within the validity period of the vaccine doses. So how to complete the vaccination task quickly and safely is another severe challenge we face. But now science and technology develop rapidly, big data, artificial intelligence, and other technologies, for the epidemic prevention and control has brought unprecedented guidance. Among them, the technology of data visualization plays a very important role, through the acquisition, screening, processing, and analysis of data. Visualizing data in a graphical way, through the integration of multi-dimensional information, and visual display of the dynamic change process of the epidemic, can help people understand the overall situation, improve public awareness of the epidemic and enhance awareness for personal protection. It can not only make people more efficient, and intuitive, but also give comprehensive access to information, but also help predicting the direction the direction of events, to achieve in-depth and shallow reporting effect to provide support for the epidemic prevention and control work. This thesis is using data visualization for showing the distribution procedure of the Covid-19 vaccine in Norway, and the visualization could be a tool for identifying problems and bottlenecks in the supply chain.

Keywords: Covid19, data visualization, vaccine, distribution.

Contents

1.0 Introduction

1.1 Description of background

The Coronavirus disease has changed the way people work, study, and live. The rapid deterioration of a pandemic has forced economic life to be suspended. During this period, the role of big data plays an important role in pandemic, pandemic prevention and control, resource allocation, and resumption of work and production. The development status of a pandemic is directly reflected by data. However, when there are huge amounts of data available, it is not easy to extract the important parts. Hence, the challenge is to visualize data in a way that gives useful information. As an effective form of public issue big data, it also satisfies users to obtain information on the epidemic situation, information, medical information, etc. Data visualization expresses epidemic data, the way from reflecting facts to awakening practical action, from academic exploration to mass communication, from macro analysis to corporate analysis, it plays an important role. A single number may not be of much significance by itself, but by analysing large amounts of data in a proper way, we can discover the insight to the problem. Figure 1 shows information about Covid-19 infection cases per country.

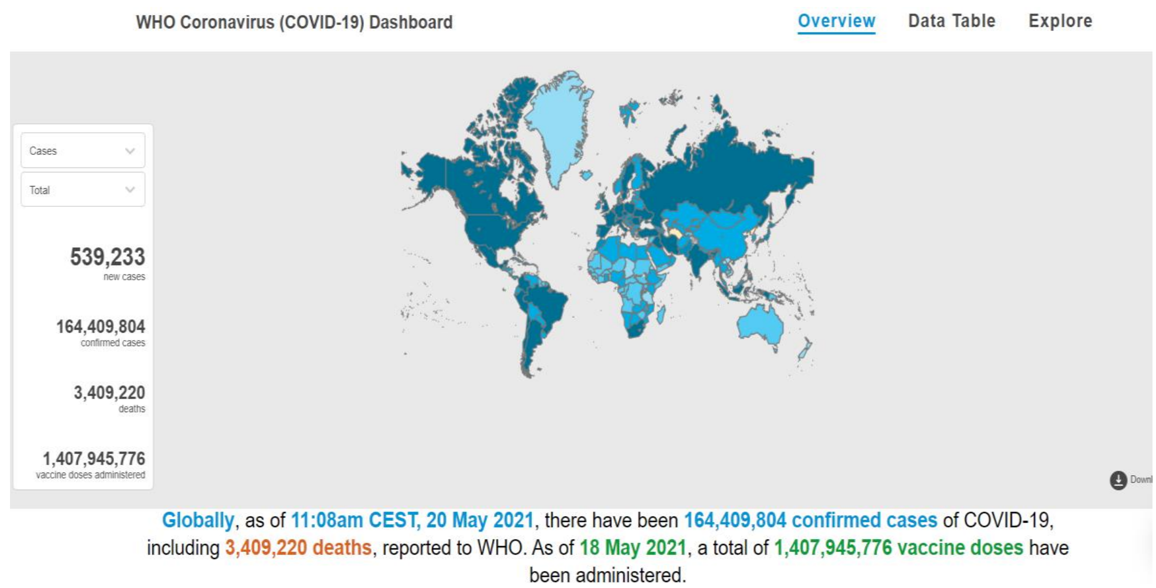


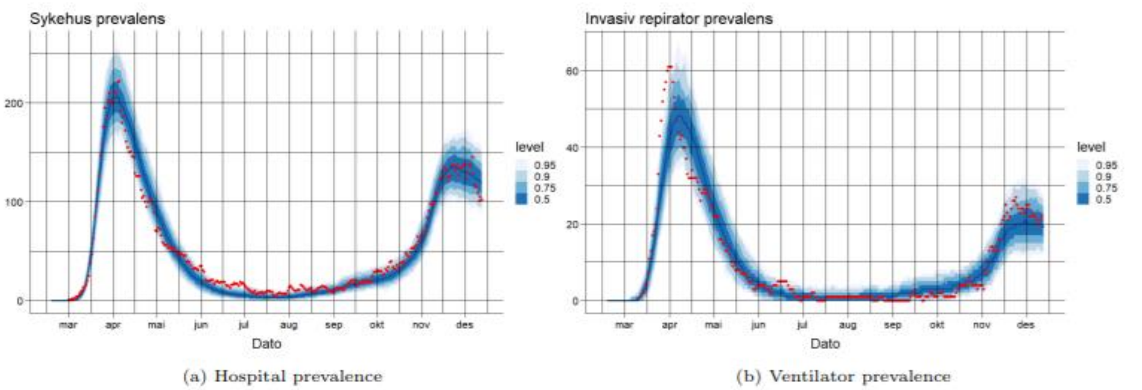
Figure 1: Covid-19 infection cases per country (source: https://covid19.who.int).

This article is about the research value of the epidemic visualization project in many aspects: first, data visualization makes it easier for us to understand how the crisis changes every day; second, the visualization of the epidemic information can also be used in media, government, and business reports; finally, the existing COVID-19 disease data research analysis is also of great reference for the scientific research of professional data analysis and processing personnel.

1.2 Norway's response to the outbreak

In the aftermath of the outbreak, the Norwegian government reacted rapidly after the first case was registered on February 26, 2020. Two weeks after the first case was confirmed, the prime minister announced Norway's toughest and most aggressive measures in peacetime [1]. Schools and kindergartens were closed and quarantined, and most restaurants and bars had to be closed until further notice. The strategy was to prevent the rapid spread of infection. This allows the number of infections to level off over a longer period and keeps the number of infections within the capacity of the health system at any time. This contrasts with Sweden, which has tried strategies to spread infection rapidly to immunizing most of the population. However, since the initial effects of policy implementation were not obvious, the Norwegian government subsequently adjusted the long-term strategic planning and response to the COVID-19 epidemic [2].

Although these measures have had a positive impact on the control of the outbreak, they have been difficult in terms of the capacity of the health-care system. Under normal circumstances, Norway has 289 ICU beds, but the health service has a plan to increase the number of beds to 1,200 if needed. According to the Ministry of Health and Care Services, there are a total of 1,100 ventilators in Norway [3]. But if the spread of the coronavirus is not stopped in time, hospitals may be overwhelmed.



(a) Hospital prevalence (b) Ventilator prevalence

Figure 2: A comparison of true data (red) and predicted values (blue) for hospital and respirator prevalence (*source: Norwegian Institute of Public Health (FHI) [4]*).

Figure 2 shows how our national model fits the national hospital prevalence data (a) and the daily number of patients receiving ventilator treatment (b).

1.3 Corona vaccine

In the case of COVID-19, a vaccine efficacy of 67% may be enough to slow the pandemic, but this assumes that the vaccine confers sterilizing immunity, which is necessary to prevent transmission. Platforms being developed in 2020 involved nucleic acid technologies (nucleoside-modified messenger RNA and DNA), non-replicating viral vectors, peptides, recombinant proteins, live attenuated viruses, and inactivated viruses.

There are three vaccine types for forming SARS-CoV-2 proteins to prompt an immune response: (1) RNA vaccine, (2) subunit vaccine, (3) viral vector vaccine.

By May 2021, four vaccines are approved, but AstraZeneca is suspended due to suspected side effects and Janssen is given outside the vaccination program only to those volunteering [5]. Hence, the Pfizer/BioNTech and the Moderna vaccines are those mainly used. The Pfizer/BioNTech vaccine is now widely used by Norway. Each person needs two doses to be effective, and the vaccine must be stored in an environment of between −80 and −60°C (−112 and −76°F). The vaccine transport box consists of a large box of dry ice, which keeps at least 70 degrees below zero. (Figure 3)

Figure 3: COLD BOX: The picture shows a specially made transport box for the Pfizer vaccine, which must be kept cold (Photo: Pfizer/AP).

There is a kit with a vaccine bottle in the box. (Figure 4) Its smallest unit delivery unit is 975 doses. After you open this kit and mix the reagents with the saline solution, the shelf life is five days. Vaccine vials need to be stored above −40°C (−40°F) and between −25 and −15°C (−13~5°F). Once refrigerated, the vaccine can be kept between 2 to 8°C (36 to 46°F) for up to 30 days [6].

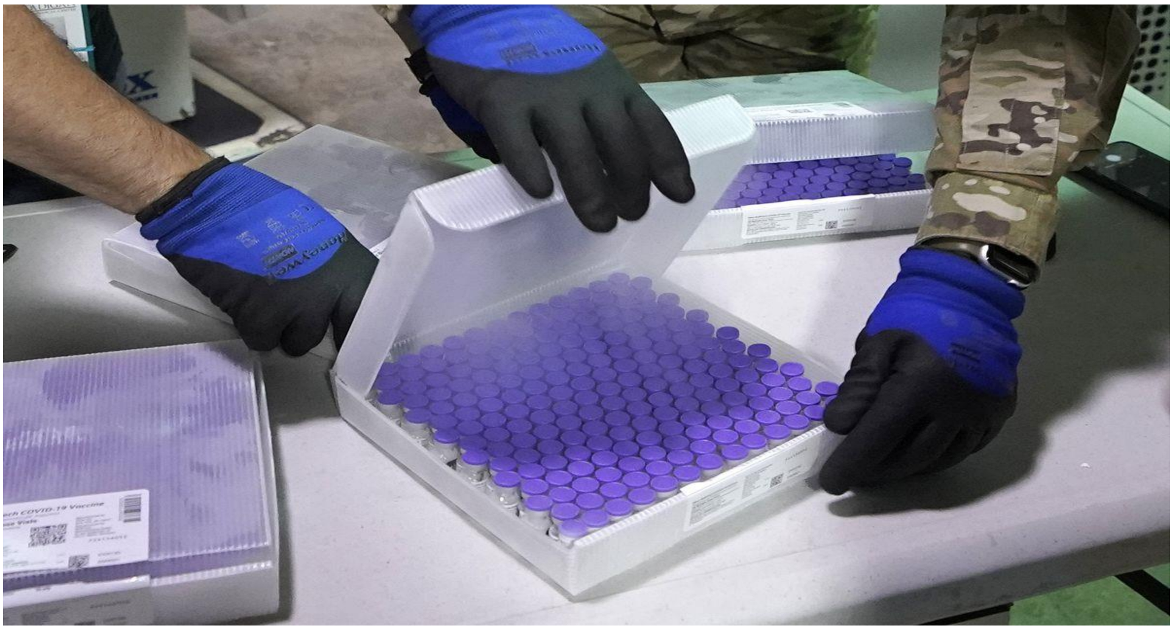


Figure 4: ICE COLD: The Pfizer vaccine must be stored in minus 70 degrees (Photo: Ted S. Warren / AP).

1.3.1 Logistics support

Different vaccines have different requirements for transportation and handling. And one important point that should be cared for is each vaccine requires a separate supply chain. This greatly increases the difficulty of transportation. It means that if medical institutions want to successfully obtain and vaccinate, they must have a complete supply chain logistics centre to support. The logistics centre includes vaccine processing and monitoring, cold chain management, and safe distribution within the vaccine network.

1.3.1.1 Cold chain

Cold chain management is the very important part in the whole process. Vaccines (and adjuvants) are inherently unstable during temperature changes and require management of the entire supply chain of the cold chain, usually at a temperature of 2-8°C (36-46°F) [7] [8]. Because the new coronary pneumonia vaccine technology is different in several new technologies, cold chain management is facing new challenges. Some vaccines are stable when frozen, but not easy to heat, while others should not be frozen, and some vaccines are stable at different temperatures [8]. In the local vaccination process, freezing damage and insufficient personnel training are the main concerns [9]. Since more than one COVID-19 vaccine has been approved, the vaccine cold chain must adapt to all these temperature sensitivities, climatic conditions, and temperature hold of local resources in different countries.

The developing Moderna vaccine technology may be more difficult to mass-produce and control degradation, requiring excessive storage and transportation [10]. For example, candidate vaccines for modern RNA vaccines require cold chain management, the temperature is slightly higher [6] [11] [12]. After the vaccine bottle is pierced to inject a dose, it can only survive for six hours, and then must be discarded, so it is also necessary to pay attention to the local management of the cold storage and the vaccination process [13] [14]. Figure 5 shows Specialized truck transporting the Pfizer vaccine from producers in Belgium to Norway.

Figure 5: Specialized truck transporting the Pfizer vaccine from producers in Belgium to Norway (Photo: Gisle Oddstad, VG).

1.3.1.2 Air and land transport

At the same time, the coordination of international air cargo is an important part of the time and temperature-sensitive COVID-19 vaccine distribution. IATA Director General and CEO Alexandre de Juniac said in September 2020 [15]. "The safe delivery of the COVID-19 vaccine will be the century mission of the global air cargo industry. However, it will not be achieved without careful advance planning. Now is the time. We urge governments to take the lead Promote cooperation across the entire logistics chain to prepare facilities, security arrangements, and border procedures for the difficult and complex tasks of the future."

The important thing here is that there are some special constraints when transporting by air, compared to trucks. The two first approved vaccines, Pfizer and BioNTech's Pfizer-BioNTech COVID-19 vaccine, and Moderna's mRNA-1273, must be kept cold during transportation. The use of specially designed containers [a] and dry ice can keep the temperature low enough, but because the gas released by sublimation may be toxic, only a small amount of dry ice can be used on airplanes. The CDC has commissioned McKesson to distribute the vaccine in the United States, and it will handle all major vaccines except Pfizer. American Airlines, Boeing, and Delta Air Lines are also working to improve dry ice transportation capabilities, while the United States, Delta, and United Airlines each operate their own cold storage networks in the United States. FedEx and UPS have installed ultra-cold refrigerators to deliver vaccines in air cargo centres in Europe and North America [16]. Figure 6 shows air cargo is the only solution to distributing vaccines over huge distances at speed.

Figure 6: IAG Cargo maintains that air cargo is the only solution to distributing vaccines over huge distances at speed (Photo: IAG Cargo).

1.3.2 Norway's vaccine immunization program

Norway has rapidly launched a vaccination program against the new coronary pneumonia in cooperation with the European Union, to achieve the highest possible immunization coverage. As of the morning of January 18, 2021, SYSVAK, the national immunization registry, had registered 48,680 new coronary pneumonia immunizations [17]. The goal of the government's immunization efforts is early immunization of the entire population. However, due to the limited number of vaccines available in the initial stages, prioritization needs to be established among groups [18]. The Norwegian Institute of Public Health recommends five goals (ranked by priority) for coronavirus vaccination [19]:

- Reduce risk of death
- Reduce risk of severe disease course
- Maintain essential services and critical infrastructure
- Protect employment and the economy
- Re-open society
- Priorities also can be adjusted according to the process of pandemics, the nature of vaccines, the extent of social infections and the degree of control and stress in health services [17].

However, throughout the implementation of the vaccination program, the geographical location of distribution centres and vaccinators, as well as differences in the situation of inoculators in different ways of inoculation, are issues to be considered. It is also very important to arrange the interaction between the vaccination centre and the vaccinators. First, the distribution of vaccines from central warehouses to vaccination centres in various regions requires cold-chain logistics, air and road transportation to complete the last kilometre of distribution. Second, the preservation conditions of vaccines and the location of warehouses are necessary considerations. Third, ensure that health personnel are not infected and have a high level of expertise. And the indicators of those vaccinators should also meet the vaccination requirements. Fourth, vaccination sites should also be set up in convenient areas, so that vaccinators can be vaccinated quickly and on time. If the vaccinators are unable to reach the receiving centre, consider sending health personnel to the vaccinator's home to complete the vaccination. At the same time, we should also make a schedule of vaccinations before distribution, arrange logistics and transportation tasks, and make careful plans to ensure the successful completion of the vaccination program. These can also be done with visual analysis.

2.0 The methodology

2.1 The development and importance of data research

Data analysis is an indispensable method of investigation for any research object. It has been established as early as the early 20th century. It was not until the rapid development of computers and the Internet that it was widely used and known by people. Previously, the methods used were labour-intensive and material-intensive, requiring more human and material resources. Due to the rapid development and dissemination of digital technology and information culture in recent years, data analysis is becoming more and more important in enterprise index analysis, project management, market research, daily life, economy, and other trends. The goal of data analysis research and analysis is mainly people-oriented, according to human behaviour and psychological thinking to design a variety of data indicators, and then achieve the results that researchers want, to develop plans and direction of action. Figure 7 explains the components of big data. We can see that Visual analysis is also an important part, and the thesis also uses this part to study the relevant issues in detail.

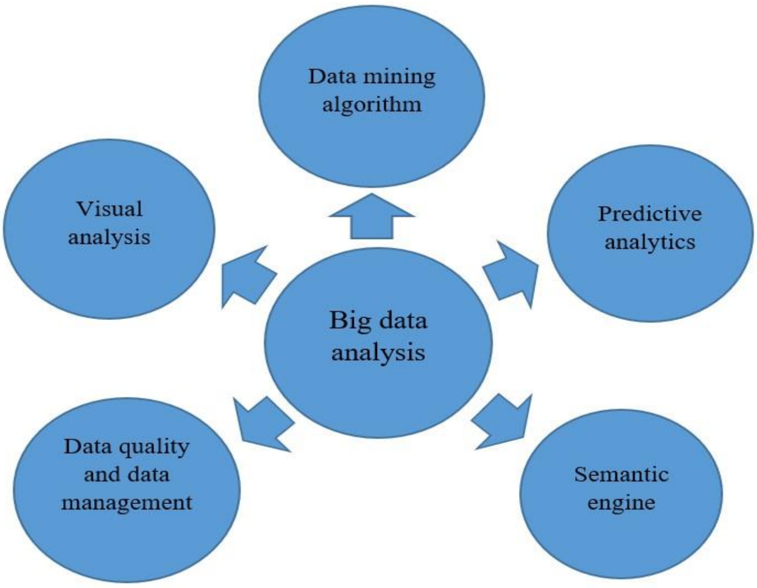


Figure 7: The components of big data.

2.2 The close connection between data and visualization

The website Baidu.com *[20]* states the following purpose of data analysis*:*

- Classification: The purpose of checking unknown or temporarily unknown data is to predict which category the data belongs to. Use similar data with known classifications to study classification rules, and then apply these rules to unknown classification data.
- Forecast: Prediction refers to the prediction of numerical continuous variables rather than categorical variables.
- Association rules and recommendation system: Association rules or association analysis refers to finding general association patterns in large databases such as bundling.

- Predictive analysis: Predictive analysis includes methods such as classification, prediction, association rules, collaborative filtering, and pattern recognition (clustering).
- Data reduction and dimensionality reduction: When the number of variables is limited and many sample data can be classified into homogeneous groups, the performance of data mining algorithms is usually improved. Reducing the number of variables is often called "dimensionality reduction". Dimensionality reduction is the most common initial step before deploying a supervised learning method, which aims to improve predictability, manageability, and interpretability.
- Data exploration and visualization: The purpose of data exploration is to understand the overall situation of the data and detect outliers. Data browsing created through charts and dashboards is called "data visualization" or "visual analysis". For numerical variables, you can use histograms, box plots and scatter plots to understand the distribution of values and detect outliers. For categorical data, use bar graph analysis. This thesis uses data visualization to visually display the data to be studied to resent and analyze relevant data in the most intuitive way to get clearer and deeper information.
- Supervised learning and unsupervised learning: Supervised learning algorithms are algorithms used for classification and prediction. The data classification must be known. Simple linear regression is an example of a supervised algorithm [21].

Big Data is used in many areas [22], it includes:

- Banking and Securities
- Communications, Media and Entertainment
- Healthcare Providers
- Education
- Manufacturing and Natural Resources
- Government
- Insurance
- Retail and Wholesale trade
- Transportation
- Energy and Utilities

Figure 8 shows that people use it to get the information they need. Big data has an impact on work, study, travel, consumption, health care, and so on. For example, it can improve health care and public health. Big data analytics helps us monitor and predict outbreaks of a pandemic or infectious disease, combining data from medical records with data from some social media; Big data is also widely used to understand and optimize business processes. Such as supply chain or distribution path optimization; And, many businesses are passionate about data sets such as social media data, browser logs, and text mining, creating predictive models using big data technology to gain a more complete understanding of customers and their behaviours and preferences, to better target customers, and so on.

Figure 8: The widespread use of Big Data [20].

The significance of data analysis:

- Tell you what happened in the past-- Current status analysis
- Tell you why this status happened-- Cause Analysis
- Tell you what will happen in the future-- Predictive analysis

In general, we can define three steps of data analysis:

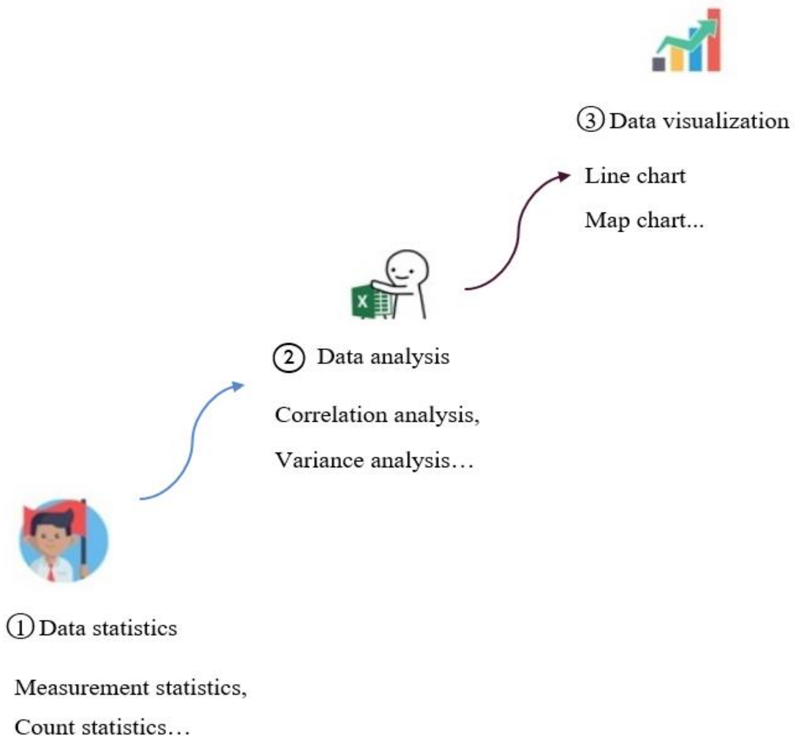


Figure 9: The three steps of data analysis.

From Figure 9 above, we can clearly understand that data statistics is the premise of all analysis, data analysis is the second step after the completion of data statistics, the data from the previous statistics will be described using appropriate analytical methods. And finally, it needs to use data visualization charts to show it.

Take the COVID-19 vaccination plan as an example. The first is to collect information on infection cases and groups everywhere. This step is the statistical process of the data. Second step is Data analysis. It refers to the process of analysing the collected data by appropriate statistical analysis methods, extracting useful information and forming conclusions, and summarizing the data in detail. Through it we will get the data to process and analyse and develop a viable vaccination plan. Finally, the analysed data is presented more intuitively through data visualization, and the data is understood and studied more clearly.

The Data visualization is mainly through the form of visual charts to present a large amount of data in a coherent and short form and use data analysis and development tools to discover the unknown information. The goal is to visualize the data so that information can be clearly and efficiently transmitted. It has a wide range of applications and is used in various fields. Its most important benefit is improved ability to interpret and understand information, help people grasp data faster, and find key points. Thus, there is a strong connection between data and visualization.

2.3 Data Mining

2.3.1 Introduction

Data mining is the process of understanding data through cleaning raw data, finding patterns, creating models, and testing those models. It includes statistics, machine learning, and database systems. Data mining often includes multiple data projects, so it is easy to confuse it with analytics, data governance, and other data processes. This guide will define data mining, share its benefits and challenges, and review how data mining works.

2.3.2 Types of data mining techniques

Calvello (2020) [23] states the several types of data mining techniques:

Correlation analysis

Correlation analysis is a statistical method for studying the dependencies between two variables in a set of data. One example could be the correlation between Corona related deaths and the age of the infected.

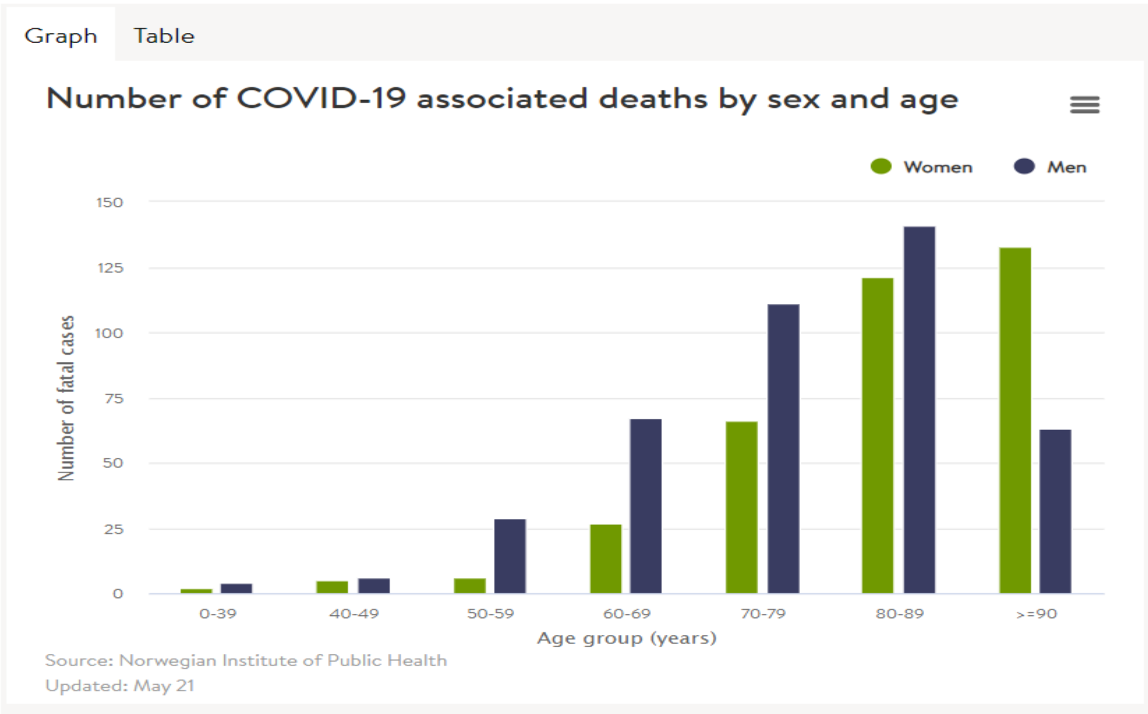


Figure 10: The number of COVID-19 associated deaths by sex and age [24].

Looking at Figure 10, one can see that the number of fatal cases gets higher when the age increases. This is an indication for correlation between age and deaths. In addition, it looks to be a higher risk of dying for men than for women. The decrease in the highest age group (e.g., over 90) can be explained by the lower number of people in this category.

Cluster analysis

A data mining technique, also known as digital taxonomy. It basically groups large amounts of data together based on the similarity of the data. Clustering means that you try to find convenient groups of objects that are similar and can be treated together. Typically, this could be geographical clusters as places within a limited area. In some sense, the counties in Norway can be treated as clusters since they are defined within specified borders and share a common administration.

In this thesis, the counties are defined as clusters since they are administrative units with a coordinated vaccination strategy. For example, do some visualizations to the data of the number of infections and vaccination in counties. The infection rate and vaccination rate were observed in each county through a cluster analysis of the data.

Classification analysis

Classification can be seen as a subset of clusters. It includes analysing various attributes related to different types of data and is an important part of identifying specific data types. Classification can be performed by using decision trees as a decision support tool. It uses a decision tree (as a predictive model) to go from observations about an item in the branches to conclusions about the item's target value in the leaves. Tree models where the target variable can take a discrete set of values are called classification trees; in these tree structures, leaves represent class labels and branches represent conjunctions of features that lead to those class labels. Decision trees where the target variable can take continuous values (typically real numbers) are called regression trees. Decision trees are commonly used in operations research, specifically in decision analysis, to help identify a strategy most likely to reach a goal but are also a popular tool in machine learning. Indecision analysis, a decision tree, and the closely related influence diagram are used as a visual and analytical decision support tool, where the expected values of competing alternatives are calculated.

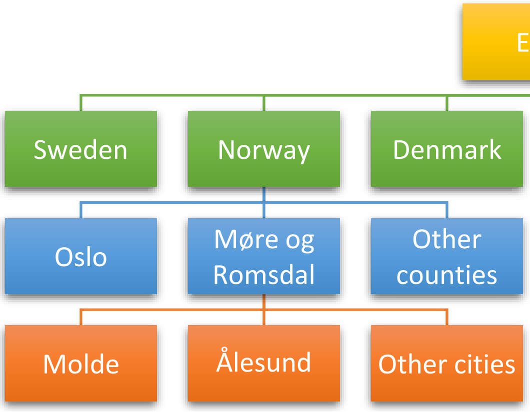


Figure 11: The distribution of the COVID-19 vaccine in the European Union.

Figure 11 shows the distribution of the COVID-19 vaccine in the European Economic Area (EEA). The order is that the EU/EEA to agree with manufacturers on a certain amount of vaccine delivery and distribute them to individual countries according to the main plan. Next, each country gets a certain number of vaccines and must decide how to assign them to lower tissue levels, such as counties. A similar issue is then dealt with by the county government, where the vaccine is distributed to municipalities and possibly to individual communities, etc.

Regression analysis

Regression analysis is a data mining technique that can identify and analyse the relationship between variables. It is statistical analysis method that determines the quantitative relationship between two or more variables. It can be divided into unitarian regression and multiple regression analysis according to the number of variables involved, simple regression analysis and multiple regression analysis according to the number of factor variables, and linear regression analysis and nonlinear regression analysis according to the type of relationship between arguments and factor variables.

In the thesis, Regression analysis can be used to forecast the development in infections and distribution of vaccines. However, it should note that the most common regression technique is linear regression, and these factors do not develop linearly. The infections appear to come in waves, and the vaccine production is increasing exponentially over the actual time period.

Others mentioned are:

- Data cleaning: A necessary technique with the purpose of cleaning up, format, and analyse raw data for making it useful for different types of analysis methods.

- Outlier detection: This is the opposite technique compared to clustering. Outlier detection is not searching for large groups of data that can be clustered together but looking for rare data points outside of established groups or averages.
- Association rule mining: A technique which looks at how one variable relates to another and it tries to discover a hidden pattern in the data set.
- Prediction: This technique is also called predictive analysis, and it uses other data mining techniques, such as clustering and classification, to analyse past events or instances to predict future events.
- Neural networks: Neural learning is a specific type of machine learning and statistical technique that is often used artificial intelligence and deep learning. It simulates the way neurons work in the human brain, and it is one of the most accurate machine learning models we use today.
- Principal component analysis: It is used to show hidden connections between input variables and reducing the number of variables while still conveying the same amount of information.
- Tracking patterns: Tracking mode is a basic pattern in data mining technology. It includes identifying and monitoring trends and patterns in data to make informed and calculated assumptions about business results.
- Data warehousing: This is also known as enterprise data warehousing and involves storing structured data in a related database management system to analyze its use for reporting and business intelligence. Now the data mining and data warehousing technologies leverage two cloud data warehouses to store these insights more securely.

The main technique used in this thesis, is however Data visualization. This is a scientific and technological study of data vision representation. It consumes data from any source through file uploads, database queries, and application connectors, and aims to visualize the performance goals by using charts and graphs in real time to give users a deeper understanding of their information.

3.0 Research objectives and questions

3.1 Objectives

The main objective of this thesis is to visualize and analyse of the logistic process of distribution Covid-19 vaccines in Norway.

The goal is to try to mine potential information in the data by studying it. And the extracted information combined with visualization technology to further intuitive interpretation. Then the results are analysed in depth to get some valuable tips or methods. It is hoped that some constructive views can be provided for distribution issues of related logistics program in the future.

3.2 Research questions

- What type of visualization is best suited for showing the distribution of Covid-19 vaccines?
- Can a combination of maps and charts give a better understanding of the distribution process?
- Can the visualization point out challenges and identify problems in the current distribution strategy?

This visualization could give some insight and information to be used for potential similar distribution problems in the future.

3.3 Research tasks

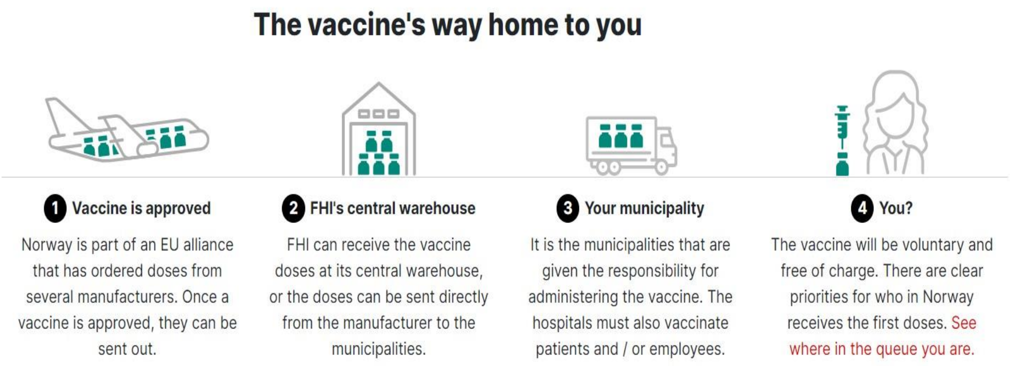


Figure 12: The trajectory of vaccine delivery (Source: https://www.vg.no/spesial/corona/vaksiner).

According to Figure 12, we can understand the whole route of the vaccines. Firstly, a vaccine must be approved, and then it is distributed to the individual countries due to an agreement between Norway and EU. Then they are ordered and sent from manufactures. Secondly, the Norwegian Institute of Public Health (FHI) can receive the vaccines and store them in warehouses before they are sent to the municipalities. And then, the municipalities administering the vaccines and organize the vaccination process for its population. Finally, people will be vaccinated voluntarily and free of charge according to priority rules.

4.0 Literature review

4.1 Research on visualization

An important source for the content of this thesis is the book "Visual display of quantitative information" by Edvard R. Tufte [25]. This is a classic book concerning theory and practice of data graphic design describing statistical charts, graphs, and tables. It explains and analyses statistical charts and how the data is displayed for accurate, effective, and rapid analysis. In addition, the book includes the potential source of deception and graphic display of aesthetics and data. Many parts of the visual design in the thesis are carried out with reference to the content of this book.

The Lancet Infectious Diseases is an authoritative forum for key opinion leaders in medicine, government and health systems to influence clinical practice, explore global policies, and inform constructive and positive changes around the world. As a global leader in clinical infectious diseases, The Lancet Infectious Diseases provides important original research, expert reviews, candid reviews and breaking news, providing context and perspective on the most important medical advances in a variety of clinical infectious diseases today. Researchers from Johns Hopkins University have created an interactive web-based dashboard to track COVID-19 in real time which is described in the Lancet article [26].

Wenqiang Cui [27] wrote an article with the purpose of drawing a complete picture of visual analysis by studying the relevant research in various applications, to guide future research. Therefore, it is proposed to classify the application of visual analysis from a technical point of view, which is based on the dimension and interaction type of visualization. On this basis, the visual analysis is investigated comprehensively, the evolution process is examined from the visualization and algorithm data analysis, and its application in various application areas

is investigated. In addition, based on observations and findings from this survey, trends, key challenges and future directions of visual analysis are discussed.
In their paper [28], Skarbez at al. proposed a definition of immersive analysis, and identified a number of general research areas and specific research issues that are critical to the development of this field, thus solving this deficiency. They also presented three case studies, all of which are examples of analytical but present different challenges and opportunities. These should help to demonstrate the breadth of immersive analysis and explain how the proposed framework could be applied to real-world research.

4.2 Visualization techniques

Visualization is any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of humanity. Examples from history include cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci's revolutionary methods of technical drawing for engineering and scientific purposes [29].
Applications:

- Scientific visualization

  Scientific visualization is an interdisciplinary research and application in science, focusing on the visualization of three-dimensional phenomena, such as architecture, meteorology, medicine, or biological systems. The focus is on realistic renderings of bodies, faces, light sources, and so on, and perhaps even some dynamic component. Its purpose is to explain, operate and process scientific and technological data and models. Computer graphics are used to create visual images to help people understand scientific and technological concepts or results.

- Educational visualization

  Educational visualization creates an image through simulation and uses it in teaching. For example, atomic structure, because atoms are very small, without expensive and sophisticated instruments, it is difficult to study it. (Figure 13).

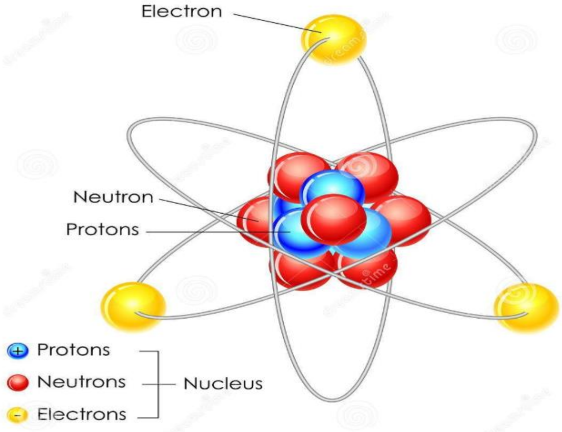


Figure 13: Atomic structure diagram.

➢ Data visualization

Data visualization is a scientific and technical study of the visual representation of data. Mainly by means of graphical means to transform the information in the data into visual charts, directly in front of people, to convey and communicate information clearly and effectively. Data visualization can be static or interactive. Related areas of data visualization include data acquisition, data analysis, data governance, data management and data mining. Figure 14 shows the total weekly distribution from week 53 2020 to week 18 2021 in Norway.

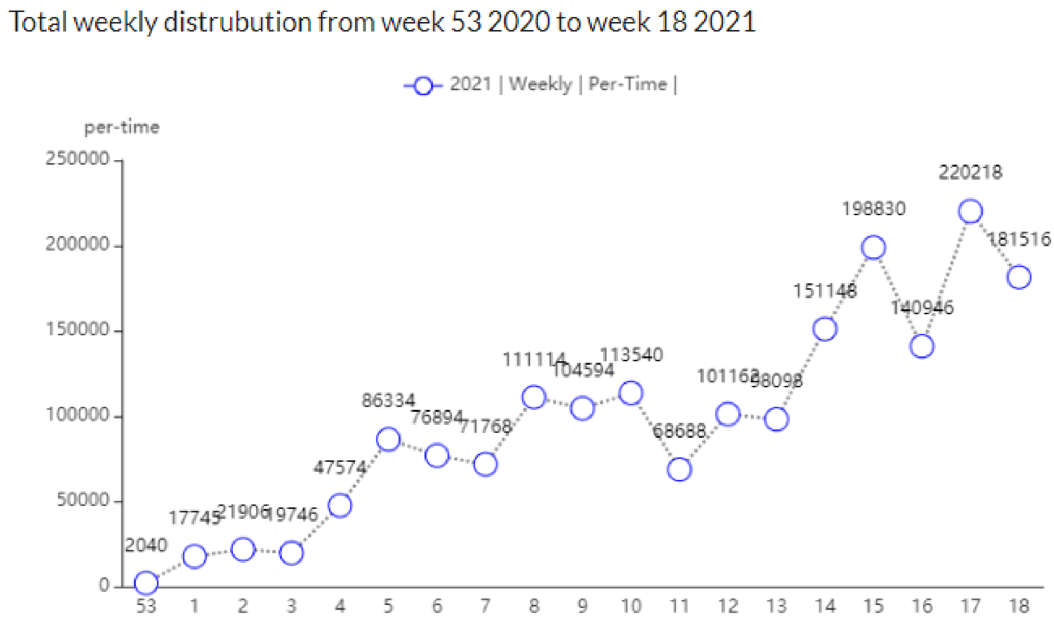


Figure 14: Total weekly distribution from week 53 2020 to week 18 2021in Norway.

- Information visualization

Information visualization is designed to study the visual representation of large-scale non-numerical information resources, to transform information into data that can be processed by computers, and to display it on the screen in graphical or image form to help people understand and analyse data.

Lei and Weidong from the MBA Think Thank Network [30] states the following application areas for information visualization:

- One-dimensional information visualization: One-dimensional information is simple linear information, such as text, or column numbers.
- Two-dimensional information visualization: In the information visualization environment, two - dimensional information refers to information that includes two main attributes. City maps and floor plans are 2D information visualizations.
- Three-dimensional information visualization: Many scientific computational visualizations are three - dimensional information visualizations, because the main purpose of scientific computational visualization is to represent real three - dimensional objects.
- Multi-dimensional information visualization: Multidimensional information refers to those with more than 3 attributes in the information visualization environment, in which the importance of these attributes is quite important.
- Time series information visualization: Some information has its own time attributes, which can be called time series information, for example, a novel or news can have a timeline.
- Visualization of hierarchical information: One of the most common relationships between abstract information is hierarchical relationships, such as disk catalogue composition, document management, book classification, and so on. The traditional way to describe hierarchical information is to organize it into a tree-like node connection representation.
- Network information visualization: Since then, the Web has had countless messages distributed across tens of thousands of websites around the world, interwoven through document-to-document overreach.

- Knowledge visualization

Knowledge visualization refers to graphical images that can be used to construct, communicate, and represent complex knowledge, and in addition to conveying information, the goal of knowledge visualization is to transmit human knowledge and help others correctly reconstruct, remember, apply knowledge, and promote meaningful learning.

- Product visualization

Product visualization is mainly aimed at using graphical and other intuitive means, clear and effective communication and communication of information, the formation of efficient functions, the use of mapping, the completion of the task objectives. Reduce people's cognitive and physical burdens by presenting products on the page in a way that is quickly understood and easy to use. It is divided into four levels: functional visualization, structural visualization, operation visualization, control visualization.

- Visual communication

Visual communication conveys a message or idea through the display of visual images such as symbols and patterns. Often associated with two-dimensional images, such as commercial or government billboards, artwork, geographic coordinates, or electronic resources.

- Visual analytics

Visual analysis is the analytical reasoning science supported by interactive visual interface. The overall goal is to detect expectations and detect surprises [31]. Visual analysis be a holistic approach that combines visualization, human factors, and data analysis. Visual analytics enables decision makers to combine their human flexibility, creativity, and background knowledge with the powerful storage and processing power of today's computers to gain insight into complex problems. With advanced visual interfaces, people can interact directly with the data analytics capabilities of today's computers, enabling them to make informed decisions in complex situations (Figure 15).

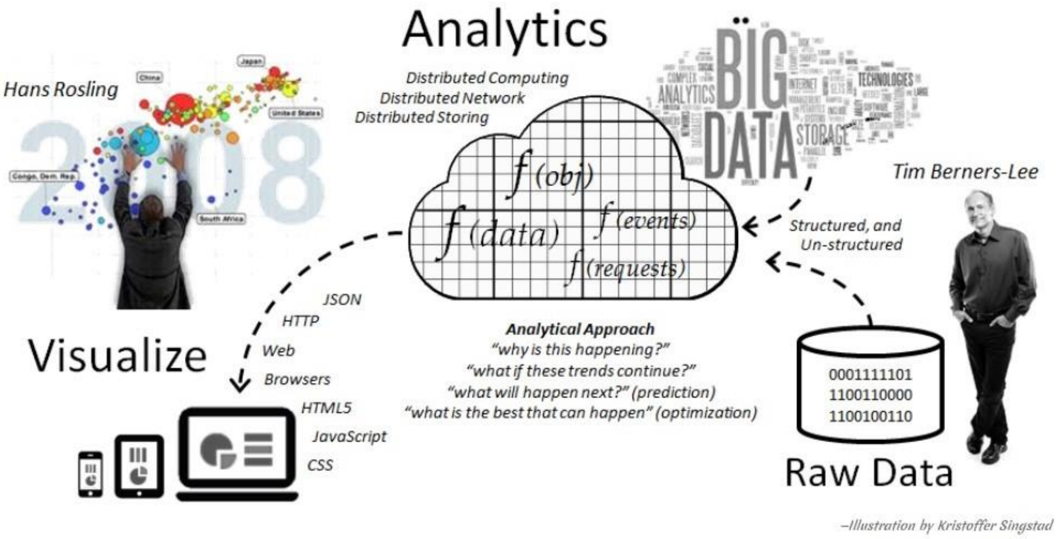


Figure 15: Learning Visual Analytics [31].

4.2.1 Methods and related examples

The visual analytic platform Tableau [32] states the common general types of data visualization.

- ➢ Tables

Thesis

File Edit View Insert Format Data Tools Add-ons Help

Week	Number of vaccination in counties
53	2040
1	17745
2	21906
3	19746
4	47574
5	86334
6	76894
7	71768
8	111114
9	104594
10	113540
11	68688
12	101162
13	98098
14	151148
15	198830
16	140946
17	220218
18	181516

Figure 16: Total weekly distribution from week 53 2020 to week 18 2021.

Data is usually initially stored as a table. There are many types of tables, and Figure 16 is a very common one. Although it can store data in its entirety, it does not visually reveal the deep information that the data hides, and not always obvious to understand, so that is why visualization is needed.

➢ Charts

Charts are essentially graphical representations of data visualization. Charts also have different meanings because of their different forms of expression. A data chart is an illustration or diagram that organizes and represents a set of numbers or quantitative data; The map adds additional information to this information for a specific purpose, such as nautical charts; Other specific areas of construction are sometimes referred to as charts, such as string charts in musical symbols. Charts are often used to simplify the understanding of the relationship between large amounts of data and parts of the data. Because they are faster than the original data reading, they are widely used in a variety of fields. There are many types of charts [33]. The most common are common charts, pie charts (Figure17), line charts, map charts, histograms/ bar charts (Figure18), and so on. In this thesis, data information is presented using some simple charts: bar charts, pie charts, line charts, tree charts (Figure19), bubbles and calendars (Figure20). And map charts will be presented as the most important part in it. They will be used to visualize and compare data to find the best visualization method for studying the distribution of the COVID-19 vaccine in Norway.

- Pie chart

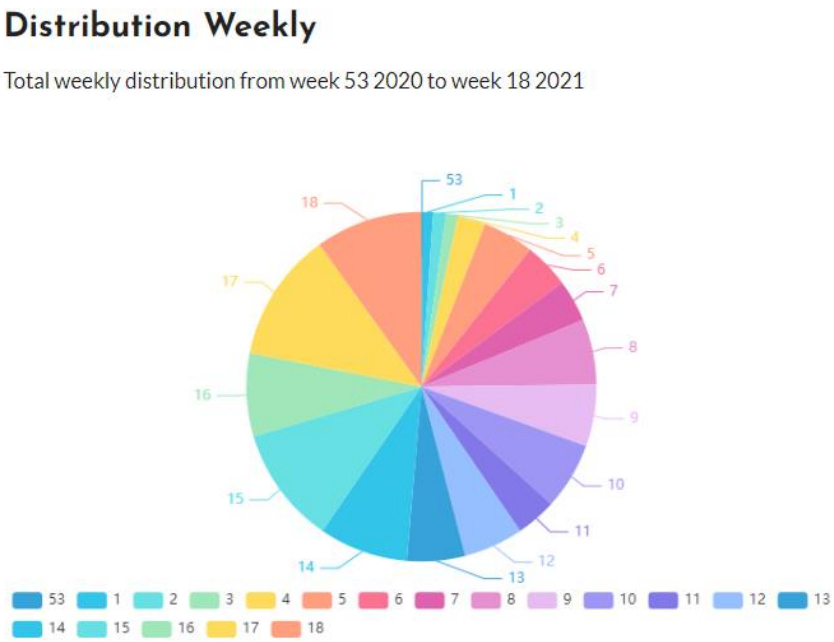


Figure 17: Total weekly distribution from week 53 2020 to week 18 2021**.**

The same data, but this pie chart is more intuitive than Figure 16. We can see intuitively the proportion of deaths in each country.

- Bar chart

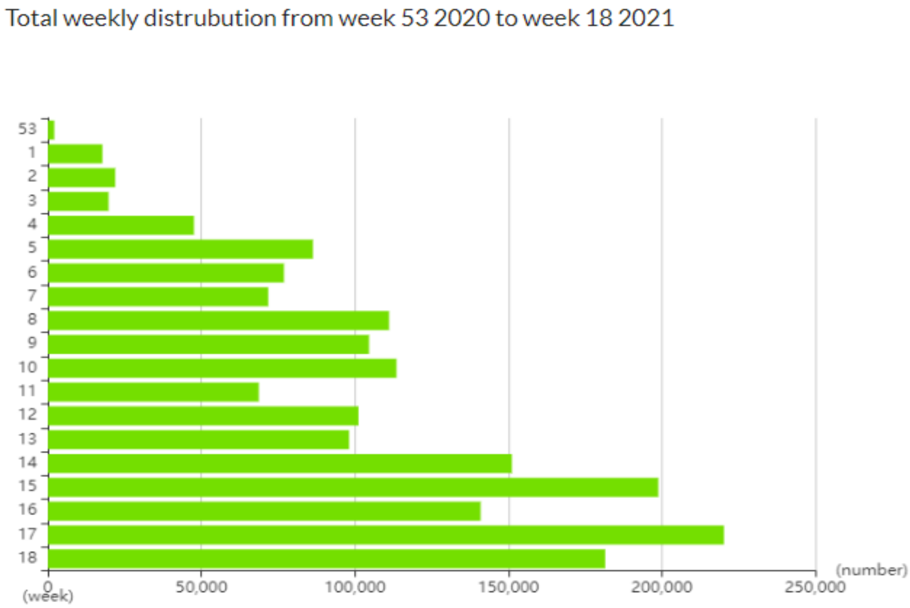


Figure 18: Total weekly distribution from week 53 2020 to week 18 2021**.**

- Tree charts

A tree-map is a visualization designed to facilitate the exploration of tree structure data, as well as more general, hierarchical data. Using visual metaphors to describe a family of visual techniques based on "containment attributes" of parent-child relationships is often referred to as tree charts. However, as tree chart changes, it becomes increasingly important to clearly distinguish between technology and its specific characteristics [34]. Figure 19 shows the Regions of Norway displayed, and can see all the municipalities in Møre og Romsdal with the demand for vaccines in parentheses.

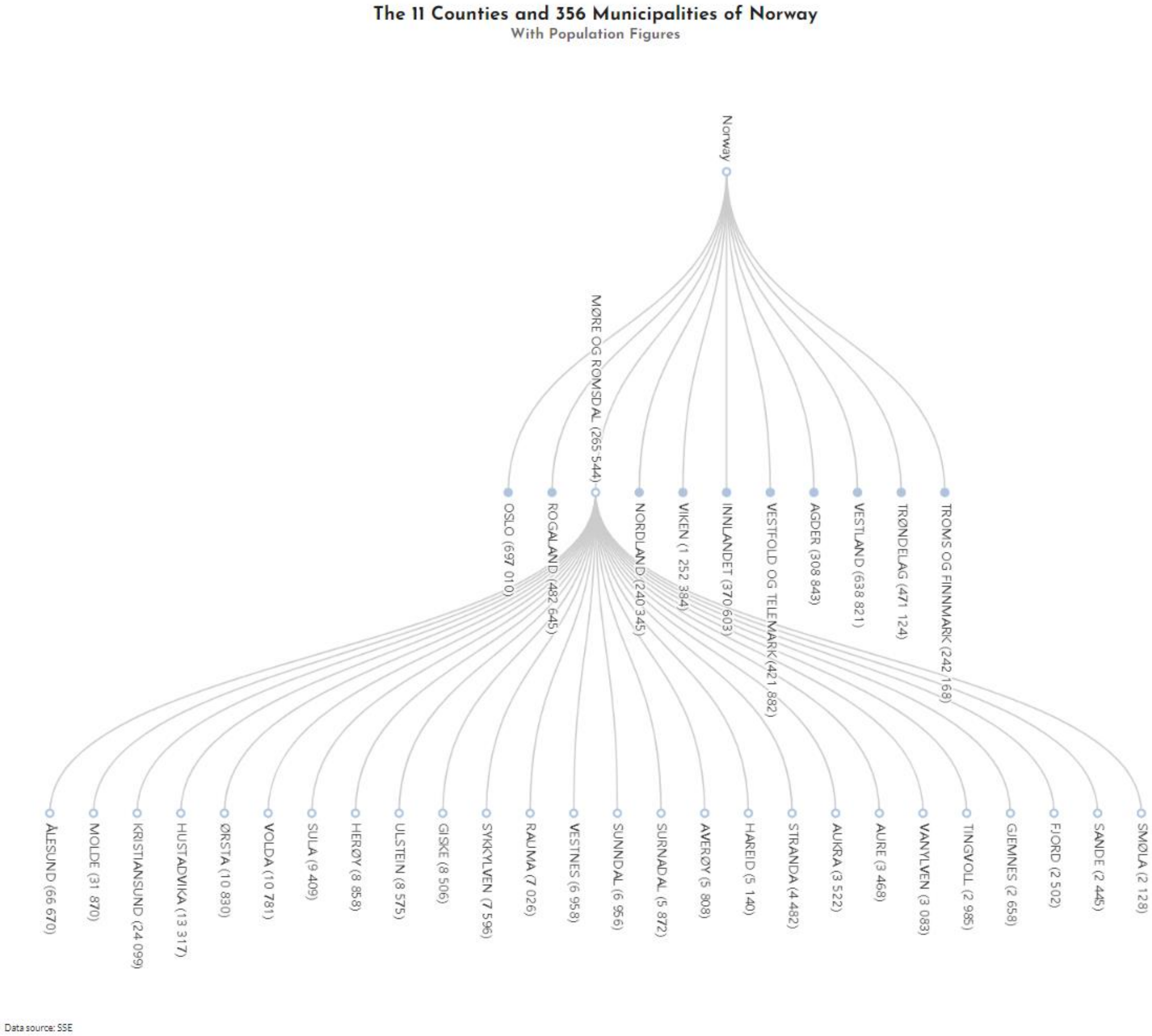


Figure19: The Regions of Norway displayed as a Tree Chart.

- Calendars

Figure 20 shows the Calendar of vaccination of Møre og Romsdal from week 53 in 2020 to week 18 in 2021. As the colour gets darker, it can be clearly seen that the immunity rate is increasing.

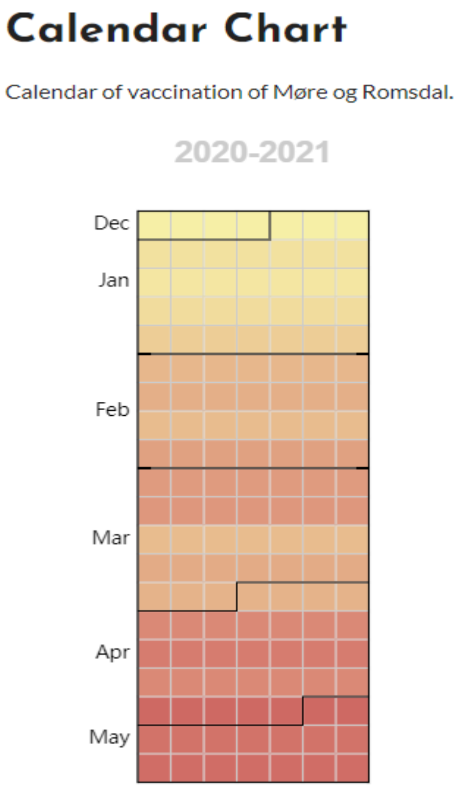


Figure 20: Weekly distribution of vaccine doses to Møre og Romsdal.

- Maps

Maps can be a very important source when visualizing information and they can be used in combination with other graphical techniques [35]. Map charts use different layers to locate data in context according to certain laws and can use maps to summarize the principles, scientifically reflecting the distribution characteristics of natural and socio-economic phenomena and their interrelationships. These layers can be data layers, such as marker or functional layers, or reference layers, such as ground layers, Web map service layers (WMS), or image layers. In this thesis, using maps to visualizing data will be an important part. Figure 21 shows Legends represent the distribution of vaccines in Norway after the delivery of the vaccine has been completed.

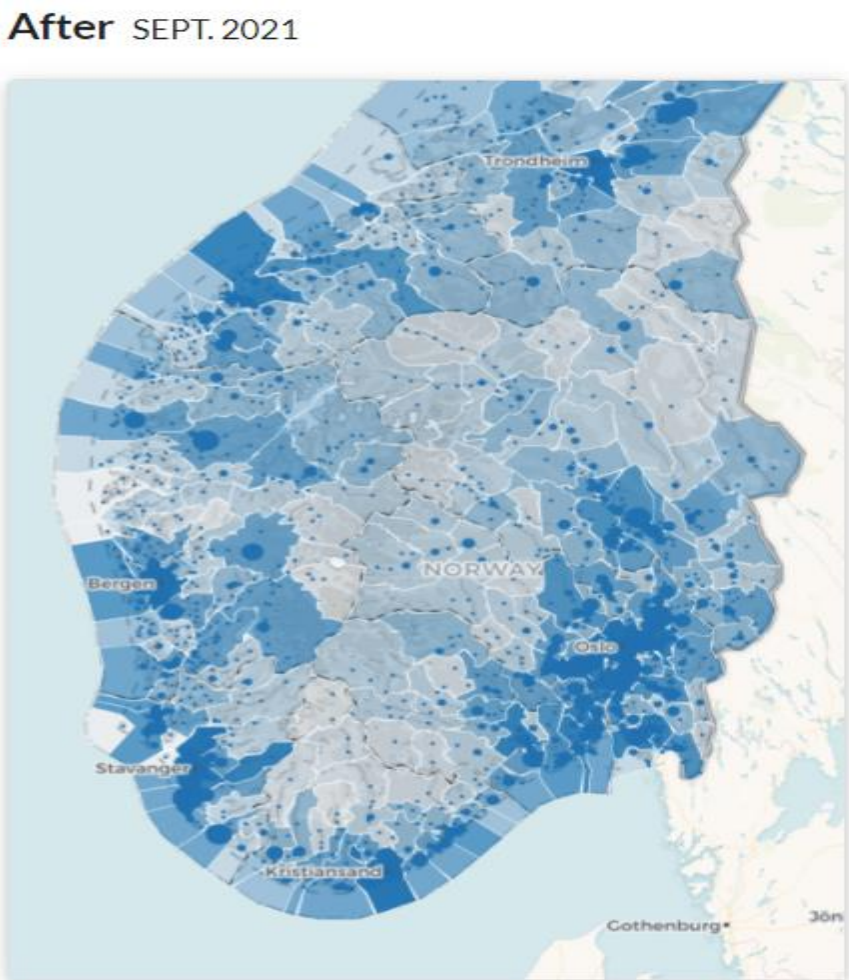


Figure 21: The distribution of vaccines in Norway after September 2021.

- Infographics

  Infographic (or information graphic) is “a visual representation of information or data”. An infographic is a collection of imagery, charts, and minimal text that gives an easy-to-understand overview of a topic [36]. Figure 22 shows WHO gives some personal safety prevention and control tips.

Figure 22: The safety prevention and control tips for COVID-19 [37].

- Dashboards

  It is like the dashboard used in the cars; the dashboard clearly shows the range in which a metric value is located. You can visually see how well the current task is accomplished, or whether a data is under control or about to exceed expectations [4]. Figure 23, for example, shows the extent of infection over a period using a dashboard to enable outbreak control canters to better carry out prevention and control efforts.

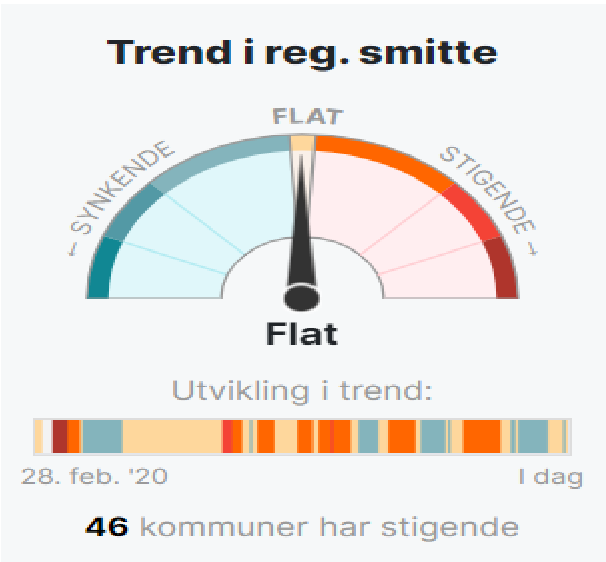


Figure 23: The trend in registered COVID-19 cases. (Source: https://www.vg.no/spesial/corona/)

4.3 Last-mile Logistics

Last mile is a term used in supply chain management and transportation planning to describe the movement of people and goods from a transportation hub to a destination. "Last mile" was adopted from the telecommunications industry which faced difficulty connecting individual homes to the main telecommunications network. Similarly, in supply chain management last mile describes the difficulty in transporting people and packages from hubs to final destinations. Last mile delivery is an increasingly studied field as the number of business to consumer (b2c) deliveries grow especially from e-commerce companies in freight transportation, and ride sharing companies in personal transportation. Some challenges of last mile delivery include minimizing cost, ensuring transparency, increasing efficiency, and improving infrastructure. However, some objectives may be contradictory and there may be problems in practice. The solution with the lowest cost could be impractical for the end-users.

In this context, the allocation of the last mile will be the final step after the city government receives the vaccines and hands them over to the patient. While vaccines can be delivered to distribution centres in different towns, the challenge will be to deliver them to end-users. Because vaccinations need to be prioritized at different ages and disease groups, different potential strategies can emerge [18]. A reasonable working time plan is needed to ensure the successful completion of coronavirus immunization. For the authorities, it is easiest if all vaccines are given at special vaccination stations manned by the required health personnel. But for some groups, such as the elderly, or some special groups with reduced mobility, it is not always easy. How to use visualization to present the feasibility of its strategy, and through analysis to develop a better plan is an important part of this thesis.

5.0 Visualization of the distribution of vaccines

5.1 Procedure

From the description of the above sections, different types of visualizations have their own characteristics for the presentation of data. But it still does not clearly show what the data means. This requires finding a visual tool that can analyse data accurately and clearly.

Interactive maps are a great tool. Interactive maps are powerful visualization tools that view what you expect and discover unexpected content. In this thesis, it will build an interactive map step by step to demonstrate its functionality. To do this, we will use the following: Norway's Coronavirus Immunization Programme, which is led by the Norwegian Institute of Public Health [38].

- Firstly, it needs to choose an optimal interactive map. There are many map tiles providers out there. Through explore a few using Leaflet [39] (an open-source JavaScript library for mobile-friendly interactive maps), and, using two other providers of great maps & location-based services are Mapbox [40] and Google Maps [41]. (Figure 24)

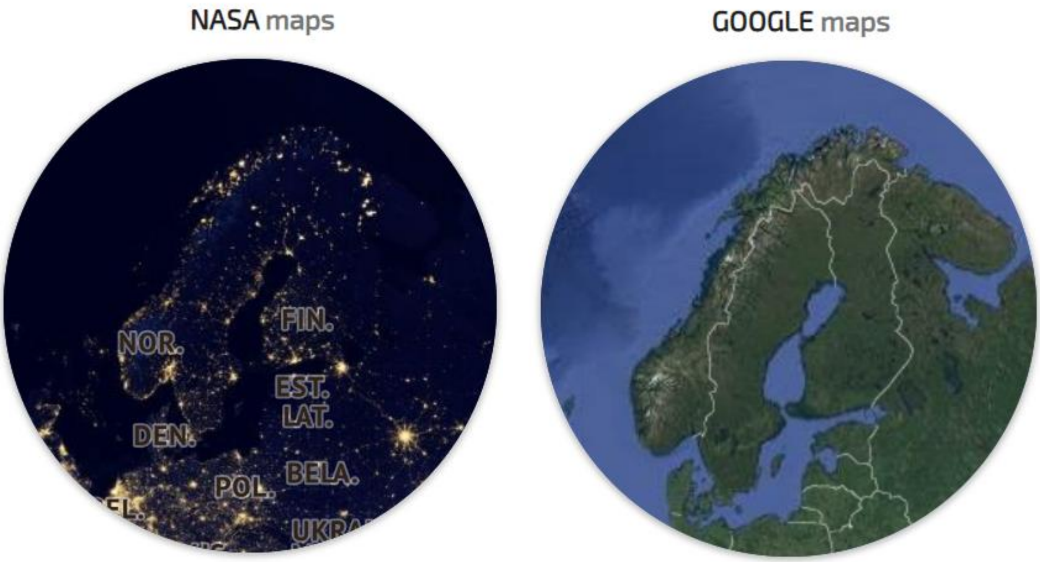


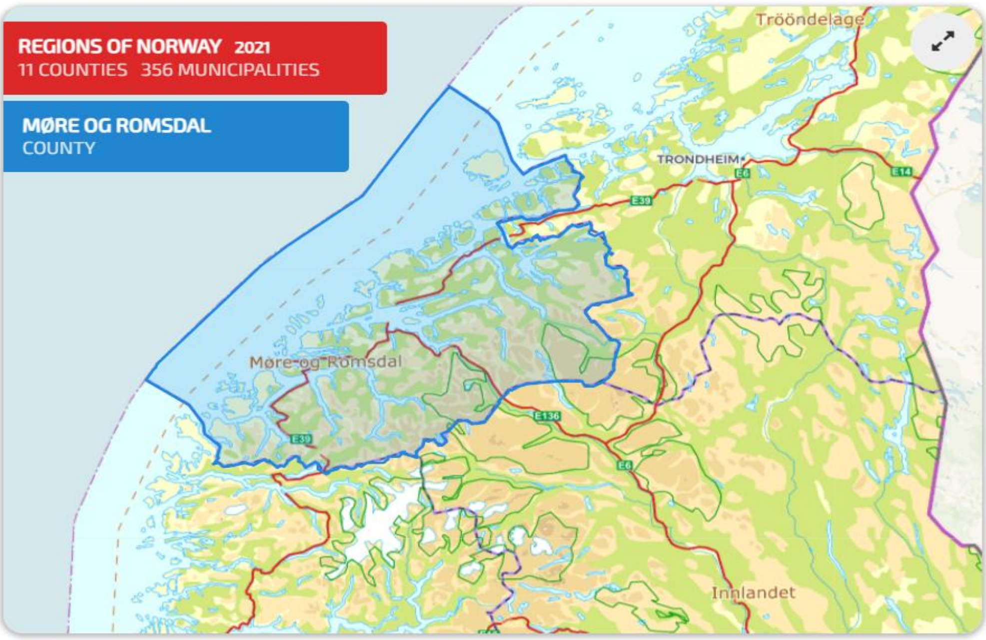
Figure 24: Six types of maps.

After trying to see how the maps above actually work, for this case (The Coronavirus Immunization Program in Norway), it will choose to select the Tiled web map [42] for Norway from the Norwegian Mapping Authority (Kartverket) [43] using the ESRI technology in combination with Carto [44] world map tiles.

Figure 25: Web Map Tiles from Kartverket [43] and Carto [44].

The reason for this is that the underlying data from NIPH is connected to the Norwegian counties and municipalities. And therefore, the tile from Kartverket is a good choice to perform data analysis with maps. Figure 25 shows Web Map Tiles from Kartverket and Carto.

- Secondly, it used Norwegian regions as map polygons to show the whole country. There are totally 11 counties and 356 municipality in Norway. Oslo, the Capital City of Norway, is both a county and a municipality. The 10 others are (number of municipalities in each county in parentheses): Viken (51), Innlandet (45), Nordland (41), Troms og Finnmark (39), Trøndelag (38), Møre og Romsdal (26), Agder (25), Rogaland (23), and Vestfold og Telemark (23).
  To get the borders for each region (county and municipality) it will use the web services from Geonorge [45] developed and run by the Norwegian Mapping Authority. According to the interactive map (Figure 26) below, it can be seen the region borders be displayed on top of the tiled web maps from Kartverket [43] and Carto [44]. There are 11 county polygons, and 356 municipality polygons with detailed border information. It is suitable for advanced location based on data analysis.



Web Map Tiles from Kartverket and Carto. Region borders from Geonorge/Kartverket.

Figure 26: Norwegian regions as map polygons.

➢ Thirdly, by using Statistics Norway (SSB) [46] to obtain population figures for each region (county, city). And obtain the total numbers, the figures for men and women, the figures for 10 years, and age group. The interactive map (Figure 27) shows the population for each region displayed as a Choropleth Maps [47] from light blue to dark blue.

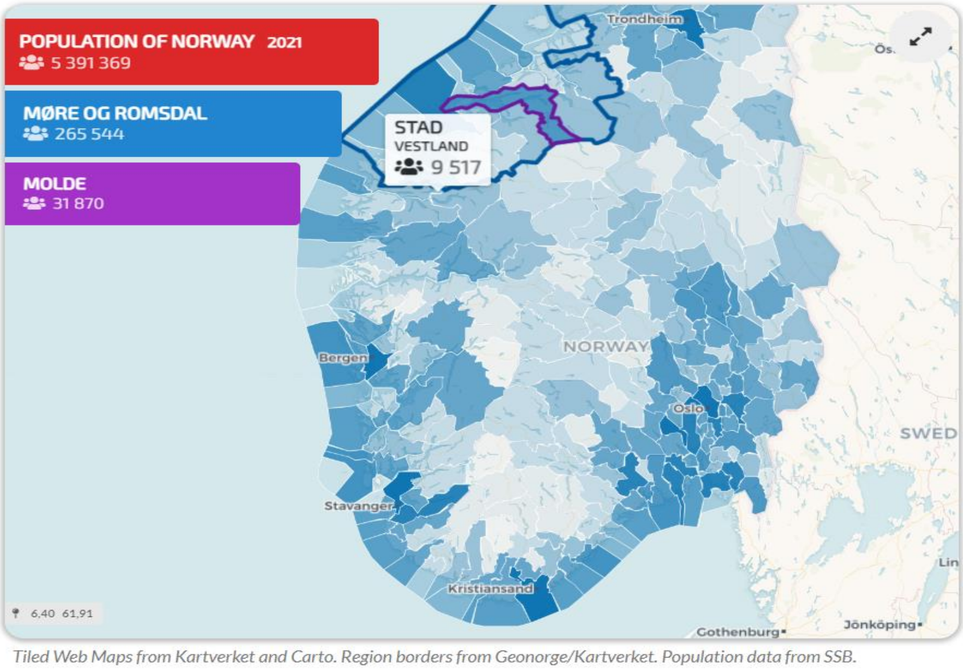


Figure 27: The population for each region displayed as a Choropleth Maps.

There are many ways to visualize data on map. So far, it used Tiled Web Maps and Choropleth Maps. In the next step it will use Proportional Symbol Maps [48] on top of the others.

➢ Fourthly, it used the map to visualize the Covid-19 vaccination program in Norway over time.

Figure 28 below shows the NIPH vaccination scenario visualized as a GANTT-chart [49]. The vaccination program starts in the last week of 2020 and is expected to end in the third quarter of 2021. The figures in the graph show that the peak for the delivery of vaccines is around June/July, and the information is published on the vaccination program in the *SYSVAK* registry by the Norwegian Institute of Public Health [50]. This is the information needed to visualize the vaccination program over time on our map.

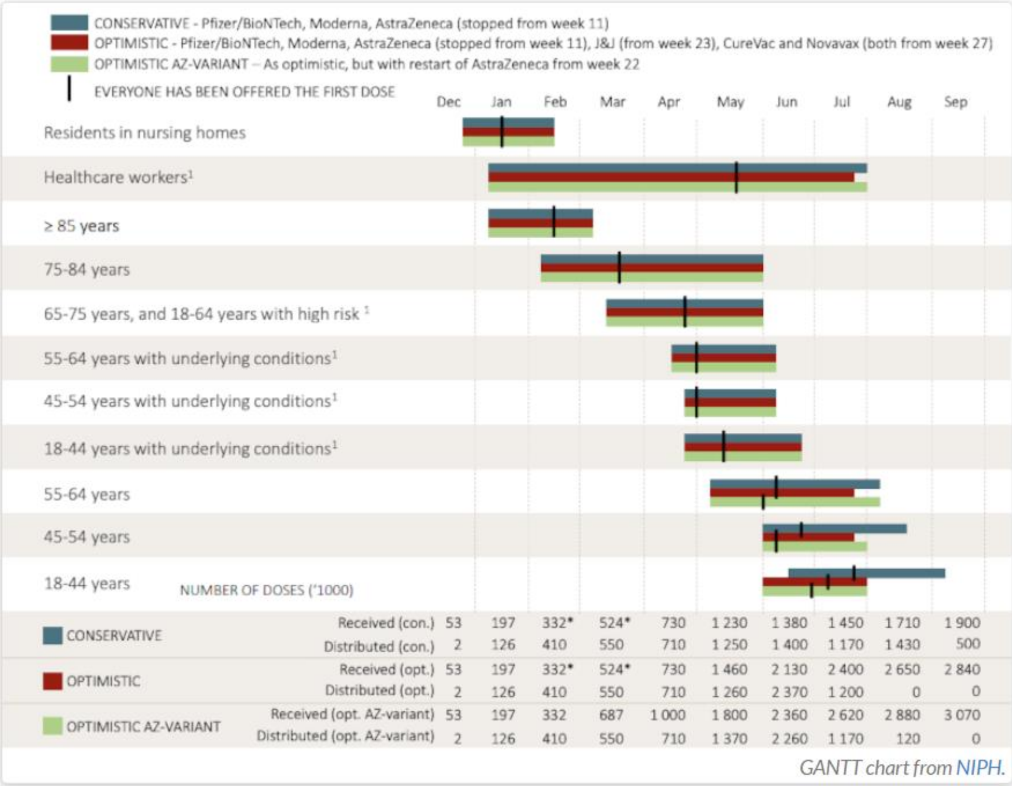


Figure 28: Conservative and optimistic.

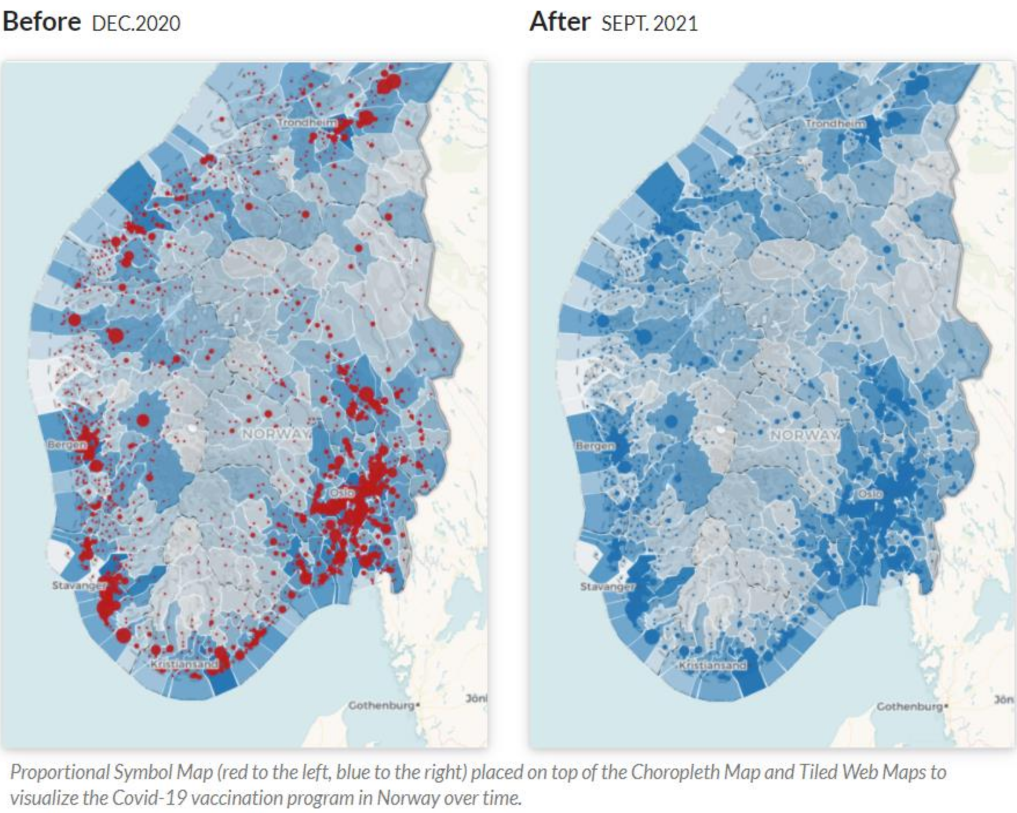


Figure 29: The map to visualize the Covid-19 vaccination program in Southern Norway over time.

Figure 29 shows the demand of the vaccine before the start of the Covid-19 vaccination program and after the completion of the program. The circles show the population both with the size represented by the diameter of the circles and the geographical position of the communities. Then, the colour indicates the progress of the program where a bright red colour means that the population is not vaccinated. The map to the left shows the total demand of vaccines in Norway, and the map to the right indicates the status after completion of the project, when all the red circles has turned blue. This is a Proportional Symbol Map visualization of the planned vaccination program in Norway.

Erik Bolstad [51] has done a great job to provide number of residents per zip code in Norway. The thesis used his dataset on the maps. In total 3 022 circles are placed on the map. It applies normalization [52] (min-max feature scaling) to calculate the circle size based on the number of residents per zip code. The red color of the circles indicates that the vaccine has not been delivered to the municipalities yet. The maps in Figures 30 and 31 below show the proportional symbol map in action on top of the choropleth and tiled web maps.

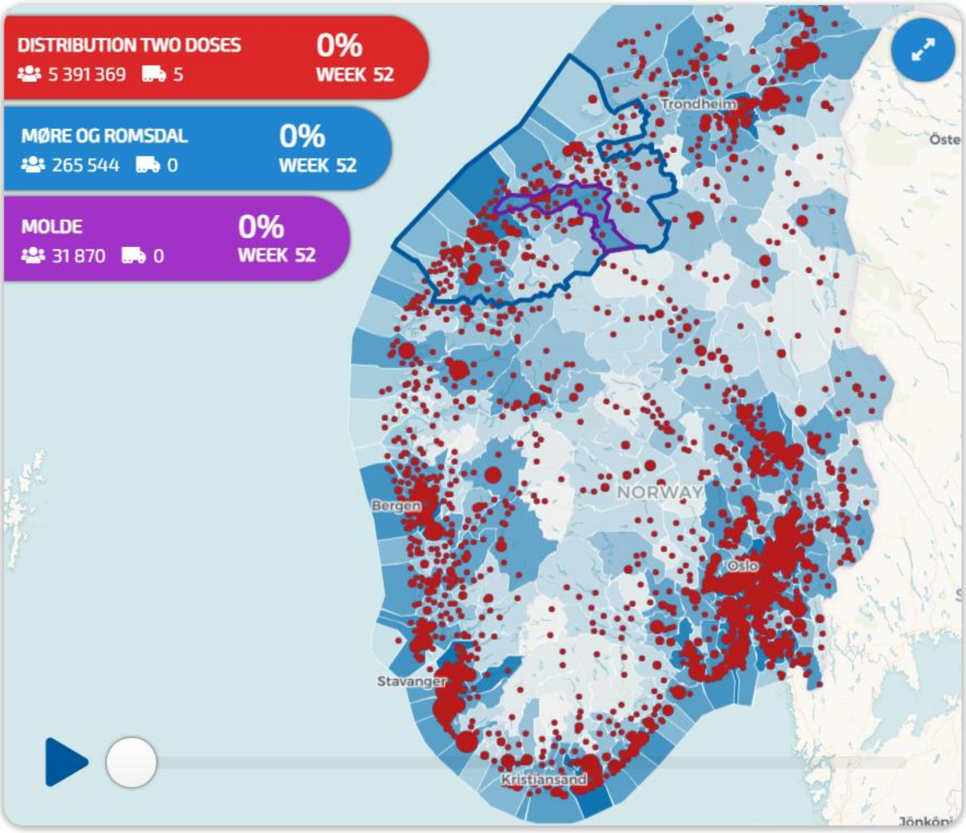


Figure 30: Demand of the vaccine before the vaccination program starts (December 2020).

Figure 30 shows the demand of the vaccine before the vaccination program starts. It shows a separate field in red for the total demand in Norway and includes a blue field for the demand in Møre og Romsdal county in addition to a third violet field showing the similar for Molde Municipality. There are separate columns to state the total population and the number of distributed vaccines for each administrative unit. The website is interactive, and in the map, it is possible to select each of the 356 municipalities in Norway to get the corresponding information.

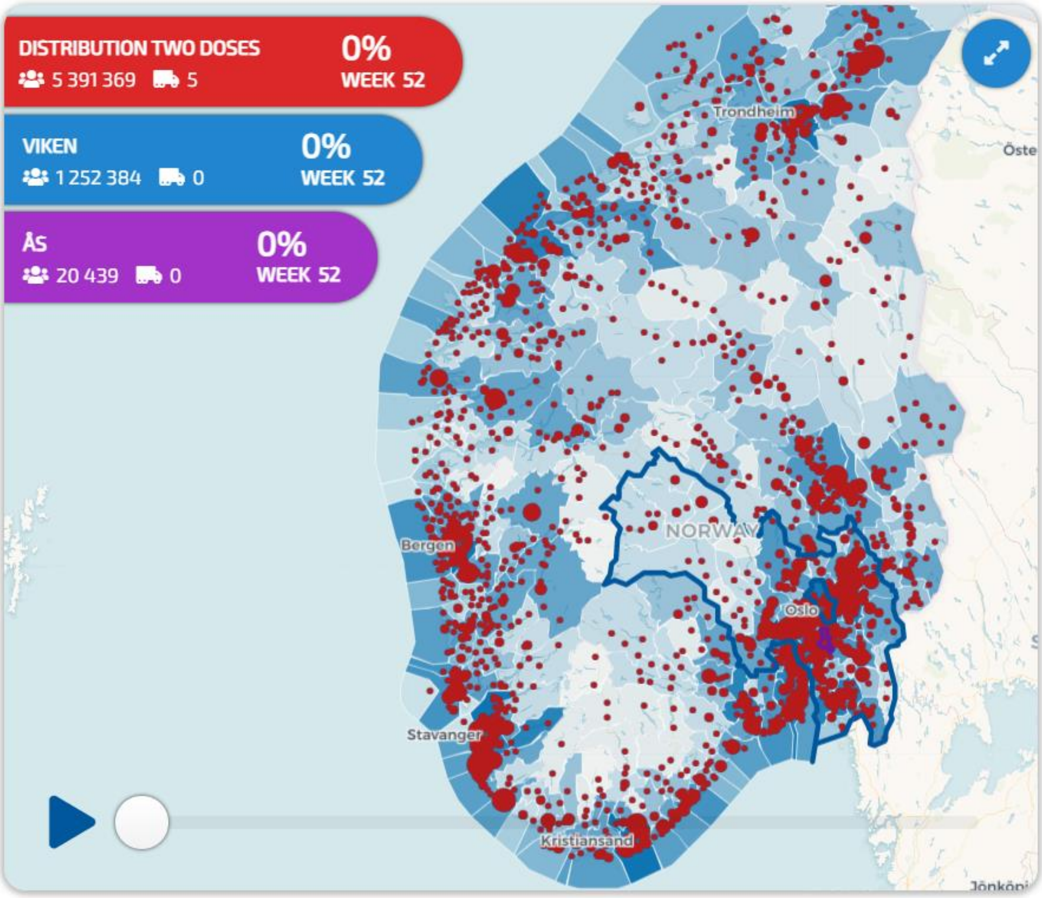


Figure 31: Demand of the vaccine before the vaccination program starts (December 2020).

Figure 31 shows the same information, but for the municipality Ås in the county Viken. It is easy to see by the density of the red circles that the demand in the eastern part of Viken county is much higher than in Møre or Romsdal even if Molde Municipality has a higher population than Ås.

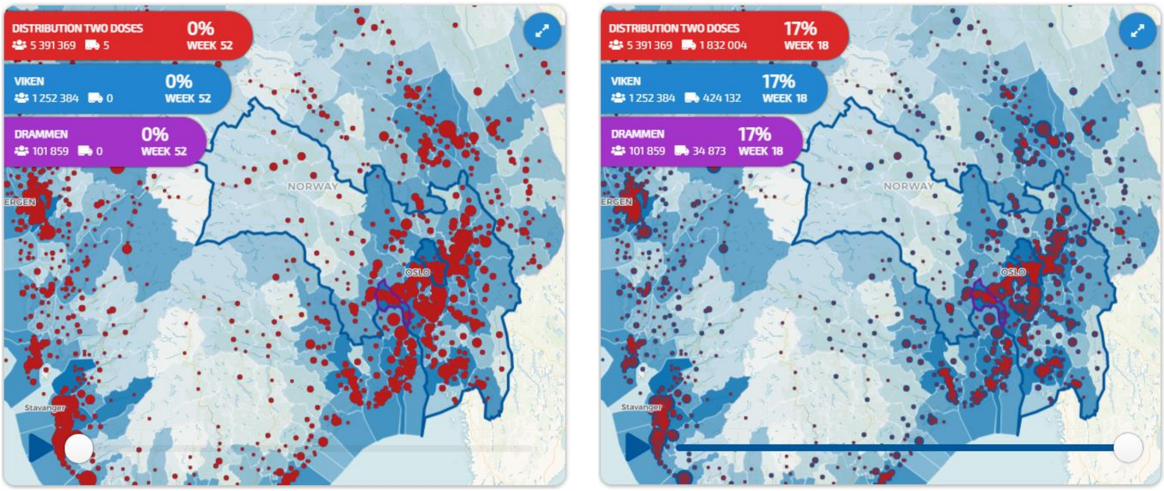
➢ The final step is using the map to see the expected and discover the unexpected.

For this point, it already has everything it needs to visualize the Norwegian vaccination program over time. As described in this thesis, it has selected the following components for the map visualization:

- Leaflet JavaScript map library [39].
- Web Map Tiles from Kartverket [43] and Carto [44].
- Choropleth map with border data from Geonorge [45], and population figures from SSB [46].
- Proportional symbol map with zip code data from Erik Bolstad [49] and vaccination figures from the Norwegian Institute of Public Health/SYSVAK [52].

5.2 Visualization over time

The animation starts at week 53 in 2020 and ends at week 18 in 2021. When it is running, it can clearly be seen that the distribution of vaccines will change over time. When more people are vaccinated, the brightness of the red color will faint and when the immunization plan is completed, the color of the circles will eventually turn blue.
However, due to the finalization of the paper, data collection was stopped at week 18, so the animations on the map will not show the completion of the immunization program.



Week 52 - 2020
First week of delivery of vaccine

Week 18 - 2021
Current status for delivery of vaccines

Figure 32: The change about the distribution of COVID-19 vaccines in Norway vaccination from week 52 to week 18.

According to Figure 32, it is easy to see that the bright red bubbles are gradually fading against a blue color according to the progress of the distribution of COVID-19 vaccines in Norway. The visualization clearly shows the status for all municipalities. However, comparing to the plan from the Norwegian Institute of Public Health [50] shown in Table 1, it is clear that the program is delayed as there are 280000 doses already behind the plan. There are some regional differences since some special infectious areas, like Oslo, have gotten a higher share of the vaccines than originally planned.

Table 1: The planned and actual vaccinations up to May 2021.

Numbers in thousands	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY** until week 18	
PLANNED	2	126	410	550	710	313	**2 111**
ACTUAL	2	104	346	486	711	182	**1 831**
DIFF	**0**	**-22**	**-64**	**-64**	**+1**	**-131**	**-280**

Figure 33 shows the distribution of COVID-19 vaccines in Oslo and six other municipalities close to the capital. These municipalities count for 22.5% of the total Norwegian population. By the week 18 Oslo has reached a level of 22% of the population fully vaccinated. This is the highest percentage distribution of vaccines among all municipalities in Norway.

In the interactive map, it is easy to select the surrounding municipalities and get the corresponding number of vaccines distributed at any point of time up to the last date for the data. The population number is in parentheses and the vaccination status by week 18 is stated explicitly.

1. Oslo (697 000): 22%
2. Bærum (128 000): 18%
3. Asker (95 000): 18%
4. Drammen (102 000): 19%
5. Lørenskog (43 000): 20%
6. Lillestrøm (87 000): 17%
7. Nordre Follo (60 000): 17%

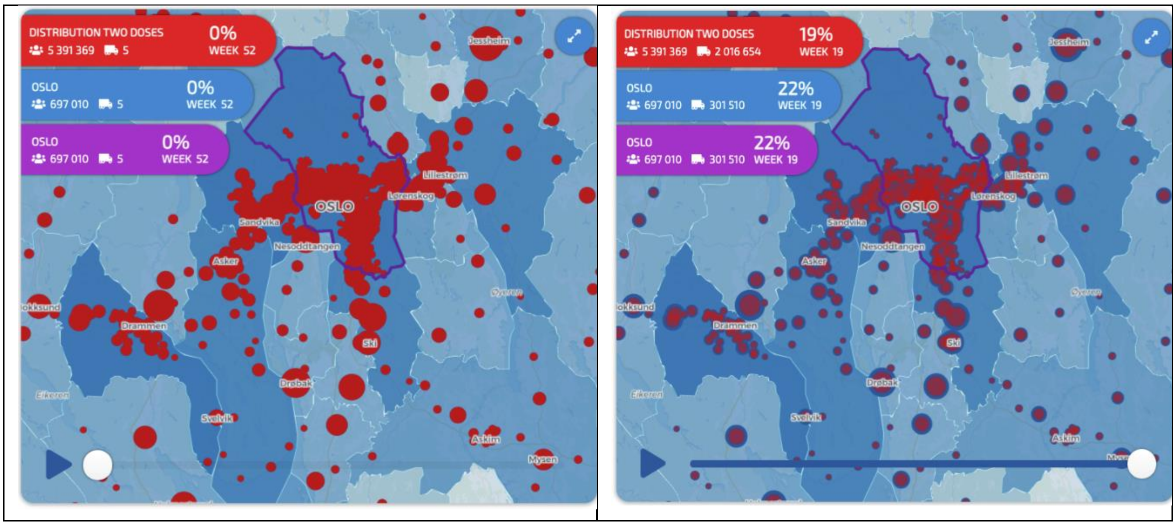


Figure 33: The distribution of COVID-19 vaccines in the Oslo area.

5.3 Visualization the distribution of vaccines as a dynamic tree

A dynamic legend named “Regions of Norway” is also included on the web site. It uses dynamic tree chart *[53]* to show the population distribution of Norway. When clicking on the different small dots, the tree will expand or shrink and display the required information as shown in Figure 34 and Figure 35. One can clearly understand the population distribution in each region representing the total demand for distribution of vaccines. Note that since each person needs two doses, the exact demand for doses should be twice the size of the population.

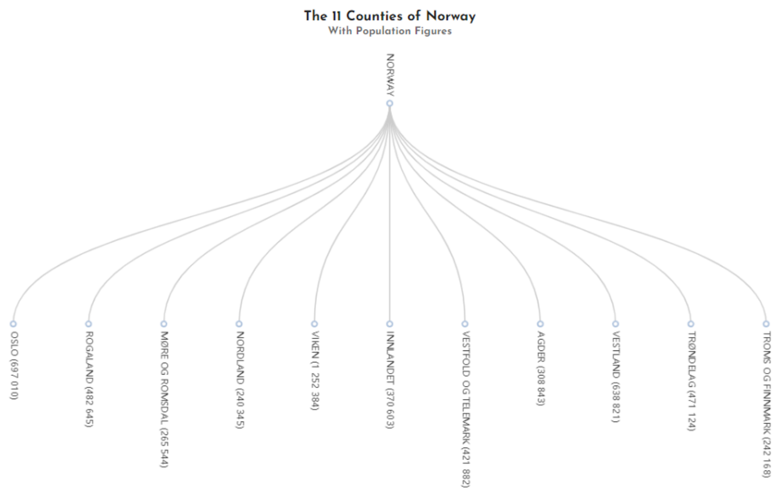


Figure 34: The 11 Counties of Norway with population figures.

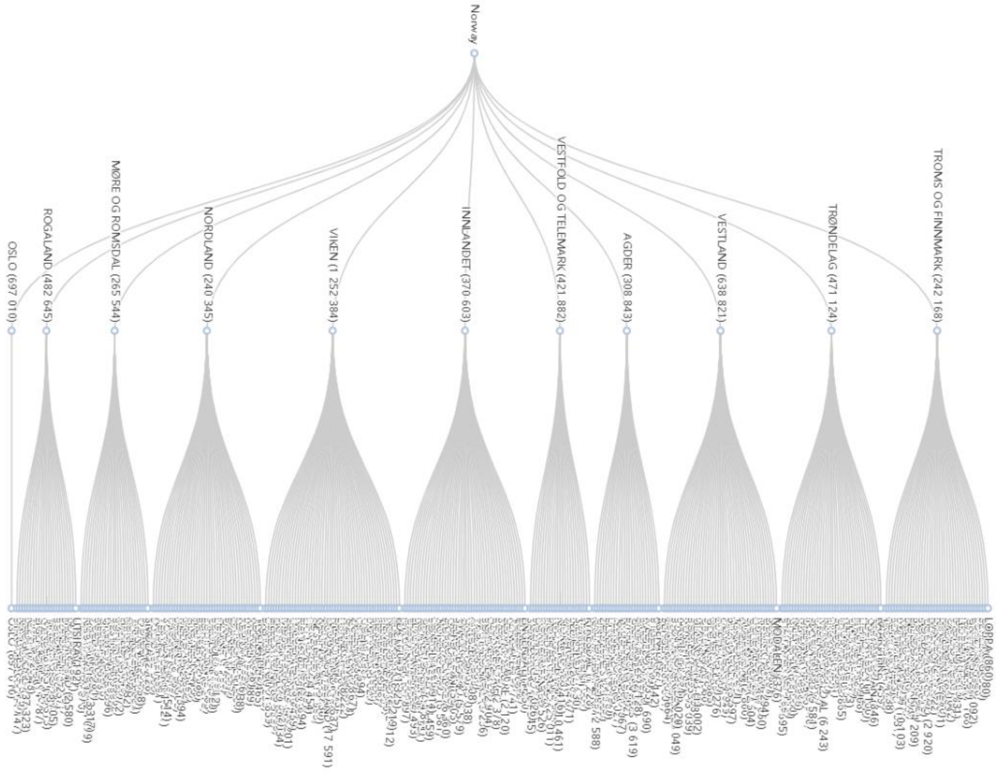


Figure 35: The 11 Counties and 356 Municipalities of Norway with population figures.

6.0 Conclusion

At the beginning of the thesis work, by collecting and consolidating a large amount of relevant data, comparing and analysing different types of visualization techniques, it was determined that Kartverket and Carto provided the most appropriate visualization techniques for showing the distribution of Covid-19 vaccines. And then, a website and a dynamic map were created to show how vaccine demand and distribution changed over time. Finally, the distribution process was studied through continuous improvement of dynamic maps and careful observation and analysis. After completing all the analysis and research, a final conclusion is that the vaccine distribution plan hardly can be completed on time according to the current distribution strategy. How to complete the vaccine distribution plan on time and achieve universal immunization across Norway will become a huge challenge for the distribution strategy.

The content of this thesis is mainly described as the design of a website for visualizing the distribution of COVID-19 vaccines in Norway. This website [54] can be further developed to show more relevant information about the problem. The next step could be to compare the actual vaccines distributed to the original plan directly on the visualization chart. Then, colours or any other visualization technique can be used to show which regions are ahead and which are behind the schedule. Another possible development could be to compare the vaccinations against the infection rate, to easily identify areas needing a higher share of the distributed vaccines.

A visualization such as described in this thesis can easily be transferred to other areas of the society to show valuable information in an easily understandable way.

7.0 References

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Appendix 1- Relevant data

Vaccine distribution in each county data

Source: https://www.fhi.no/en/id/infectious-diseases/coronavirus/daily-reports/daily-reports-COVID19/

County	Population	WEEK 53	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
Oslo	697,010	447	2,315	4,730	1,650	5,070	9,636
Rogaland	482,645	0	1,265	885	1,302	3,396	6,372
Møre og Romsdal	265,544	0	975	625	1,332	2,346	3,840
Nordland	240,345	0	1,030	775	1,566	2,538	4,464
Viken	1,252,384	948	3,740	3,365	4,344	10,620	19,476
Innlandet	370,603	645	1,530	1,820	2,226	3,918	8,394
Vestfold og Telemark	421,882	0	1,460	1,530	2,418	4,092	8,352
Agder	308,843	0	965	1,110	756	2,892	5,556
Vestland	638,821	0	2,150	1,950	1,500	6,570	9,246
Trøndelag	471,124	0	1,460	1,265	1,524	4,086	7,722
Troms og Finnmark	242,168	0	855	500	1,128	2,046	3,276

County	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK12
Oslo	9,310	6,198	13,934	7,368	17,060	18,176	12,252
Rogaland	5,430	4,938	9,210	7,228	8,328	4,794	7,206
Møre og Romsdal	4,422	3,510	5,390	5,790	6,054	3,510	4,680
Nordland	5,094	3,906	5,234	5,628	6,600	2,532	3,882
Viken	14,694	17,924	25,504	25,036	24,116	14,326	29,564
Innlandet	6,510	5,608	9,010	9,566	7,978	4,068	7,614
Vestfold og Telemark	7,764	6,850	9,816	8,708	7,388	4,572	7,974
Agder	3,822	4,750	6,824	5,266	6,150	3,396	4,554
Vestland	8,310	9,144	11,806	13,248	13,630	6,630	9,948
Trøndelag	7,728	5,844	10,004	11,474	10,010	4,680	9,360
Troms og Finnmark	3,810	3,096	4,382	5,282	6,226	2,004	4,128

County	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK12
Oslo	9,310	6,198	13,934	7,368	17,060	18,176	12,252
Rogaland	5,430	4,938	9,210	7,228	8,328	4,794	7,206
Møre og Romsdal	4,422	3,510	5,390	5,790	6,054	3,510	4,680
Nordland	5,094	3,906	5,234	5,628	6,600	2,532	3,882
Viken	14,694	17,924	25,504	25,036	24,116	14,326	29,564
Innlandet	6,510	5,608	9,010	9,566	7,978	4,068	7,614
Vestfold og Telemark	7,764	6,850	9,816	8,708	7,388	4,572	7,974
Agder	3,822	4,750	6,824	5,266	6,150	3,396	4,554
Vestland	8,310	9,144	11,806	13,248	13,630	6,630	9,948
Trøndelag	7,728	5,844	10,004	11,474	10,010	4,680	9,360
Troms og Finnmark	3,810	3,096	4,382	5,282	6,226	2,004	4,128

1. dose vaccination data

County	Population	WEEK 53	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
Oslo	697,010	439	2,717	4,392	4,421	2,964	7,751
Rogaland	482,645	0	1,416	1,670	1,887	2,251	5,352
Møre og Romsdal	265,544	0	1,144	1,167	1,627	1,168	3,046
Nordland	240,345	0	949	1,235	1,878	1,448	3,390
Viken	1,252,384	1,035	4,310	5,690	5,007	6,611	15,526
Innlandet	370,603	679	1,627	2,646	2,105	2,236	6,307
Vestfold og Telemark	421,882	1	1,744	2,344	2,827	2,505	6,549
Agder	308,843	0	1,150	1,671	1,204	1,778	4,392
Vestland	638,821	0	2,493	3,419	2,723	4,112	6,902
Trøndelag	471,124	0	1,693	2,365	2,237	2,356	6,205
Troms og Finnmark	242,168	0	995	1,132	1,495	1,100	2,688

County	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK12
Oslo	6,354	5,001	3,239	5,790	3,762	8,344	19,335
Rogaland	4,156	3,480	3,423	4,198	5,515	4,924	8,286
Møre og Romsdal	3,028	3,183	2,080	3,470	2,714	3,578	4,973
Nordland	3,594	2,848	2,527	2,561	3,005	2,447	4,680
Viken	11,465	14,782	9,902	16,755	13,968	12,723	26,336
Innlandet	4,971	4,083	3,864	4,224	4,125	4,028	8,013
Vestfold og Telemark	5,381	5,676	2,563	5,898	3,054	4,443	9,106
Agder	3,125	3,201	2,534	3,236	2,721	3,376	5,575
Vestland	6,903	6,884	4,483	6,537	6,136	6,525	10,205
Trøndelag	6,094	5,216	2,399	6,244	4,252	4,626	9,025
Troms og Finnmark	2,728	2,598	1,320	3,051	2,799	2,085	4,774

County	WEEK13	WEEK14	WEEK15	WEEK16	week17
Oslo	15,786	24,201	23,521	19,023	20,944
Rogaland	7,216	14,320	16,496	14,505	13531
Møre og Romsdal	4,311	7,315	8,431	7,095	6,665
Nordland	3,070	6,619	8,164	7,965	6,917
Viken	23,219	38,255	50,842	32,854	38,587
Innlandet	6,222	10,938	12,498	11,183	11,120
Vestfold og Telemark	7,023	12,218	14,408	12,006	12,326
Agder	4,421	8,848	11,679	8,535	9,258
Vestland	8,380	19,655	22,100	19,409	18,205
Trøndelag	4,748	13,895	15,560	13,870	12,311
Troms og Finnmark	3,418	7,890	8,347	7,263	6,700

2. dose vaccination data

County	Population	WEEK 53	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
Oslo	697,010	0	0	5	426	2,468	4346
Rogaland	482,645	0	0	0	0	1,285	1548
Møre og Romsdal	265,544	0	0	0	0	1,066	1129
Nordland	240,345	0	0	0	0	1,129	1091
Viken	1,252,384	0	0	0	869	3,666	5375
Innlandet	370,603	0	0	0	618	1,519	2465
Vestfold og Telemark	421,882	0	0	0	0	1,615	2117
Agder	308,843	0	0	0	0	1,055	1406
Vestland	638,821	0	0	0	0	2,198	3219
Trøndelag	471,124	0	0	0	0	1,450	2197
Troms og Finnmark	242,168	0	0	0	1	869	1105

County	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK12
Oslo	2,857	4,346	7,454	612	8,099	899	461
Rogaland	1,900	2,122	5,061	3,907	3,142	295	390
Møre og Romsdal	1,633	1,077	2,690	2,915	2,417	236	164
Nordland	1,643	1,423	3,278	3,345	2,472	171	131
Viken	4,936	6,464	13,947	8,247	11,921	1,159	1,785
Innlandet	2,032	2,068	5,898	4,780	2,765	288	951
Vestfold og Telemark	2,738	2,308	6,070	5,171	3,349	278	1,288
Agder	1,110	1,764	3,417	2,879	2,061	246	156
Vestland	2,613	3,895	6,488	6,516	4,847	524	1,428
Trøndelag	2,201	2,268	5,817	6,075	3,457	349	1,288
Troms og Finnmark	1,411	1,032	2,519	2,556	1,995	207	111

County	WEEK13	WEEK14	WEEK15	WEEK16	WEEK17
Oslo	1,422	529	686	1,958	10,504
Rogaland	990	763	187	626	4,545
Møre og Romsdal	346	191	123	141	3,168
Nordland	609	540	62	167	2,493
Viken	4,160	6,908	1,455	1,493	13,451
Innlandet	815	234	222	244	3,968
Vestfold og Telemark	593	268	196	1,623	4,470
Agder	527	145	91	172	3,248
Vestland	2,054	665	502	316	6,676
Trøndelag	1,208	417	438	401	4,833
Troms og Finnmark	488	456	183	219	1,863

Total distribution in Norway data

County	Vaccine distribution
Oslo	265614
Rogaland	143646
Møre og Romsdal	88752
Nordland	86029
Viken	423459
Innlandet	136057
Vestfold og Telemark	144976
Agder	98787
Vestland	205648
Trøndelag	157177
Troms og Finnmark	80365

Total number of vaccination data

Week	Number of vaccination in counties
53	2040
1	17745
2	21906
3	19746
4	47574
5	86334
6	76894
7	71768
8	111114
9	104594
10	113540
11	68688
12	101162
13	98098
14	151148
15	198830
16	140946
17	220218
18	181516

Appendix 2- html code for website in Visual Studio

The frontpage.

```html
<!DOCTYPE html>
<html lang="en">
<head>
<!-- Browser title -->
<title>Manru - Thesis</title>
<!-- Character encoding -->
<meta charset="utf-8">
<!-- Description -->
<meta name="description" content="Code to Learn. Learn to Code.">
<!-- Layout control on mobile browsers -->
<meta name="viewport" content="width=device-width, initial-scale=1.0, viewport-fit=cover">
<!-- Web manifest -->
<link rel="manifest" href="favicons/site.webmanifest">
<!-- Use Microsoft Edge - not Explorer-->
<meta http-equiv="X-UA-Compatible" content="IE=Edge">
<!-- Apple Safari Web App. Fullscreen when adding to home screen -->
<meta name="apple-mobile-web-app-capable" content="yes">
<!-- Window icon file -->
<link rel="shortcut icon" href="favicons/favicon.ico">
<!-- CSS libraries -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.css"> <!-- Fomantic UI Library (mobile first) -->
<link rel="stylesheet" href="//fonts.googleapis.com/css?family=Merienda+One"> <!-- Selected Google Fonts -->
<link rel="stylesheet" href="styles.css"> <!-- Custom styles -->
</head>
<body>
<!-- Main container -->
<div class="ui pusher">
<!-- Cover image from Unsplash -->
```

```
<div class="ui fluid container" style="height:500px;
background-size: cover;
background-repeat: no-repeat;
background-position: center center;
background-image: url(https://akamai.vgc.no/v2/images/5c22f03b-8dda-4fc9-ba90-
7ebab0fb6092?fit=crop&h=800&w=1200&s=bd7a24cf5f481fccc9df4a7ac7bbef7a8ac9c808);">
</div>
<!-- Photo Attribution -->
<div style="float:right;padding-right:5px">
<span class="ui gray small text">
COVID-19 Vaccine. Photo: VG
</span>
</div>
<!-- Centered text column -->
<div class="ui text container">
<br>
<div class="ui big basic fitted segment">
<h1 class="ui center aligned header google-font">
Visualization of the Distribution of COVID-19 Vaccines in Norway
<div class="sub header">
Molde University College, 2021
</div>
</h1>
<!-- Sub Header -->
<h3 class="ui center aligned header google-font">
<address class="name">
<a rel="author" itemprop="url name" href="about.html">
<img class="ui avatar image" src="images/ru.jpg">
<span class="firstname">Manru</span>
<span class="lastname">Xue</span>
</a>
<div class="sub header">
Master Student in Logistics
</div>
```

</h3>

<!-- Header: What happened -->

<h2 class="ui header">

Background

</h2>

<p>

With the rapid spread and expansion of the COVID-19 pandemic, the entire world has entered a state of extreme tension. In order to effectively control the epidemic, the World Health Organization (WHO) and its member states have stepped up the research and development of a variety of vaccines, and they have started to distribute them. This is great news for the people of the world. However, although the vaccine has been successfully developed, there are many constraints and challenges when distributing it to the population. It has very high requirements for temperature and environment and requires that the vaccinations must be completed within the validity period of the vaccine doses. So how to complete the vaccination task quickly and safely is another severe challenge we face. But now science and technology develop rapidly, big data, artificial intelligence, and other technologies, for the epidemic prevention and control has brought unprecedented guidance. Among them, the technology of data visualization plays a very important role, through the acquisition, screening, processing, and analysis of data. Visualizing data in a graphical way, through the integration of multi-dimensional information, and visual display of the dynamic change process of the epidemic, can help people understand the overall situation, improve public awareness of the epidemic and enhance awareness for personal protection. It can not only make people more efficient, and intuitive, but also give comprehensive access to information, but also help predicting the direction the direction of events, to achieve in-depth and shallow reporting effect to provide support for the epidemic prevention and control work. This thesis is using data visualization for showing the distribution procedure of the Covid-19 vaccine in Norway, and the visualization could be a tool for identifying problems and bottlenecks in the supply chain.

</p>

<p>

Keywords:

Covid19, data visualization, vaccine, distribution.

</p>

<p>

Thesis:

<a href="PDF/Thesis.pdf" target="_blank">

Click to download the PDF-version

```
</a>
(opens a new window)
</p>
</div>
<br>
<br>
</div>
</div>
<!-- JavaScript libraries -->
<script src="//cdn.jsdelivr.net/npm/jquery@3.5.1/dist/jquery.min.js"></script> <!-- jQuery Library -->
<script src="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.js"></script> <!-- Fomantic UI Library -->
<!-- Inline JavaScript -->
<script>
// jQuery is ready
$(function(){
// Load Table of Contents (do not cache)
$.get({url: "toc.html", cache: false}).then(function(data){
$("body").prepend(data);
});
});
</script>
</body>
</html>
```

The vaccination weekly reports.

```
<!DOCTYPE html>
<html lang="en">
<head>


<!-- Browser title -->
<title>Vaccination Weekly</title>


<!-- Character encoding -->
```

```html
<meta charset="utf-8">

<!-- Description -->
<meta name="description" content="Capital Cities">

<!-- Layout control on mobile browsers -->
<meta name="viewport" content="width=device-width, initial-scale=1.0, viewport-fit=cover">

<!-- Web manifest -->
<link rel="manifest" href="favicons/site.webmanifest">

<!-- Use Microsoft Edge - not Explorer-->
<meta http-equiv="X-UA-Compatible" content="IE=Edge">

<!-- Apple Safari Web App. Fullscreen when adding to home screen -->
<meta name="apple-mobile-web-app-capable" content="yes">

<!-- Window icon file -->
<link rel="shortcut icon" href="favicons/favicon.ico">

<!-- CSS libraries -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.css"> <!-- Fomantic UI Library (mobile first) -->
<link rel="stylesheet" href="//fonts.googleapis.com/css?family=Josefin+Sans:700"> <!-- Selected Google Fonts -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/leaflet@1.6.0/dist/leaflet.css"> <!-- Leaflet Map Library -->
<link rel="stylesheet" href='//cdn.jsdelivr.net/npm/leaflet-fullscreen@1.0.2/dist/leaflet.fullscreen.css'> <!-- Leaflet Fullscreen Plugin -->
<link rel="stylesheet" href="styles.css"> <!-- Custom styles -->

</head>

<body>

<!-- Main container -->
```

```
<div class="ui pusher" style="padding-bottom: 250px;">

<!-- Cover image from Unsplash -->
<div class="ui fluid container" style="height:500px;
background-size: cover;
background-repeat: no-repeat;
background-position: center center;
background-image: url(https://images.unsplash.com/photo-1584515979956-
d9f6e5d09982?ixid=MnwxMjA3fDB8MHxwaG90by1wYWdlfHx8fGVufDB8fHx8&ixlib=rb-
1.2.1&auto=format&fit=crop&w=925&q=80);">
</div>

<!-- Photo Attribution -->
<div style="float:right;padding-right:5px">
<span class="ui gray small text">
Photo: National Cancer Institute on Unsplash
</span>
</div>

<!-- Centered text column -->
<div class="ui text container">

<br>

<!-- Pie Chart -->
<div class="ui big basic fitted segment">

<!-- Title -->
<h1 class="ui header">
Distribution Weekly
</h1>

<!-- Description-->
<p>
```

```
Total weekly distribution from week 53 2020 to week 18 2021
</p>

<!--Chart -->
<div id="pie-chart" style="width:100%;min-height:450px"></div>

</div>

<br>
<br>

<!-- Bar Chart -->
<div class="ui big basic fitted segment">

<!-- Description-->
<p>
Total weekly distribution from week 53 2020 to week 18 2021
</p>

<!--Chart -->
<div id="bar-chart" style="width:100%;min-height:450px"></div>

</div>

<br>
<br>

<!-- Line Chart -->
<div class="ui big basic fitted segment">

<!-- Description-->
<p>
Total weekly distribution from week 53 2020 to week 18 2021
</p>
```

```
<!--Chart -->
<div id="line-chart" style="width:100%;min-height:400px"></div>

</div>

<br>
<br>
</div>
</div>

<!-- JavaScript libraries -->
<script src="//cdn.jsdelivr.net/npm/jquery@3.5.1/dist/jquery.min.js"></script> <!-- jQuery Library -->
<script src="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.js"></script> <!-- Fomantic UI Library
-->
<script src="//www.gstatic.com/charts/loader.js"></script> <!-- Google Charts Library -->
<script src="//cdn.jsdelivr.net/npm/echarts@4.6.0/dist/echarts.min.js"></script> <!-- echarts -->
<script src="//cdn.jsdelivr.net/npm/leaflet@1.6.0/dist/leaflet.js"></script> <!-- Leaflet Map Library -->
<script src='//cdn.jsdelivr.net/npm/leaflet-fullscreen@1.0.2/dist/Leaflet.fullscreen.min.js'></script> <!-- Leaflet
Fullscreen Plugin -->
<script src="//cdn.jsdelivr.net/npm/numeral@2.0.6/numeral.min.js"></script> <!-- Utility -->
<script src="//cdn.jsdelivr.net/npm/moment@2.27.0/moment.min.js"></script> <!-- Utility -->

<!-- Inline JavaScript -->
<script>

// jQuery is ready
$(function(){

// Load Table of Contents (do not cache)
$.get({url: "toc.html", cache: false}).then(function(data){
$("body").prepend(data);
});
```

```
// Set locale for numerial.js
numeral.register('locale', 'no', { delimiters: { thousands: ' ', decimal: ',' } });
numeral.locale('no');

// Set locale for moment
moment.locale('nb');
});

// Load Google Charts
google.charts.load('current', { language: 'en' });

// Google Charts is ready
google.charts.setOnLoadCallback(function(){
pieChart.getData();
barChart.getData();
lineChart.getData();
});

// Resize charts if window resize
$(window).resize(function(){
pieChart.chart.resize();
barChart.chart.resize();
lineChart.chart.resize();
});

// Chart
var pieChart = {

// Data from Google Sheet
table: null,

// EChart dom id
chart: echarts.init(document.getElementById('pie-chart'), 'light'), // see theme builder:
https://echarts.apache.org/en/download-theme.html
```

```
// ECharts options
options: {
baseOption: {
dataset: {
source: null, // assign google sheet data here. See the init function below
},
tooltip: {
//trigger: 'item',
formatter: ' {c} ({d}%)'
},
legend: {
bottom: 10,
left: 'center',
},
series: [
// Serie 1
{

type: 'pie',
radius: '65%',
center: ['50%', '50%'],
selectedMode: 'single',
},
]
}
},

// Get data from google sheet
getData: function(){
var query = new google.visualization.Query("https://docs.google.com/spreadsheets/d/1BhvdIU-TPEV9-TJERAKzCRaTY8-gVbDqZHFLvYOxrRo/gviz/tq?gid=1875299369&headers=1");
query.setQuery("select *");
query.send( (data) => {
```

```
if (data.isError() === false) {
$('#loader').removeClass("active");
this.table = data.getDataTable();
this.showData();
}
});
},

// Show data
showData: function(){

// Init the echarts dataset source array (array of array)
var source = [];

// Push header array into source array
source.push(['Product', 'Percentage'])

// Loop through data and create each row
for (var i = 0; i < this.table.getNumberOfRows(); i++) {
// Push row array into source array
source.push([this.table.getFormattedValue(i, 0), this.table.getValue(i, 2)]);
}

// Assign source to chart options datasource
this.options.baseOption.dataset.source = source;

// Hide chart loader icon
this.chart.hideLoading();

// Set options and show chart
this.chart.setOption( this.options );

},
}
```

```
// Chart
var barChart = {

// Data from Google Sheet
table: null,

// chart id
chart: echarts.init(document.getElementById('bar-chart'), 'light'), // see theme builder:
https://echarts.apache.org/en/download-theme.html

// Set chart options
options: {
baseOption: {
tooltip: {
trigger: 'axis',
axisPointer: {
type: 'shadow'
}
},
legend: {
data: ['Vaccination']
},
grid: {
left: '10px',
right: '15%',
top:'50px',
bottom: '3%',
containLabel: true
},
xAxis:
[
{
type: 'value',
```

```
}

boundaryGap: [0, 0.01],
name: '(number)',
},
],
yAxis: {
inverse: true,
type: 'category',
data:null,
name: '(week)',
},
series: [
{
type: 'bar',
name: 'Infection',
data: null, // Get data from Google Sheet. See init function below
color: '#74DF00',
},
]
}
},

// Get data from google sheet
getData: function(){
var query = new google.visualization.Query("https://docs.google.com/spreadsheets/d/1BhvdIU-TPEV9-TJERAKzCRaTY8-gVbDqZHFLvYOxrRo/gviz/tq?gid=1875299369&headers=1");
query.setQuery("select *");
query.send( (data) => {
if (data.isError() === false) {
$('#loader').removeClass("active");
this.table = data.getDataTable();
this.showData();
}
});
},
```

```
// Show data
showData: function(){

// Init axis data (category labels)
var axis = [];

// Init data
var data = []; //Vaccination



// Loop through rows
for(var i = 0; i < this.table.getNumberOfRows(); i++){
axis.push( this.table.getValue(i,0) ); // Week
data.push( this.table.getValue(i,2) ); // Vaccination

}

// Assign data
this.options.baseOption.yAxis.data = axis; // Week
this.options.baseOption.series[0].data = data; // Vaccination

// Hide chart loader icon
this.chart.hideLoading();

// Set options and show chart
this.chart.setOption(this.options);

},

}

// Line Chart
var lineChart = {
```

```
},

// Data from Google Sheet
table: null,

// EChart dom id
chart: echarts.init(document.getElementById('line-chart'), 'light'), // see theme builder:
https://echarts.apache.org/en/download-theme.html

// ECharts options
options: {
baseOption:{
legend: {
show: true,
},

grid:{
left: '75px', // make space for the y-axis labels
right: '20px', // make space for the x-axis name
},
xAxis: {
show: true,
type: 'category',
//data: ['06:00','09:00','12:00','15:00','18:00','21:00','24:00','03:00','06:00'],
axisLine: {
show: true,
},
axisTick: {
show: false,
},
splitLine: {
show: false,
},
},
yAxis: {
```

```
show: true,
type: 'value',
name: 'per-time',
axisLine: {
show: true,
},
axisTick: {
show: true,
},
splitLine: {
show: false,
},
axisLabel: {
show: true,
formatter: function(value){
return value ;
}
},
},
tooltip: {
show: true,
},
series: [
{
type: 'line',
name: '2021 | Weekly | Per-Time |',
//data: [-2.8, 4.1, 8.2, 8.9, 7.2, 3.5, -1.3, -3.2, -2.6],
color: 'blue',
symbolSize: 15,
lineStyle: {
color: 'grey',
type: 'dotted',
},
label: {
```

```
show: true,
position: 'top',
color: 'black',
padding: 5,
formatter: function(obj){
return obj.data ;
},
},
},
],
}
},

// Get data from google sheet
getData: function(){
var query = new google.visualization.Query("https://docs.google.com/spreadsheets/d/1BhvdIU-TPEV9-TJERAKzCRaTY8-gVbDqZHFLvYOxrRo/gviz/tq?gid=1875299369&headers=1");
query.setQuery("select *");
query.send( (data) => {
if (data.isError() === false) {
$('#loader').removeClass("active");
this.table = data.getDataTable();
this.showData();
}
});
},

// Show data
showData: function(){

// Init xAxis data (category labels)
var xAxis = [];

// Init data
```

```
var data = []; // Temperatures

// Loop through rows
for(var i = 0; i < this.table.getNumberOfRows(); i++){
xAxis.push( this.table.getValue(i,0) ); // Time
data.push( this.table.getValue(i,2) ); // Temperatures
}

// Assign data
this.options.baseOption.xAxis.data = xAxis; // xAxis
this.options.baseOption.series[0].data = data; // Temperatures

// Hide chart loader icon
this.chart.hideLoading();

// Set options and show chart
this.chart.setOption(this.options);
},
}

</script>

</body>
</html>
```

The vaccination calendar for Møre og Romsdal.

```
<!DOCTYPE html>
<html lang="en">
<head>
<!-- Browser title -->
<title>Vaccination Weekly</title>
<!-- Character encoding -->
<meta charset="utf-8">
```

```
<!-- Description -->
<meta name="description" content="Capital Cities">
<!-- Layout control on mobile browsers -->
<meta name="viewport" content="width=device-width, initial-scale=1.0, viewport-fit=cover">
<!-- Web manifest -->
<link rel="manifest" href="favicons/site.webmanifest">
<!-- Use Microsoft Edge - not Explorer-->
<meta http-equiv="X-UA-Compatible" content="IE=Edge">
<!-- Apple Safari Web App. Fullscreen when adding to home screen -->
<meta name="apple-mobile-web-app-capable" content="yes">
<!-- Window icon file -->
<link rel="shortcut icon" href="favicons/favicon.ico">
<!-- CSS libraries -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.css"> <!-- Fomantic UI Library (mobile first) -->
<link rel="stylesheet" href="//fonts.googleapis.com/css?family=Josefin+Sans:700"> <!-- Selected Google Fonts -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/leaflet@1.6.0/dist/leaflet.css"> <!-- Leaflet Map Library -->
<link rel="stylesheet" href='//cdn.jsdelivr.net/npm/leaflet-fullscreen@1.0.2/dist/leaflet.fullscreen.css'> <!-- Leaflet Fullscreen Plugin -->
<link rel="stylesheet" href="styles.css"> <!-- Custom styles -->
</head>
<body>
<!-- Main container -->
<div class="ui pusher" style="padding-bottom: 250px;">
<!-- Cover image from Unsplash -->
<div class="ui fluid container" style="height:500px;
background-size: cover;
background-repeat: no-repeat;
background-position: center center;
background-image: url(https://images.unsplash.com/photo-1584515979956-d9f6e5d09982?ixid=MnwxMjA3fDB8MHxwaG90by1wYWdlfHx8fGVufDB8fHx8&ixlib=rb-1.2.1&auto=format&fit=crop&w=925&q=80);">
</div>
```

```
<!-- Photo Attribution -->
<div style="float:right;padding-right:5px">
<span class="ui gray small text">
Photo: National Cancer Institute on Unsplash
</span>
</div>
<!-- Centered text column -->
<div class="ui text container">
<br>
<!-- Title -->
<h1 class="ui header">
Calendar Chart
</h1>
<!-- Description-->
<p>
Weekly distribution of vaccine doses to Møre og Romsdal displayed in a calendar chart.
</p>
<!--Chart -->
<div id="main" style="width:100%;min-height:1550px"></div>
</div>|
<br>
<br>
</div>
<!-- JavaScript libraries -->
<script src="//cdn.jsdelivr.net/npm/jquery@3.5.1/dist/jquery.min.js"></script> <!-- jQuery Library -->
<script src="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.6/dist/semantic.min.js"></script> <!-- Fomantic UI Library -->
<script src="//www.gstatic.com/charts/loader.js"></script> <!-- Google Charts Library -->
<script src="//cdn.jsdelivr.net/npm/echarts@4.6.0/dist/echarts.min.js"></script> <!-- echarts -->
<script src="//cdn.jsdelivr.net/npm/leaflet@1.6.0/dist/leaflet.js"></script> <!-- Leaflet Map Library -->
<script src='//cdn.jsdelivr.net/npm/leaflet-fullscreen@1.0.2/dist/Leaflet.fullscreen.min.js'></script>
<!-- Leaflet Fullscreen Plugin -->
<script src="//cdn.jsdelivr.net/npm/numeral@2.0.6/numeral.min.js"></script> <!-- Utility -->
<script src="//cdn.jsdelivr.net/npm/moment@2.27.0/moment.min.js"></script> <!-- Utility -->
```

```
<!-- Inline JavaScript -->
<script>
// jQuery is ready
$(function(){
// Load Table of Contents (do not cache)
$.get({url: "toc.html", cache: false}).then(function(data){
$("body").prepend(data);
});
});
function getCalendarData() {
var data = [];
// Week 53-2020
data.push([ '2020-12-28', 0 ]);
data.push([ '2020-12-29', 0 ]);
data.push([ '2020-12-30', 0 ]);
data.push([ '2020-12-31', 0 ]);
data.push([ '2021-01-01', 0 ]);
data.push([ '2021-01-02', 0 ]);
data.push([ '2021-01-03', 0 ]);
// Week 1-2021
data.push([ '2021-01-04', 975 ]);
data.push([ '2021-01-05', 975 ]);
data.push([ '2021-01-06', 975 ]);
data.push([ '2021-01-07', 975 ]);
data.push([ '2021-01-08', 975 ]);
data.push([ '2021-01-09', 975 ]);
data.push([ '2021-01-10', 975 ]);
// Week 2-2021
data.push([ '2021-01-11', 625 ]);
data.push([ '2021-01-12', 625 ]);
data.push([ '2021-01-13', 625 ]);
data.push([ '2021-01-14', 625 ]);
data.push([ '2021-01-15', 625 ]);
data.push([ '2021-01-16', 625 ]);
```

```
data.push([ '2021-01-17', 625 ]);
// Week 3-2021
data.push([ '2021-01-18', 1332 ]);
data.push([ '2021-01-19', 1332 ]);
data.push([ '2021-01-20', 1332 ]);
data.push([ '2021-01-21', 1332 ]);
data.push([ '2021-01-22', 1332 ]);
data.push([ '2021-01-23', 1332 ]);
data.push([ '2021-01-24', 1332 ]);
// Week 4-2021
data.push([ '2021-01-25', 2346 ]);
data.push([ '2021-01-26', 2346 ]);
data.push([ '2021-01-27', 2346 ]);
data.push([ '2021-01-28', 2346 ]);
data.push([ '2021-01-29', 2346 ]);
data.push([ '2021-01-30', 2346 ]);
data.push([ '2021-01-31', 2346 ]);
// Week 5-2021
data.push([ '2021-02-01', 3840 ]);
data.push([ '2021-02-02', 3840 ]);
data.push([ '2021-02-03', 3840 ]);
data.push([ '2021-02-04', 3840 ]);
data.push([ '2021-02-05', 3840 ]);
data.push([ '2021-02-06', 3840 ]);
data.push([ '2021-02-07', 3840 ]);
// Week 6-2021
data.push([ '2021-02-08', 4422 ]);
data.push([ '2021-02-09', 4422 ]);
data.push([ '2021-02-10', 4422 ]);
data.push([ '2021-02-11', 4422 ]);
data.push([ '2021-02-12', 4422 ]);
data.push([ '2021-02-13', 4422 ]);
data.push([ '2021-02-14', 4422 ]);
```

```
// Week 7-2021
data.push([ '2021-02-15', 3510 ]);
data.push([ '2021-02-16', 3510 ]);
data.push([ '2021-02-17', 3510 ]);
data.push([ '2021-02-18', 3510 ]);
data.push([ '2021-02-19', 3510 ]);
data.push([ '2021-02-20', 3510 ]);
data.push([ '2021-02-21', 3510 ]);
// Week 8-2021
data.push([ '2021-02-22', 5390 ]);
data.push([ '2021-02-23', 5390 ]);
data.push([ '2021-02-24', 5390 ]);
data.push([ '2021-02-25', 5390 ]);
data.push([ '2021-02-26', 5390 ]);
data.push([ '2021-02-27', 5390 ]);
data.push([ '2021-02-28', 5390 ]);
// Week 9-2021
data.push([ '2021-03-01', 5790 ]);
data.push([ '2021-03-02', 5790 ]);
data.push([ '2021-03-03', 5790 ]);
data.push([ '2021-03-04', 5790 ]);
data.push([ '2021-03-05', 5790 ]);
data.push([ '2021-03-06', 5790 ]);
data.push([ '2021-03-07', 5790 ]);
// Week 10-2021
data.push([ '2021-03-08', 6054 ]);
data.push([ '2021-03-09', 6054 ]);
data.push([ '2021-03-10', 6054 ]);
data.push([ '2021-03-11', 6054 ]);
data.push([ '2021-03-12', 6054 ]);
data.push([ '2021-03-13', 6054 ]);
data.push([ '2021-03-14', 6054 ]);
// Week 11-2021
data.push([ '2021-03-15', 3510 ]);
```

```
data.push([ '2021-03-16', 3510 ]);
data.push([ '2021-03-17', 3510 ]);
data.push([ '2021-03-18', 3510 ]);
data.push([ '2021-03-19', 3510 ]);
data.push([ '2021-03-20', 3510 ]);
data.push([ '2021-03-21', 3510 ]);
// Week 12-2021
data.push([ '2021-03-22', 4680 ]);
data.push([ '2021-03-23', 4680 ]);
data.push([ '2021-03-24', 4680 ]);
data.push([ '2021-03-25', 4680 ]);
data.push([ '2021-03-26', 4680 ]);
data.push([ '2021-03-27', 4680 ]);
data.push([ '2021-03-28', 4680 ]);
// Week 13-2021
data.push([ '2021-03-29', 4158 ]);
data.push([ '2021-03-30', 4158 ]);
data.push([ '2021-03-31', 4158 ]);
data.push([ '2021-04-01', 4158 ]);
data.push([ '2021-04-02', 4158 ]);
data.push([ '2021-04-03', 4158 ]);
data.push([ '2021-04-04', 4158 ]);
// Week 14-2021
data.push([ '2021-04-05', 7020 ]);
data.push([ '2021-04-06', 7020 ]);
data.push([ '2021-04-07', 7020 ]);
data.push([ '2021-04-08', 7020 ]);
data.push([ '2021-04-09', 7020 ]);
data.push([ '2021-04-10', 7020 ]);
data.push([ '2021-04-11', 7020 ]);
// Week 15-2021
data.push([ '2021-04-12', 8190 ]);
data.push([ '2021-04-13', 8190 ]);
data.push([ '2021-04-14', 8190 ]);
```

```
data.push([ '2021-04-15', 8190 ]);
data.push([ '2021-04-16', 8190 ]);
data.push([ '2021-04-17', 8190 ]);
data.push([ '2021-04-18', 8190 ]);
// Week 16-2021
data.push([ '2021-04-19', 7020 ]);
data.push([ '2021-04-20', 7020 ]);
data.push([ '2021-04-21', 7020 ]);
data.push([ '2021-04-22', 7020 ]);
data.push([ '2021-04-23', 7020 ]);
data.push([ '2021-04-24', 7020 ]);
data.push([ '2021-04-25', 7020 ]);
// Week 17-2021
data.push([ '2021-04-26', 10530 ]);
data.push([ '2021-04-27', 10530 ]);
data.push([ '2021-04-28', 10530 ]);
data.push([ '2021-04-29', 10530 ]);
data.push([ '2021-04-30', 10530 ]);
data.push([ '2021-05-01', 10530 ]);
data.push([ '2021-05-02', 10530 ]);
// Week 18-2021
data.push([ '2021-05-03', 9360 ]);
data.push([ '2021-05-04', 9360 ]);
data.push([ '2021-05-05', 9360 ]);
data.push([ '2021-05-06', 9360 ]);
data.push([ '2021-05-07', 9360 ]);
data.push([ '2021-05-08', 9360 ]);
data.push([ '2021-05-09', 9360 ]);
return data;
}
// Create chart
var myChart = echarts.init(document.getElementById('main'));
// Set chart options
```

```
var option = {
visualMap: {
show: false,
min: 0,
max: 15000,
},
calendar: {
range: ['2020-12-28','2021-05-09'],
orient: 'vertical',
dayLabel: {
show: false,
firstDay: 1
},
},
series: {
type: 'heatmap',
coordinateSystem: 'calendar',
data: getCalendarData()
}
};
// Show chart
myChart.setOption(option);
</script>
</body>
</html>
```

The Coronavirus immunisation programme animation.

```
<!DOCTYPE html>
<html lang="en">
<head>
<!-- Browser title -->
<title>Covid-19 Vaccination</title>
<!-- Character encoding -->
```

```
<meta charset="utf-8">
<!-- HTML meta information -->
<meta name="description" content="Covid-19 Vaccination. The Coronavirus Immunisation Programme in Norway on Map">
<meta name="viewport" content="width=device-width, initial-scale=1.0, viewport-fit=cover">
<meta name="format-detection" content="telephone=no,date=no,address=no,email=no,url=no">
<meta http-equiv="X-UA-Compatible" content="IE=Edge">
<!-- Icons generated from http://realfavicongenerator.net -->
<!-- <link rel="apple-touch-icon" sizes="180x180" href="favicons/apple-touch-icon.png">
<link rel="icon" type="image/png" sizes="32x32" href="favicons/favicon-32x32.png">
<link rel="icon" type="image/png" sizes="16x16" href="favicons/favicon-16x16.png">
<link rel="manifest" href="favicons/site.webmanifest">
<link rel="mask-icon" href="favicons/safari-pinned-tab.svg" color="#e5b41f">
<link rel="shortcut icon" href="favicons/favicon.ico">
<meta name="msapplication-TileColor" content="#2d89ef">
<meta name="msapplication-config" content="favicons/browserconfig.xml">
<meta name="theme-color" content="#ffffff"> -->
<!-- CSS libraries -->
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.7/dist/semantic.min.css">
<link rel="stylesheet" href="//fonts.googleapis.com/css?family=Exo+2">
<link rel="stylesheet" href="//cdn.jsdelivr.net/npm/leaflet@1.7.1/dist/leaflet.css">
<link rel="stylesheet" href="final.min.css">
</head>
<body>
<!-- Main container -->
<div class="ui pusher">
<div class="ui fluid container"
style="height:500px;position:relative;
color:#fafafa;
background-size: cover;
background-repeat: no-repeat;
background-position: center center;
```

```
background-image: url(https://images.unsplash.com/photo-1615631775440-
470d07c9a9c1?ixid=MnwxMjA3fDB8MHxwaG90by1wYWdlfHx8fGVufDB8fHx8&ixlib=rb-
1.2.1&auto=format&fit=crop&w=634&q=80);">
<!-- Photo attribution -->
<div style="position: absolute; bottom:5px; right:5px">
<span class="ui small text">
Photo: Mat Napo on Unsplash
</span>
</div>
</div>
<!-- Main container-->
<div class="ui text container" style="padding-bottom:300px">
<br>
<br>
<!-- Inner container -->
<div id="maplifies-content" class="ui big basic fitted segment">
<!-- Sub title -->
<h2 class="ui header">
Covid-19 Vaccination
<div class="sub header">
<span style="font-size:0.90em">The Coronavirus Immunisation Programme in Norway on Map</span>
<div style="margin-top:10px">
<blockquote>
<em>
A scientific work by
Master Student Manru Xue,
in close cooporation with
Professor Arild Hoff, and
Kristoffer Singstad.
<a href="https://www.himolde.no" target="_blank">
Molde University College</a>,
2021.
</em>
</blockquote>
```

```
</div>
</div>
</h2>
<!-- Description -->
<p>
Interactive maps are powerful visualization tools to see the expected and discover the unexpected.
Below you can try the final map visualization of <em>The Coronavirus Immunisation Programme in
Norway</em>, a programme led by the
<a href="https://www.fhi.no/en/id/vaccines/coronavirus-immunisation-programme/"
target="_blank">Norwegian Institute of Public Health</a>.
</p>
<br>
<!-- Map container -->
<div class="maplifies viz-container rounded shadow" style="width:100%;height:600px">
<!-- Loader -->
<div class="maplifies_loader ui active blue elastic massive loader"></div>
<!-- Map -->
<div id="NIPH" class="map-container" style="background-color:#D5E8EB"></div>
<!-- Fullscreen button -->
<div class="ui circular icon big inverted- button blue shadow map-btn"
style="position:absolute;top:0px;right:0px;margin:5px;z-index:11;margin-top:10px;box-shadow: 0px 0px
3px 0px rgba(0,0,0,0.8)" onclick="_maplifies.toggleFullscreen($(this))">
<i class="expand alternate icon"></i>
</div>
<!-- Card info -->
<div class="maplifies mobile-zoom" style="position:absolute;top:8px;left:-
30px;width:0px;height:0px;overflow:visible;z-index:500">
<!-- Country label -->
<div class="ui red huge circular label card-0" style="display:none;width:340px;box-shadow: 0px 0px 3px
0px rgba(0,0,0,0.8)">
<h4 class="ui inverted header" style="padding-top:3px;padding-left:30px;padding-right:15px;text-
align:left;">
<div>
<div style="float:right;font-size:1.5em;">
```

```
<div class="ratio"></div>
<div class="week" style="font-size:0.6em;padding-top:2px"></div>
</div>
<div style="font-size:0.9em">DISTRIBUTION TWO DOSES</div>
</div>
<div class="sub header" style="color:#fff;font-size:0.9em;padding-top:4px">
<i class="users icon"></i> <span class="population"></span>
  
<i class="truck moving icon"></i> <span class="doses"></span>
</div>
</h4>
</div>
<!-- County label -->
<div class="ui blue huge circular label card-1" style="display:none;width:310px;box-shadow: 0px 0px
3px 0px rgba(0,0,0,0.8);margin-top:5px;">
<h4 class="ui inverted header" style="padding-top:3px;padding-left:30px;padding-right:15px;text-
align:left;">
<div>
<div style="float:right;font-size:1.5em;">
<div class="ratio"></div>
<div class="week" style="font-size:0.6em;padding-top:2px"></div>
</div>
<div class="county" style="font-size:0.9em"></div>
</div>
<div class="sub header" style="color:#fff;font-size:0.9em;padding-top:4px">
<i class="users icon"></i> <span class="population"></span>
  
<i class="truck moving icon"></i> <span class="doses"></span>
</div>
</h4>
</div>
<!-- Municipality label -->
<div class="ui purple huge circular label card-2" style="display:none;width:280px;box-shadow: 0px 0px
3px 0px rgba(0,0,0,0.8);margin-top:5px;">
```

```
<h4 class="ui inverted header" style="padding-top:3px;padding-left:30px;padding-right:15px;text-align:left;">
<div>
<div style="float:right;font-size:1.5em;text-align:left;">
<div class="ratio"></div>
<div class="week" style="font-size:0.6em;padding-top:2px"></div>
</div>
<div class="municipality" style="font-size:0.9em"></div>
</div>
<div class="sub header" style="color:#fff;font-size:0.9em;padding-top:4px">
<i class="users icon"></i> <span class="population"></span>
  
<i class="truck moving icon"></i> <span class="doses"></span>
</div>
</h4>
</div>
</div>
<!-- Slider -->
<div class="maplifies" onclick="event.stopPropagation()" style="color:#fff;background-color:rgba(255,255,255,0.0);position:absolute;bottom:0px;width:100%;padding-top:0px;padding-bottom:10px;z-index:10;">
<div class="timeline ui large slider" style="color: #1e88e5;cursor:pointer;padding-left:93px;padding-right:40px;"></div>
<div class="play" style="display:none;cursor:pointer;position:absolute;bottom:28px;left:25px;" onclick="_maplifies.play($(this),500)"><i class="play big blue icon" style="color: #01579b"></i></div>
<div class="pause" style="display:none;cursor:pointer;position:absolute;bottom:28px;left:25px;" onclick="_maplifies.pause($(this))"><i class="pause big blue icon" style="color: #01579b"></i></div>
</div>
</div>
<footer>
<span class="ui text grey small">
<em>
<ol>
<li><a href="https://leafletjs.com/" target="_blank">Leaflet</a> JavaScript library for interactive maps</li>
```

```
<li>Web Map Tiles from <a href="https://www.kartverket.no/en" target="_blank">Kartverket</a> and <a
href="https://carto.com/" target="_blank">Carto</a></li>
<li>Choropleth map with border data from <a href="https://www.geonorge.no/en"
target="_blank">Geonorge</a>, and population figures from <a href="https://www.ssb.no/en/"
target="_blank">SSB</a></li>
<li>Proportional symbol map with zip code data from <a href="https://www.erikbolstad.no/"
target="_blank">Erik Bolstad</a> and vaccination figures from <a
href="https://www.fhi.no/en/hn/health-registries/norwegian-immunisation-registry-sysvak/"
target="_blank">NIPH/SYSVAK</a></li>
</ol>
</em>
</span>
</footer>
</div>
</div>
</div>
<script src="//www.gstatic.com/charts/loader.js"></script>
<script src="//cdn.jsdelivr.net/npm/jquery@3.5.1/dist/jquery.min.js"></script>
<script src="//cdn.jsdelivr.net/npm/fomantic-ui@2.8.7/dist/semantic.min.js"></script>
<script src="//cdn.jsdelivr.net/npm/echarts@5.1.1/dist/echarts.min.js"></script>
<script src="//cdn.jsdelivr.net/npm/leaflet@1.7.1/dist/leaflet.js"></script>
<script src="//cdn.jsdelivr.net/npm/numeral@2.0.6/numeral.min.js"></script>
<script src="final.min.js"></script>
<script>
jQuery(()=>{
numeral.register('locale', 'no', { delimiters: { thousands: ' ', decimal: ',' } });
numeral.locale('no');
google.charts.load('current', { language: 'en' }).then(()=>{
setData('NIPH');
_maplifies.init().then(()=>{
$('.maplifies_loader').removeClass();
initMap('NIPH');
});
});
```

```
$.get({url: "toc.html", cache: false}).then(function(data){ $("body").prepend(data) });
});
</script>
</body>
</html>
```