

**COS30045 Data Visualisation**

(Project Process Book – Group 21)



**Title: Comparative Analysis of Vaccination**

(Link to website: <https://kellykhor.github.io/DataVisualization/index.html>)

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## **1. Introduction**

### **1.1 Background and Motivation**

Vaccinations are a critical public health intervention that protects populations from infectious diseases, reduces morbidity and mortality rates, and helps achieve herd immunity. According to the World Health Organization (WHO), vaccination successfully prevents between 3.5 million and 5 million deaths annually from various diseases, significantly improving life expectancy by averting life-threatening conditions. Vaccination enhances the body's natural immune response, promoting antibody production to strengthen internal defenses and reduce infection risks. It provides protection against a variety of diseases, including Hepatitis B, Malaria, Measles, Mumps, Tetanus, and Covid-19. However, vaccination strategies and coverage differ across regions and populations due to factors like healthcare infrastructure, government policies, cultural beliefs, and socio-economic conditions, leading to uneven disease prevention and exposing certain populations to preventable infections.

The focus of this visualization project is on the comparative analysis of vaccination rates in European countries for Measles, Hepatitis A, and Tetanus over a ten-year period (2013–2023).

- **Measles** is a highly contagious viral infection that can lead to severe complications, including pneumonia, encephalitis, and death. Despite the availability of an effective vaccine, outbreaks continue to occur in areas with low vaccination coverage. Understanding the vaccination rates for measles is crucial for preventing potential epidemics, particularly given the recent resurgence of the disease in some regions.
- **Hepatitis A** is a viral liver infection primarily spread through contaminated food and water. Vaccination is essential, especially for populations in areas with higher transmission risks.
- **Tetanus** is a serious bacterial infection that affects the nervous system, leading to muscle stiffness and spasms. Vaccination against tetanus is particularly important for adults and individuals in high-risk occupations. Tracking tetanus vaccination rates aids in assessing the effectiveness of public health campaigns and identifying gaps in coverage.

The primary users who will be interested in the visualizations of this project include public health officials, policymakers, researchers, and economists. These stakeholders will use the visualizations to track vaccination coverage, identify trends, and assess the economic and health outcomes across different nations.

These individuals may want to perform tasks such as identifying countries with low vaccination rates, comparing vaccination costs between different suppliers, and analyzing correlations between vaccination rates and disease incidence. This is important because understanding vaccination trends can help inform public health strategies, optimize resource allocation, and guide future vaccine procurement policies.

By providing a comprehensive view of vaccination rates and their relationship with economic factors and disease incidence, these visualizations aim to empower stakeholders to make informed decisions that enhance public health and vaccination efforts across Europe.

## 1.2 Project Objectives

The objectives of this project include:

- Identifying which European countries have the highest or lowest vaccination coverage for measles, hepatitis B, and tetanus.
- Analyzing how vaccination costs vary by year.
- Investigating the correlation between disease incidence and vaccination rates in European countries.
- Examining the relationship between GDP and vaccination rates across different countries.

The completed visualizations will provide several valuable insights:

- They offer a clear view of vaccination disparities across European countries, highlighting areas where improvement is needed.

- They allow for the detection of patterns and correlations that may influence health policy decisions.
- By integrating economic data such as GDP, the visualizations offer insights into how a country's wealth impacts vaccination rates and public health outcomes.

## 2. Data

### 2.1 Data Source

Data Source	Explanation of Dataset
<i>WIISE detail page.</i> (n.d.). Immunization Data. <a href="https://immunizationdata.who.int/global/wiise-detail-page/measles-reported-cases-and-incidence?YEAR=">https://immunizationdata.who.int/global/wiise-detail-page/measles-reported-cases-and-incidence?YEAR=</a>	The number of reported measles cases and incidence rates are gathered annually through the WHO/UNICEF Joint Reporting Form on Immunization (JRF).
<i>WIISE detail page.</i> (n.d.). Immunization Data. <a href="https://immunizationdata.who.int/global/wiise-detail-page/tetanus-reported-cases-and-incidence?">https://immunizationdata.who.int/global/wiise-detail-page/tetanus-reported-cases-and-incidence?</a>	The number of reported tetanus cases and incidence rates are gathered annually through the WHO/UNICEF Joint Reporting Form on Immunization (JRF).
<a href="https://www.unicef.org/supply/vaccines-pricing-data">https://www.unicef.org/supply/vaccines-pricing-data</a>	<p>The datasets here show the price per dose (in US\$) for the vaccines.</p> <p>The dataset is structured as a table, with years as columns and various vaccine sources as rows, indicating the cost per dose for each source over time. The primary attributes include the years and vaccine sources, with the values representing the cost per dose, categorized as ratio/quantitative data due to their meaningful comparisons and true zero point. As the project is focused on comparing</p>

	vaccination coverage across Europe, only the vaccine sources from European countries will be included, and the others excluded.
<a href="https://ourworldindata.org/vaccination">https://ourworldindata.org/vaccination</a>	The dataset shows vaccination coverage for multiple diseases, including measles, hepatitis B, yellow fever, tetanus, influenza, and others across various countries. Data was recorded from 1980 to 2021. However, not all data is complete, as there are missing values within the dataset. Since the project focuses on visualizations for European countries, only relevant countries were filtered for use, and the project centers specifically on measles, tetanus, and hepatitis B.
<a href="https://data-explorer.oecd.org/vis?lc=en&amp;tm=DF_TABLE1_EXPENDITURE_HCPC&amp;pg=0&amp;snb=1&amp;df[ds]=dsDisseminateFinalDMZ&amp;df[id]=DSD_NAMAIN10%40DF_TABLE1_EXPENDITURE_HCPC&amp;df[ag]=OECD.SDD.NAD&amp;df[vs]=&amp;pd=%2C&amp;dq=A.AUS%2BAUT%2BBEL%2BCAN%2BCHL%2BCOL%2BCRI%2BCZE%2BDNK%2BEST%2BFIN%2BFRA%2BDEU%2BGRC%2BHUN%2BISL%2BIRL%2BISR%2BITA%2BJPN%2BKOR%2BLVA%2BLTU%2BLUX%2BMEX%2BNLD%2BNZL%2BNOR%2BPOL%2BPRT%2BSVK%2BSVN%2BESP%2BSWE%2BCHE%2BTUR%2BGBR%2BUSA...B1GQ_POP.....&amp;to[TIME_PERIOD]=false&amp;vw=tb">https://data-explorer.oecd.org/vis?lc=en&amp;tm=DF_TABLE1_EXPENDITURE_HCPC&amp;pg=0&amp;snb=1&amp;df[ds]=dsDisseminateFinalDMZ&amp;df[id]=DSD_NAMAIN10%40DF_TABLE1_EXPENDITURE_HCPC&amp;df[ag]=OECD.SDD.NAD&amp;df[vs]=&amp;pd=%2C&amp;dq=A.AUS%2BAUT%2BBEL%2BCAN%2BCHL%2BCOL%2BCRI%2BCZE%2BDNK%2BEST%2BFIN%2BFRA%2BDEU%2BGRC%2BHUN%2BISL%2BIRL%2BISR%2BITA%2BJPN%2BKOR%2BLVA%2BLTU%2BLUX%2BMEX%2BNLD%2BNZL%2BNOR%2BPOL%2BPRT%2BSVK%2BSVN%2BESP%2BSWE%2BCHE%2BTUR%2BGBR%2BUSA...B1GQ_POP.....&amp;to[TIME_PERIOD]=false&amp;vw=tb</a>	The dataset provides details on the annual GDP per capita for different countries around the world from 1960 to 2023. The data is formatted to one decimal place and presented in dollars. However, there are multiple missing values that need to be filled by integrating data from another dataset. Additionally, data from only European countries is filtered and formatted for use in this project.

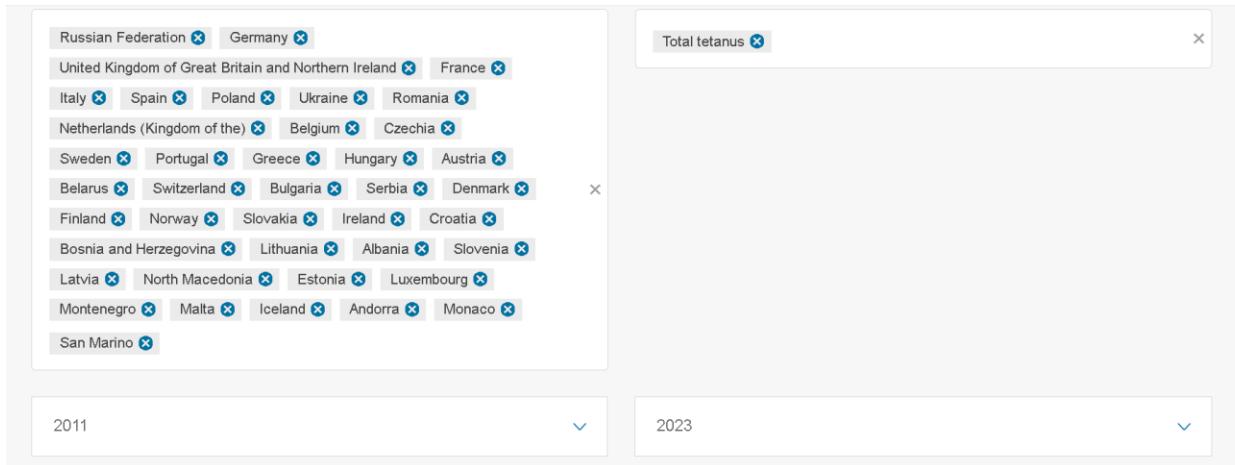
<p><a href="https://databank.worldbank.org/reports.aspx?source=2&amp;series=SH.XPD.CHEX.GD.ZS&amp;country=EUU#">https://databank.worldbank.org/reports.aspx?source=2&amp;series=SH.XPD.CHEX.GD.ZS&amp;country=EUU#</a></p>	<p>This dataset provides details on the healthcare expenditure of different European countries. The data is represented as a percentage of the country's total GDPs.</p> <p>The dataset is provided in the form of a table, with the column headings being the years (2016-2020 available), and the rows being the European countries.</p>
<p><i>Population estimates and projections.</i> DataBank. (n.d.). <a href="https://databank.worldbank.org/source/population-estimates-and-projections#">https://databank.worldbank.org/source/population-estimates-and-projections#</a></p>	<p>This dataset provided the Europe countries population from 2013 to 2023. The value is by the populations.</p>

## 2.2 Data Processing

### 2.2.1 Data Processing for Total Reported Cases



First we select individually select the European countries on the Wise website, followed by the years we wish to cover in our database. The data can then be generated into an excel sheet, and downloaded.



Next, we need to extract the data from the Excel file. The data is shown below.

Country / Region	Disease	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
Albania	Total tetanus	1	0	0	0	2	0	1	0	0	0	0	0	0
Andorra	Total tetanus	0	0	0	0	0	0	0	0	0	0	0	0	0
Austria	Total tetanus												0	0
Belarus	Total tetanus	0	0	1	1	0		0	0	0	0	0	0	0
Belgium	Total tetanus					0	0						0	0
Bosnia and Herzegovina	Total tetanus	1	0	0				0	0	0		0	0	0
Bulgaria	Total tetanus	0	0	0	1				4	0	0	1	2	4
Croatia	Total tetanus	0	0	0	0	2	3	2	0	3		1	1	2
Czechia	Total tetanus	0	2	0	0	1	0	0	1	1	0	0	0	0
Denmark	Total tetanus	1	0	1	1	0	2	2			1	0	0	0
Estonia	Total tetanus	1	0	0	0	0	1	1	0	0	0	1	0	2
Finland	Total tetanus	0	0		0	0	0	0	0	0				
France	Total tetanus	2	4	5	3			4	4			10		9
Germany	Total tetanus													
Greece	Total tetanus	2	3	2	2	5	4	2	3	6	2	1	7	11
Hungary	Total tetanus	1	1	2	3	5	1	0	5	3	2	2	5	4
Iceland	Total tetanus	0	0	0	0		0	0	0	0	0	0	0	0
Ireland	Total tetanus	0	0	0	0	0	0	1	0	1	1	2	1	0
Italy	Total tetanus	0	21	27	12			33		47			64	58
Latvia	Total tetanus	0	0	0	0				0	0	0	0	0	0
Lithuania	Total tetanus	3	0	0	0	1	1	3	2	2	1	2	2	2
Luxembourg	Total tetanus	0	0	0	0			0	0	0		0	0	0
Malta	Total tetanus	0	0	0	0		0	1	0	0	0			0
Monaco	Total tetanus	0						0						1
Montenegro	Total tetanus	0	0	0	0				0			0	0	1
Netherlands (Kingdom of the)	Total tetanus	5	2	0	2	0	1	1	1	0	0	1	1	5
North Macedonia	Total tetanus	0	0	0	0			0		0	0	0	2	0

Each year column is extracted into their own separate sheets on Excel, with the corresponding incidence rates. The rows with empty values are then deleted.

Before		After	
country	incidence	country	incidence
Albania	2	Andorra	0
Andorra	0	Belarus	0
Austria	151	Bosnia and Herzegovina	0
Belarus	0	Bulgaria	0
Belgium	0	Croatia	3
Bosnia and Herzegovina	0	Czechia	1
Bulgaria	0	Estonia	0
Croatia	3	Finland	0
Czechia	1	Greece	6
Denmark	0	Hungary	3
Estonia	0	Iceland	0
Finland	0	Ireland	1
France	47	Italy	47
Germany	0	Latvia	0
Greece	5	Lithuania	2
Hungary	3	Luxembourg	0
Iceland	0	Malta	0
Ireland	1	Netherlands (Kingdom of the)	0
Italy	47	North Macedonia	0
Latvia	0	Norway	2
Lithuania	2	Portugal	0
Luxembourg	0	Romania	7
Malta	0	Russia	0
Monaco	0	Ukraine	0
...	...	...	...

Finally, we add two columns to the dataset – vaccination rate (processing will be shown in sections below) and disease. This is how the final dataset looks.

country	incidence	vaccine_rate	disease
Albania	2	0.99	Tetanus
Andorra	0	0.99	Tetanus
Belarus	0	0.98	Tetanus
Belgium	0	0.97	Tetanus
Croatia	2	0.94	Tetanus
Czechia	1	0.97	Tetanus
Denmark	0	0.97	Tetanus
Estonia	0	0.91	Tetanus
Finland	0	0.91	Tetanus
Greece	5	0.99	Tetanus
Hungary	5	0.99	Tetanus
Ireland	0	0.94	Tetanus
Latvia	0	0.99	Tetanus
Lithuania	1	0.92	Tetanus
Albania	488	0.95	Measles
Andorra	0	0.99	Measles
Austria	151	0.95	Measles
Belarus	201	0.98	Measles
Belgium	480	0.96	Measles
Bosnia and Herzegovina	1,404	0.68	Measles
Bulgaria	1,231	0.95	Measles
Croatia	52	0.93	Measles
Czechia	590	0.92	Measles
Denmark	15	0.96	Measles
Estonia	27	0.88	Measles
Finland	12	0.96	Measles

< > 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022

## 2.2.2 Data Processing for Country GDP

Annual GDP and consumption per capita, US \$, current prices, current PPPs												
Institutional sector: Total economy												
Counterpart institutional sector: Total economy												
Transaction: Gross domestic product, per capita												
Time period		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Reference area	Combined unit of measure											
Australia	US dollars per person, PPP converted, Units	2,412.6	2,583.2	2,577.3	2,752.6	2,902.6	3,001.9	3,275.6	3,447.1	3,835.1	4,207.9	4,652.1
Austria	US dollars per person, PPP converted, Units											€ 3,625.3
Bahrain	US dollars per person, PPP converted, Units											€ 3,873.5
Canada	US dollars per person, PPP converted, Units											4,578.6
Chile	US dollars per person, PPP converted, Units											
Colombia	US dollars per person, PPP converted, Units											
Costa Rica	US dollars per person, PPP converted, Units											
Czechia	US dollars per person, PPP converted, Units											
Denmark	US dollars per person, PPP converted, Units											
Estonia	US dollars per person, PPP converted, Units											€ 3,980.2
Iceland	US dollars per person, PPP converted, Units											€ 4,042.4
Israel	US dollars per person, PPP converted, Units											€ 4,042.4
Italy	US dollars per person, PPP converted, Units											€ 3,829.7
Japan	US dollars per person, PPP converted, Units											€ 3,548.5
Korea	US dollars per person, PPP converted, Units											600.5
Lithuania	US dollars per person, PPP converted, Units											
Luxembourg	US dollars per person, PPP converted, Units											€ 5,480.0
Mexico	US dollars per person, PPP converted, Units											€ 1,907.3
Netherlands	US dollars per person, PPP converted, Units											€ 4,092.9
New Zealand	US dollars per person, PPP converted, Units											€ 3,917.1
Poland	US dollars per person, PPP converted, Units											5,362.5

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
8	35,683.4	37,964.6	39,703.5	40,136.1	41,684.6	42,823.9	44,460.6	45,911.7	47,796.0	47,648.6	47,266.6	50,152.5	50,761.9	53,125.9	53,681.4	56,905.5	64,120.5	71,753.6	€ 72,952.5	
10	35,024.6	37,663.1	39,443.1	40,116.0	40,213.9	40,447.2	40,477.3	40,856.1	40,943.3	40,923.5	40,923.7	40,943.1	32,665.1	54,184.4	56,956.1	60,390.2	58,610.9	63,451.5	64,889.4	
11	35,278.9	35,987.8	36,505.5	37,789.1	39,098.7	40,943.5	40,923.5	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	40,923.7	73,744.1	
12	32,600.9	35,182.2	36,120.2	36,171.2	36,371.6	38,864.0	40,098.3	41,666.8	42,291.9	44,501.0	45,758.1	44,668.1	46,670.7	48,317.4	49,982.1	50,699.0	48,597.6	55,781.7	62,041.6	
13	8,676.1	9,433.2	10,228.2	10,651.5	10,720.9	11,206.2	12,108.2	12,530.8	13,266.0	13,777.2	13,762.8	14,514.2	14,930.9	15,814.7	16,712.4	15,959.5	P 18,141.9	P 21,650.6	P 21,994.5	
14	10,296.5	11,214.4	12,936.4	13,936.4	14,068.2	14,852.9	15,542.4	16,616.0	17,649.3	19,119.3	20,368.2	21,312.7	23,082.5	23,778.8	23,667.7	€ 26,027.9	€ 26,027.9	€ 26,027.9	€ 26,027.9	
15	22,056.5	23,854.7	26,207.8	27,817.1	27,579.3	28,042.3	29,256.6	29,476.6	31,048.1	32,810.7	34,218.0	36,627.6	39,620.9	42,016.5	46,139.5	49,675.1	50,019.1	53,702.7	55,803.2	
16	34,542.8	37,242.9	39,501.0	40,743.1	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	40,923.5	
17	16,587.6	17,293.9	22,164.7	22,786.1	22,660.1	21,587.1	24,610.5	24,610.5	27,784.3	29,375.6	29,765.1	31,514.5	31,514.5	37,201.0	40,650.5	45,938.8	49,650.5	52,370.5	58,350.0	49,650.5
18	32,051.8	34,454.7	37,847.1	40,083.7	37,971.0	38,849.4	40,916.6	40,872.9	41,492.9	41,492.9	42,492.7	44,934.6	47,570.3	52,669.9	53,657.8	57,783.8	62,900.1	64,496.6		
19	30,536.1	32,547.5	34,196.5	35,192.1	34,809.9	36,065.8	37,675.7	37,841.7	39,772.4	40,395.7	42,988.7	45,427.6	46,397.6	51,119.7	49,462.7	53,878.5	P 57,860.3	P 61,473.3		
20	32,336.7	34,666.6	36,842.4	37,446.0	39,670.2	42,541.5	43,359.5	44,993.7	47,011.3	47,609.6	50,579.5	50,071.5	55,195.7	P 58,251.7	P 57,903.1	P 61,939.7	P 66,161.3	P 69,329.9		
21	25,577.4	28,548.9	29,326.9	30,855.9	30,558.2	27,790.2	25,571.4	25,886.6	26,625.2	26,760.3	27,511.8	28,604.8	29,617.5	31,611.3	29,088.3	P 32,797.3	P 38,864.5	P 40,521.1		
22	17,108.6	18,383.6	19,098.6	20,721.5	21,738.9	23,029.4	23,267.4	24,548.0	25,691.9	26,798.9	27,841.9	31,908.9	35,152.5	38,648.0	43,394.6	45,941.1				
23	34,374.1	36,804.1	38,501.9	40,548.6	41,493.5	42,420.7	45,541.0	46,747.5	48,818.7	52,700.5	71,682.1	73,170.4	80,556.5	86,433.7	92,189.2	97,903.7	116,741.6	135,774.0	128,156.6	
24	30,455.1	44,271.1	46,770.9	44,105.4	41,435.3	43,120.7	45,541.0	46,747.5	48,818.7	52,700.5	71,682.1	73,170.4	80,556.5	86,433.7	92,189.2	97,903.7	116,741.6	135,774.0	128,156.6	
25	25,572.7	26,265.5	28,119.1	27,922.4	28,110.5	29,466.5	31,324.9	32,497.3	34,843.1	35,883.7	38,201.0	39,487.9	40,206.2	41,369.1	41,416.9	42,492.7	46,531.0	52,346.8	53,823.8	
26	30,028.5	32,311.2	33,964.3	35,292.6	34,833.6	36,091.4	36,267.9	36,476.0	37,206.3	40,267.3	41,951.5	43,427.7	46,397.6	47,470.0	49,901.6	55,838.9	58,523.5			
27	32,174.4	33,638.8	35,021.7	35,278.7	35,550.7	35,942.8	36,215.0	37,618.7	39,436.7	40,908.8	42,644.7	43,513.2	42,264.6	42,835.6	42,625.0	44,613.1	47,185.5	50,273.1		
28	25,186.4	26,884.4	29,064.7	29,945.9	29,508.3	31,736.7	37,546.5	33,557.0	34,244.2	35,324.3	37,902.4	39,575.3	40,957.3	40,944.3	45,143.0	48,594.5	P 51,666.5	P 54,059.7		
29	14,142.4	15,771.1	18,554.8	19,500.9	17,907.1	19,507.1	21,200.7	22,600.0	23,000.0	24,495.8	25,724.8	26,800.9	28,500.9	30,500.9	33,723.8	36,500.9	36,500.9	36,500.9	36,500.9	
30	14,515.1	16,483.8	19,049.9	20,211.1	18,116.2	20,099.3	22,884.9	25,705.7	26,721.3	28,184.3	28,834.5	29,205.5	30,376.2	36,376.5	37,778.8	41,285.2	46,285.4	50,599.3	55,977.0	
31	68,707.8	78,830.0	85,004.0	90,863.8	86,797.4	90,142.0	94,278.9	96,535.7	100,581.4	104,917.9	107,888.5	112,955.9	114,862.5	116,334.9	113,105.8	121,978.6	137,716.4	145,971.0	P 145,526.8	
32	13,099.5	14,385.7	14,892.0	15,549.5	15,078.3	15,815.9	17,200.9	18,287.4	18,481.0	19,153.9	19,395.3	20,410.4	21,151.4	21,151.4	19,413.8	P 20,981.2	P 23,559.1	P 25,430.9		
33	37,778.2	41,217.1	44,204.4	46,713.2	44,936.8	45,307.4	47,653.2	49,623.9	49,751.3	50,956.5	53,163.3	56,038.5	58,818.0	62,344.8	62,594.8	69,323.5	P 77,884.5	P 80,751.1		
34	25,590.4	27,669.3	29,274.0	29,748.9	30,574.2	31,127.3	32,659.0	32,917.7	36,085.5	37,089.2	37,255.4	39,709.4	41,998.6	42,312.9	44,852.7	45,221.9	48,171.4	51,947.5	E 53,801.8	
35	47,869.9	54,363.4	56,183.0	60,757.5	55,615.5	58,222.6	62,461.2	65,768.8	67,372.9	68,335.5	69,261.6	59,283.3	64,589.2	70,252.7	70,938.7	67,116.5	89,214.4	124,355.7	109,994.1	
36	14,515.1	16,483.8	18,854.7	18,854.7	18,854.7	18,854.7	20,000.0	20,000.0	20,000.0	20,495.8	21,730.4	22,495.8	23,495.8	24,495.8	30,500.9	30,500.9	40,206.2	46,285.4	49,650.5	
37	27,255.5	24,682.6	25,719.0	26,665.5	26,458.1	27,257.2	28,676.9	26,438.0	28,741.4	29,650.0	31,607.8	30,044.7	34,928.5	37,845.2	35,878.8	39,056.5	P 44,962.0	P 46,745.0		
38	16,595.3	18,851.2	21,140.9	23,609.0	22,948.3	25,218.3	B 26,260.2	27,000.7	28,021.1	29,029.6	30,062.2	29,737.5	30,147.0	31,374.2	33,549.0	34,991.0	B 37,836.5	40,629.7	43,818.8	
39	23,678.4	25,564.0	27,458.9	29,494.14	27,187.9	27,737.9	28,715.7	28,792.2	29,639.9	30,574.7	31,339.8	33,581.8	36,190.5	38,656.3	42,860.5	41,759.7	46,281.9	51,288.8	55,708.8	
40	27,600.9	30,745.5	32,420.3	33,242.3	32,088.3	31,687.0	31,872.4	31,724.8	32,463.1	33,559.0	34,945.5	37,533.1	39,601.5	40,776.						

a. Extracting Countries GDP from the Original Dataset

<i>Time period</i>	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
<b>Countries</b>											
Albania	11361.00	11587.00	11878.00	12292.00	12771.00						
Andorra											
Armenia	10677.00	11106.00	11506.00	11580.00	12510.00						
Austria	47936.68	48813.53	49942.06	52665.09	54188.36	56956.11	60590.20	58610.93	63451.49	70889.43	73743.97
Azerbaijan	14652.00	14868.00	14853.00	14232.00	14121.00						
Belarus	18805.00	19119.00	18363.00	49830.00	18356.00						
Belgium	43672.71	44929.93	46201.69	48599.20	50442.95	52530.84	56621.43	55729.03	62124.24	68308.21	70830.91
Bosnia and Herzegovina	11483.00	11767.00	12438.00	13001.00	13582.00						
Bulgaria	18915.00	19203.00	19983.00	20733.00	21458.00						
Croatia	25484.00	24170.00	24985.00	26056.00	27268.00						
Czech Republic	31048.12	32810.69	34217.98	36627.61	39620.87	42016.46	46139.56	45675.06	50019.14	53270.20	55803.22
Denmark	46883.13	47880.69	48906.11	51814.24	55270.42	57231.33	60568.74	62700.58	70370.11	78255.73	77223.38
Estonia	27784.71	29375.59	29760.31	31945.12	34553.45	37201.04	40650.01	40685.53	45083.85	49130.00	49652.99
Finland	41492.92	41749.86	42490.21	44934.49	47570.27	49573.26	52569.86	53657.58	57783.83	62590.08	64496.64
France	39772.37	40395.67	41049.73	42983.75	44527.55	46397.54	51119.65	49462.66	53878.48	57860.34	61473.32
Georgia	11739.00	12254.00	12605.00	12964.00	13590.00						
Germany	44993.67	47011.28	47609.56	50579.48	53071.48	55195.72	58251.74	57905.09	61939.72	66616.05	69329.87
Greece	25986.64	26625.16	26760.28	27511.80	28604.83	29617.52	31611.26	29088.26	32797.28	38364.49	40521.06
Hungary	24547.98	25691.53	26798.85	27941.93	29496.16	31908.86	35152.60	35029.91	38648.00	43394.76	45941.05
Iceland	45243.08	46853.65	50158.55	54477.41	56644.70	58342.55	62031.41	57404.39	63837.75	75834.46	80449.13
Ireland	48878.66	52700.50	71682.51	73170.44	80556.53	86433.67	92189.16	97903.15	116741.57	135774.00	128156.55
Italy	36267.93	36475.98	37206.33	40267.22	41951.47	43427.66	46470.02	44202.20	49901.58	55838.85	58523.50
Kazakhstan	23721.00	24356.00	24290.00	24211.00	24863.00						
Kosovo	8487.00	8797.00	9445.00	10031.00	10436.00						
Latvia	22637.27	23810.01	24975.54	26724.54	28689.65	30891.88	33305.57	33725.72	36806.73	40957.41	42505.80
Liechtenstein											
Lithuania	26721.69	28184.26	28834.53	30925.26	33761.99	36376.54	40577.85	41168.18	46285.42	50997.27	51877.05
Luxembourg	100561	104918	107898.30	112955.47	114862.53	116334.92	121105.79	121973.63	137716.45	145971.05	143526.89
Malta	35339.00	37284.00	39903.00	40319.00	43494.00						
Moldova	9682.00	10173.00	10216.00	10816.00	11464.00						
Monaco											
Montenegro	17382.00	17675.00	18264.00	18798.00	19682.00						
Netherlands	49623.33	49751.32	50956.45	53163.28	56038.53	58818.01	62344.80	62594.83	69323.51	77284.54	80752.09
North Macedonia	14109.00	14597.00	15139.00	15554.00	15707.00						

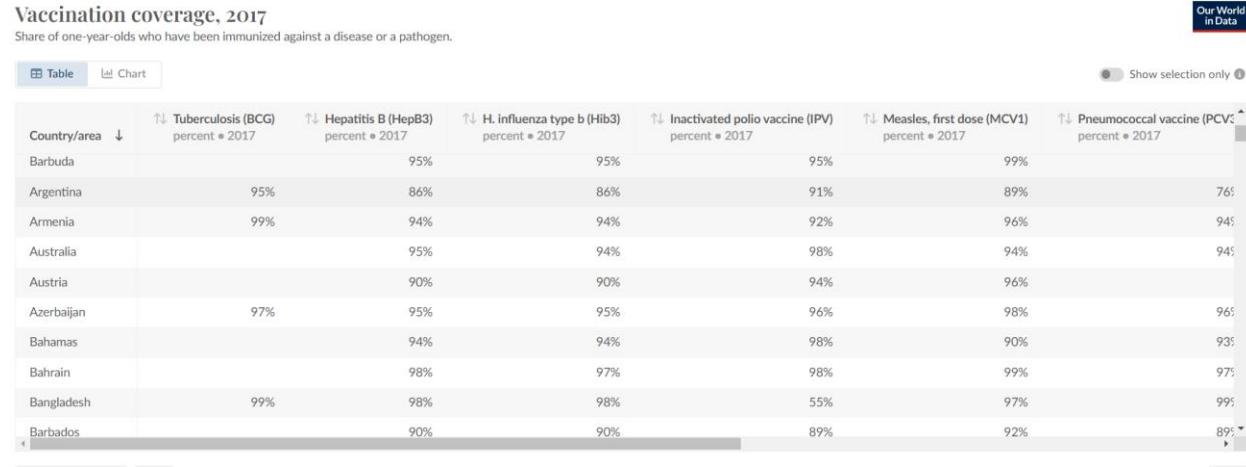
The above dataset contains the original data extracted from the OECD, without any data combined from the Our World in Data dataset.

b. Combining data from another dataset

Time period	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Countries											
Albania	11361.00	11587.00	11878.00	12292.00	12771.00	13317.00	13653.00	13278.00	14596.00	15492.00	
Andorra											
Armenia	10677.00	11106.00	11506.00	11580.00	12510.00	13231.00	14318.00	13358.00	14207.00	55867.00	
Austria	47936.68	48813.53	49942.06	52665.09	54188.36	56956.11	60590.20	58610.93	63451.49	70889.43	73743.97
Azerbaijan	14652.00	14868.00	14853.00	14232.00	14121.00	14210.00	14442.00	13727.00	14434.00	15094.00	
Belarus	18805.00	19119.00	18363.00	49830.00	18356.00	18975.00	19288.00	19240.00	19873.00	19092.00	
Belgium	43672.71	44929.93	46201.69	48599.20	50442.95	52530.84	56621.43	55729.03	62124.24	68308.21	70830.91
Bosnia and Herzegovina	11483.00	11767.00	12438.00	13001.00	13582.00	14268.00	14852.00	14588.00	15893.00	16737.00	
Bulgaria	18915.00	19203.00	19983.00	20733.00	21458.00	22196.00	23255.00	22467.00	24386.00	26961.00	
Croatia	25484.00	24170.00	24985.00	26056.00	27268.00	28288.00	29412.00	27002.00	32061.00	34302.00	
Czech Republic	31048.12	32810.69	34217.98	36627.61	39620.87	42016.46	46139.56	45675.06	50019.14	53270.20	55803.22
Denmark	46883.13	47880.69	48906.11	51814.24	55270.42	57231.33	60568.74	62700.58	70370.11	78255.73	77223.38
Estonia	27784.71	29375.59	29760.31	31945.12	34553.45	37201.04	40650.01	40685.53	45083.85	49130.00	49652.99
Finland	41492.92	41749.86	42490.21	44934.49	47570.27	49573.26	52569.86	53657.58	57783.83	62590.08	64496.64
France	39772.37	40395.67	41049.73	42983.75	44527.55	46397.54	51119.65	49462.66	53878.48	57860.34	61473.32
Georgia	11739.00	12254.00	12605.00	12964.00	13590.00	14253.00	14989.00	13966.00	15487.00	17078.00	
Germany	44993.67	47011.28	47609.56	50579.48	53071.48	55195.72	58251.74	57905.09	61939.72	66616.05	69329.87
Greece	25986.64	26625.16	26760.28	27511.80	28604.83	29617.52	31611.26	29088.26	32797.28	38364.49	40521.06
Hungary	24547.98	25691.53	26798.85	27941.93	29496.16	31908.86	35152.60	35029.91	38648.00	43394.76	45941.05
Iceland	45243.08	46853.65	50158.55	54477.41	56644.70	58342.55	62031.41	57404.39	63837.75	75834.46	80449.13
Ireland	48878.66	52700.50	71682.51	73170.44	80556.53	86433.67	92189.16	97903.15	116741.57	135774.00	128156.55
Italy	36267.93	36475.98	37206.33	40267.22	41951.47	43427.66	46470.02	44202.20	49901.58	55838.85	58523.50
Kazakhstan	23721.00	24356.00	24290.00	24211.00	24863.00	25544.00	26352.00	25362.00	42563.00	26093.00	
Kosovo	8487.00	8797.00	9445.00	10031.00	10436.00	10755.00	11318.00	10707.00	11884.00	12675.00	
Latvia	22637.27	23810.01	24975.54	26724.54	28689.65	30891.88	33305.57	33725.72	36806.73	40957.41	42505.80
Liechtenstein											
Lithuania	26721.69	28184.26	28834.53	30925.26	33761.99	36376.54	40577.85	41168.18	46285.42	50997.27	51877.05
Luxembourg	100561	104918	107898.30	112955.47	114862.53	116334.92	121105.79	121973.63	137716.45	145971.05	143526.89
Malta	35339.00	37284.00	39903.00	40319.00	43494.00	45116.00	46439.00	41754.00	46599.00	48642.00	
Moldova	9682.00	10173.00	10216.00	10816.00	11464.00	12143.00	12777.00	11849.00	13704.00	13308.00	
Monaco											
Montenegro	17382.00	17675.00	18264.00	18798.00	19682.00	20687.00	21534.00	18259.00	20711.00	22109.00	
Netherlands	49623.33	49751.32	50956.45	53163.28	56038.53	58818.01	62344.80	62594.83	69323.51	77284.54	80752.09
North Macedonia	14109.00	14597.00	15139.00	15554.00	15707.00	16146.00	16773.00	15780.00	16709.00	17129.00	

The missing values are filled with the data from Our World in Data's dataset.

### 2.2.3 Data Processing for Vaccination Rate of Measles, Tetanus, and Hepatitis B



The original dataset for vaccination rates of various diseases is sourced from Our World in Data. This dataset includes vaccination rates for diseases such as tuberculosis, hepatitis B, influenza, measles, yellow fever, and tetanus, covering nearly every country from 1980 to 2021. However,

we could not find the Excel file available to download. Therefore, we manually extracted the values for the specific diseases we need—measles, tetanus, and hepatitis B—from 2013 to 2023.

### a. Extracting Vaccination Rates from the Original Dataset

A	B	C	D	E	F	G	H	I	J	K	L
7 Azerbaijan	0.92	0.94	0.98	0.98	0.98	0.98	0.96	0.98	0.98	0.82	0.93
8 Belarus	0.99	0.98	0.99	0.99	0.98	0.97	0.98	0.98	0.97	0.98	
9 Belgium	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
10 Bosnia and Herzegovina	0.89	0.94	0.92	0.89	0.83	0.68	0.69	0.68	0.68	0.68	0.68
11 Bulgaria	0.95	0.94	0.95	0.93	0.92	0.92	0.94	0.93	0.95	0.88	0.89
12 Croatia	0.96	0.95	0.94	0.94	0.93	0.90	0.89	0.93	0.93	0.91	0.89
13 Cyprus	0.87	0.86	0.86	0.86	0.90	0.90	0.90	0.90	0.86	0.86	0.86
14 Czech Republic	0.98	0.98	0.99	0.99	0.98	0.97	0.96	0.92	0.94	0.97	
15 Denmark	0.87	0.90	0.89	0.90	0.91	0.94	0.97	0.95	0.96	0.94	0.95
16 Estonia	0.94	0.94	0.94	0.93	0.93	0.93	0.93	0.87	0.88	0.91	0.89
17 Finland	0.97	0.97	0.97	0.96	0.95	0.94	0.94	0.96	0.96	0.95	0.93
18 France	0.89	0.91	0.90	0.91	0.91	0.90	0.90	0.90	0.92	0.92	0.92
19 Georgia	0.91	0.93	0.97	0.92	0.96	0.93	0.95	0.98	0.99	0.91	0.90
20 Germany	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
21 Greece	0.99	0.99	0.99	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
22 Hungary	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
23 Iceland	0.94	0.90	0.91	0.90	0.93	0.91	0.92	0.93	0.93	0.93	0.92
24 Ireland	0.92	0.92	0.93	0.93	0.93	0.92	0.92	0.92	0.91	0.92	0.90
25 Italy	0.90	0.90	0.90	0.87	0.85	0.87	0.92	0.93	0.94	0.92	0.92
26 Kazakhstan	0.99	0.96	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.93	0.97
27 Kosovo	NA										
28 Latvia	0.92	0.90	0.96	0.95	0.96	0.93	0.96	0.98	0.99	0.99	0.97
29 Liechtenstein	NA										
30 Lithuania	0.94	0.93	0.93	0.93	0.94	0.94	0.94	0.92	0.93	0.90	0.88
31 Luxembourg	0.96	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
32 Malta	0.84	0.93	0.99	0.98	0.89	0.93	0.91	0.96	0.96	0.95	0.90
33 Moldova	0.91	0.91	0.91	0.90	0.89	0.88	0.93	0.93	0.97	0.84	0.83
34 Monaco	0.91	0.91	0.91	0.90	0.89	0.89	0.88	0.88	0.88	0.88	0.88
35 Montenegro	0.91	0.90	0.88	0.76	0.64	0.47	0.58	0.42	0.33	0.24	0.18
36 Netherlands	0.96	0.96	0.96	0.96	0.95	0.94	0.93	0.93	0.94	0.94	0.93
37 North Macedonia	0.97	0.96	0.96	0.93	0.89	0.82	0.83	0.75	0.75	0.63	0.70
38 Norway	0.93	0.94	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97
39 Poland	0.98	0.98	0.98	0.97	0.96	0.96	0.94	0.93	0.93	0.80	0.80
40 Portugal	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98
41 Romania	0.93	0.94	0.92	0.89	0.86	0.86	0.86	0.90	0.90	0.87	0.86

Measles	Tetanus	Hepatitis B	+/-	...							
1 Percentage	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2 Countries											
3 Albania	0.99	0.99	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.98
4 Andorra	0.99	0.99	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99	0.99
5 Armenia	0.95	0.95	0.95	0.93	0.94	0.94	0.94	0.92	0.92	0.91	0.85
6 Austria	0.89	0.92	0.95	0.98	0.93	0.87	0.90	0.85	0.85	0.85	0.85
7 Azerbaijan	0.87	0.89	0.93	0.94	0.96	0.97	0.95	0.95	0.95	0.94	0.89
8 Belarus	0.98	0.98	0.98	0.97	0.99	0.98	0.97	0.97	0.98	0.97	0.98
9 Belgium	0.98	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.98
10 Bosnia and Herzegovina	0.88	0.92	0.89	0.86	0.82	0.78	0.75	0.73	0.73	0.73	0.73
11 Bulgaria	0.95	0.95	0.95	0.88	0.91	0.92	0.92	0.92	0.93	0.91	0.89
12 Croatia	0.96	0.96	0.96	0.95	0.94	0.93	0.92	0.93	0.94	0.94	0.92
13 Cyprus	0.99	0.99	0.99	0.99	0.97	0.97	0.97	0.99	0.96	0.96	0.96
14 Czech Republic	0.99	0.99	0.98	0.97	0.97	0.96	0.96	0.97	0.97	0.97	0.94
15 Denmark	0.91	0.94	0.94	0.94	0.93	0.94	0.98	0.97	0.97	0.97	0.97
16 Estonia	0.93	0.94	0.94	0.93	0.93	0.93	0.93	0.92	0.91	0.91	0.90
17 Finland	0.99	0.99	0.98	0.98	0.97	0.92	0.89	0.91	0.91	0.90	0.89
18 France	0.99	0.99	0.99	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.96
19 Georgia	0.94	0.92	0.93	0.91	0.94	0.92	0.91	0.93	0.94	0.88	0.85
20 Germany	0.95	0.95	0.93	0.93	0.93	0.91	0.91	0.91	0.91	0.91	0.91
21 Greece	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
22 Hungary	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
23 Iceland	0.95	0.89	0.91	0.90	0.92	0.91	0.89	0.91	0.92	0.93	0.92
24 Ireland	0.95	0.95	0.96	0.96	0.95	0.95	0.95	0.94	0.94	0.94	0.94
25 Italy	0.96	0.97	0.96	0.95	0.93	0.94	0.95	0.95	0.96	0.94	0.94
26 Kazakhstan	0.99	0.99	0.98	0.95	0.98	0.82	0.99	0.98	0.97	0.88	0.95
27 Kosovo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28 Latvia	0.92	0.91	0.94	0.92	0.94	0.98	0.98	0.96	0.99	0.99	0.94
29 Liechtenstein	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30 Lithuania	0.92	0.93	0.93	0.93	0.93	0.94	0.94	0.92	0.92	0.91	0.90
31 Luxembourg	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
32 Malta	0.96	0.99	0.99	0.99	0.97	0.97	0.98	0.97	0.98	0.98	0.99
33 Moldova	0.93	0.92	0.90	0.90	0.87	0.89	0.88	0.93	0.91	0.86	0.87
34 Monaco	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
35 Montenegro	0.95	0.94	0.94	0.91	0.89	0.89	0.87	0.86	0.85	0.84	0.83

Measles	Tetanus	Hepatitis B	+/-	...
1 Percentage	2011	2012	2013	2014
2 Countries				
3 Albania	0.99	0.99	0.99	0.98
4 Andorra	0.99	0.99	0.96	0.97
5 Armenia	0.95	0.95	0.95	0.93
6 Austria	0.89	0.92	0.95	0.98
7 Azerbaijan	0.87	0.89	0.93	0.94
8 Belarus	0.98	0.98	0.98	0.97
9 Belgium	0.98	0.99	0.99	0.99
10 Bosnia and Herzegovina	0.88	0.92	0.89	0.86
11 Bulgaria	0.95	0.95	0.95	0.88
12 Croatia	0.96	0.96	0.96	0.95
13 Cyprus	0.99	0.99	0.99	0.99
14 Czech Republic	0.99	0.99	0.98	0.97
15 Denmark	0.91	0.94	0.94	0.94
16 Estonia	0.93	0.94	0.94	0.93
17 Finland	0.99	0.99	0.98	0.98
18 France	0.99	0.99	0.99	0.98
19 Georgia	0.94	0.92	0.93	0.91
20 Germany	0.95	0.95	0.93	0.93
21 Greece	0.99	0.99	0.99	0.99
22 Hungary	0.99	0.99	0.99	0.99
23 Iceland	0.95	0.89	0.91	0.90
24 Ireland	0.95	0.95	0.96	0.95
25 Italy	0.96	0.97	0.96	0.95
26 Kazakhstan	0.99	0.99	0.98	0.95
27 Kosovo	NA	NA	NA	NA
28 Latvia	0.92	0.91	0.94	0.92
29 Liechtenstein	NA	NA	NA	NA
30 Lithuania	0.92	0.93	0.93	0.93
31 Luxembourg	0.99	0.99	0.99	0.99
32 Malta	0.96	0.99	0.99	0.97
33 Moldova	0.93	0.92	0.90	0.87
34 Monaco	0.99	0.99	0.99	0.99
35 Montenegro	0.95	0.94	0.94	0.89

1 Percentage	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	202
2 Countries												
3 Albania	0.99	0.99	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.98	0.98
4 Andorra	0.99	0.96	0.94	0.95	0.94	0.94	0.99	0.98	0.98	0.98	0.98	0.98
5 Armenia	0.95	0.95	0.95	0.93	0.94	0.94	0.94	0.92	0.92	0.92	0.93	0.93
6 Austria	0.89	0.92	0.95	0.98	0.93	0.87	0.90	0.85	0.85	0.85	0.85	0.85
7 Azerbaijan	0.84	0.88	0.93	0.94	0.96	0.97	0.95	0.95	0.94	0.79	0.89	
8 Belarus	0.98	0.97	0.98	0.97	0.99	0.96	0.98	0.98	0.97	0.97	0.98	
9 Belgium	0.97	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97
10 Bosnia and Herzegovina	0.88	0.92	0.91	0.89	0.82	0.78	0.77	0.80	0.80	0.80	0.80	0.80
11 Bulgaria	0.96	0.95	0.95	0.95	0.92	0.91	0.92	0.85	0.93	0.91	0.89	
12 Croatia	0.96	0.96	0.96	0.95	0.94	0.92	0.92	0.93	0.93	0.91	0.90	
13 Cyprus	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.94	0.94	0.94	
14 Czech Republic	0.99	0.99	0.99	0.99	0.97	0.96	0.94	0.96	0.97	0.96	0.94	
15 Denmark	NA											
16 Estonia	0.94	0.94	0.93	0.93	0.91	0.93	0.92	0.93	0.91	0.90	0.84	
17 Finland	NA											
18 France	0.74	0.78	0.82	0.83	0.88	0.90	0.90	0.91	0.91	0.91	0.91	0.91
19 Georgia	0.89	0.92	0.96	0.91	0.94	0.92	0.91	0.93	0.94	0.88	0.85	
20 Germany	0.87	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.87	
21 Greece	0.95	0.98	0.98	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	
22 Hungary	NA											
23 Iceland	NA											
24 Ireland	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.93	0.94	0.93	
25 Italy	0.96	0.96	0.96	0.95	0.93	0.93	0.94	0.95	0.95	0.94	0.94	
26 Kazakhstan	0.99	0.95	0.99	0.92	0.98	0.82	0.99	0.98	0.91	0.88	0.95	
27 Kosovo	NA											
28 Latvia	0.89	0.90	0.94	0.92	0.94	0.98	0.98	0.96	0.99	0.99	0.94	
29 Liechtenstein	NA											
30 Lithuania	0.95	0.93	0.93	0.94	0.94	0.95	0.94	0.93	0.92	0.91	0.90	
31 Luxembourg	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.96	0.96	0.96	0.96	
32 Malta	0.82	0.93	0.94	0.90	0.95	0.95	0.97	0.88	0.98	0.98	0.98	0.99
33 Moldova	0.96	0.94	0.91	0.92	0.88	0.90	0.89	0.94	0.94	0.87	0.87	
34 Monaco	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
35 Montenegro	0.91	0.90	0.90	0.87	0.82	0.75	0.73	0.72	0.62	0.52	0.51	

The vaccination rates for measles, tetanus, and hepatitis B are organized into three individual sheets, with rows representing countries and columns representing years. After extracting the data into an Excel sheet, we encountered multiple "NA" entries, indicating 'Not Available.' To address these missing values, we searched online to individually fill in the missing data.

### b. Filling in Missing Values

4 Andorra	0.95	0.96	0.96	0.97	0.99	0.99	0.99	0.98	0.99	0.99	0.99
5 Armenia	0.97	0.97	0.97	0.97	0.96	0.95	0.95	0.94	0.94	0.93	0.93
6 Austria	0.92	0.96	0.96	0.95	0.96	0.94	0.95	0.95	0.95	0.95	0.94
7 Azerbaijan	0.98	0.98	0.98	0.98	0.98	0.96	0.98	0.82	0.93	0.94	0.93
8 Belarus	0.99	0.99	0.99	0.98	0.97	0.98	0.98	0.97	0.98	0.94	0.95
9 Belgium	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
10 Bosnia and Herzegovina	0.92	0.89	0.83	0.68	0.69	0.68	0.68	0.68	0.68	0.50	0.66
11 Bulgaria	0.95	0.93	0.92	0.92	0.94	0.93	0.95	0.88	0.89	0.95	0.91
12 Croatia	0.94	0.94	0.93	0.90	0.89	0.93	0.93	0.91	0.89	0.86	0.84
13 Czech Republic	0.99	0.99	0.99	0.98	0.97	0.96	0.92	0.94	0.97	0.95	0.92
14 Denmark	0.89	0.90	0.91	0.94	0.97	0.95	0.96	0.94	0.95	0.92	0.86
15 Estonia	0.94	0.93	0.93	0.93	0.93	0.87	0.88	0.91	0.89	0.91	0.71
16 Finland	0.97	0.96	0.95	0.94	0.94	0.96	0.96	0.95	0.93	0.93	0.92
17 France	0.90	0.91	0.91	0.90	0.90	0.90	0.92	0.92	0.92	0.90	0.91
18 Georgia	0.97	0.92	0.96	0.93	0.95	0.98	0.99	0.91	0.90	0.96	0.94
19 Germany	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.92	0.82
20 Greece	0.99	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.94	0.96
21 Hungary	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.92	0.90
22 Iceland	0.91	0.90	0.93	0.91	0.92	0.93	0.93	0.93	0.92	0.90	0.91
23 Ireland	0.93	0.93	0.93	0.92	0.92	0.92	0.91	0.92	0.90	0.90	0.86
24 Italy	0.90	0.87	0.85	0.87	0.92	0.93	0.94	0.92	0.92	0.95	0.95
25 Kazakhstan	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.97	0.92	0.90
26 Kosovo	0.92	0.92	0.91	0.91	0.90	0.87	0.86	0.87	0.86	0.79	0.76
27 Latvia	0.96	0.95	0.96	0.93	0.96	0.98	0.99	0.99	0.97	0.90	0.86
28 Liechtenstein	0.91	0.92	0.94	0.95	0.96	0.97	0.95	0.92	0.89	0.91	0.83
29 Lithuania	0.93	0.93	0.94	0.94	0.94	0.92	0.93	0.90	0.88	0.92	0.89
30 Luxembourg	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.95	0.95
31 Malta	0.99	0.98	0.89	0.93	0.91	0.96	0.96	0.95	0.90	0.98	0.99
32 Moldova	0.91	0.90	0.89	0.88	0.93	0.93	0.97	0.84	0.83	0.81	0.80
33 Monaco	0.91	0.90	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.90	0.90
34 Montenegro	0.88	0.76	0.64	0.47	0.58	0.42	0.33	0.24	0.18	0.49	0.56
35 Netherlands	0.96	0.96	0.95	0.94	0.93	0.93	0.94	0.94	0.93	0.94	0.93
36 North Macedonia	0.96	0.93	0.89	0.82	0.83	0.75	0.75	0.63	0.70	0.73	0.72
37 Norway	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.95	0.96
38 Poland	0.98	0.97	0.96	0.96	0.94	0.93	0.93	0.80	0.80	0.93	0.90

1	Percentage	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2	Countries											
3	Albania	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.98	0.92	0.84
4	Andorra	0.96	0.97	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.96	0.96
5	Armenia	0.95	0.93	0.94	0.94	0.94	0.92	0.92	0.91	0.85	0.90	0.90
6	Austria	0.95	0.98	0.93	0.87	0.90	0.85	0.85	0.85	0.85	0.95	0.92
7	Azerbaijan	0.93	0.94	0.96	0.97	0.95	0.95	0.94	0.79	0.89	0.91	0.90
8	Belarus	0.98	0.97	0.99	0.98	0.97	0.97	0.98	0.97	0.98	0.93	0.93
9	Belgium	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.98	0.95	0.98
10	Bosnia and Herzegovina	0.89	0.86	0.82	0.78	0.75	0.73	0.73	0.73	0.73	0.73	0.74
11	Bulgaria	0.95	0.88	0.91	0.92	0.92	0.92	0.93	0.91	0.89	0.97	0.97
12	Croatia	0.96	0.95	0.94	0.93	0.92	0.93	0.94	0.94	0.92	0.90	0.84
13	Czech Republic	0.98	0.97	0.97	0.96	0.96	0.97	0.97	0.97	0.94	0.95	0.94
14	Denmark	0.94	0.94	0.93	0.94	0.98	0.97	0.97	0.97	0.97	0.97	0.97
15	Estonia	0.94	0.93	0.93	0.93	0.93	0.92	0.91	0.91	0.90	0.93	0.91
16	Finland	0.98	0.98	0.97	0.92	0.89	0.91	0.91	0.90	0.89	0.91	0.90
17	France	0.99	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95
18	Georgia	0.93	0.91	0.94	0.92	0.91	0.93	0.94	0.88	0.85	0.94	0.94
19	Germany	0.93	0.93	0.93	0.91	0.91	0.91	0.91	0.91	0.91	0.94	0.96
20	Greece	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.94	0.95
21	Hungary	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
22	Iceland	0.91	0.90	0.92	0.91	0.89	0.91	0.92	0.93	0.92	0.99	0.99
23	Ireland	0.96	0.96	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.95
24	Italy	0.96	0.95	0.93	0.94	0.95	0.95	0.96	0.94	0.94	0.93	0.95
25	Kazakhstan	0.98	0.95	0.98	0.82	0.99	0.98	0.97	0.88	0.95	0.93	0.90
26	Kosovo	0.95	0.93	0.95	0.95	0.97	0.97	0.96	0.90	0.90	0.90	0.90
27	Latvia	0.94	0.92	0.94	0.98	0.98	0.96	0.99	0.99	0.94	0.95	0.94
28	Liechtenstein	0.92	0.95	0.95	0.95	0.96	0.94	0.95	0.90	0.90	0.87	0.90
29	Lithuania	0.93	0.93	0.93	0.94	0.94	0.92	0.92	0.91	0.90	0.87	0.90
30	Luxembourg	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.99
31	Malta	0.99	0.99	0.97	0.97	0.98	0.97	0.98	0.98	0.99	0.98	0.99
32	Moldova	0.90	0.90	0.87	0.89	0.88	0.93	0.91	0.86	0.87	0.93	0.94
33	Monaco	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
34	Montenegro	0.94	0.91	0.89	0.89	0.87	0.86	0.85	0.84	0.83	0.80	0.82
35	Netherlands	0.97	0.96	0.95	0.95	0.94	0.93	0.94	0.94	0.95	0.95	0.95

< > Measles Tetanus Hepatitis B +

Albania	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.98	0.96	0.94
Andorra	0.94	0.95	0.94	0.94	0.99	0.98	0.98	0.98	0.98	0.98	0.97
Armenia	0.95	0.93	0.94	0.94	0.94	0.92	0.92	0.92	0.92	0.93	0.96
Austria	0.95	0.98	0.93	0.87	0.90	0.85	0.85	0.85	0.85	0.85	0.88
Azerbaijan	0.93	0.94	0.96	0.97	0.95	0.95	0.94	0.79	0.89	0.94	0.97
Belarus	0.98	0.97	0.99	0.96	0.98	0.98	0.97	0.97	0.98	0.98	0.90
Belgium	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.90
Bosnia and Herzegovina	0.91	0.89	0.82	0.78	0.77	0.80	0.80	0.80	0.80	0.75	0.98
Bulgaria	0.95	0.95	0.92	0.91	0.92	0.85	0.93	0.91	0.89	0.91	0.91
Croatia	0.96	0.95	0.94	0.92	0.92	0.93	0.93	0.91	0.90	0.95	0.92
Czech Republic	0.99	0.99	0.97	0.96	0.94	0.96	0.97	0.96	0.94	0.94	0.94
Denmark	0.97	0.96	0.96	0.97	0.99	0.97	0.97	0.97	0.98	0.97	0.97
Estonia	0.93	0.93	0.91	0.93	0.92	0.93	0.91	0.90	0.84	0.95	0.98
Finland	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.99	0.99
France	0.82	0.83	0.88	0.90	0.90	0.91	0.91	0.91	0.91	0.97	0.95
Georgia	0.96	0.91	0.94	0.92	0.91	0.93	0.94	0.88	0.85	0.85	0.90
Germany	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.87	0.90	0.95
Greece	0.98	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.99	0.99
Hungary	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.97	0.96	0.96	0.96
Iceland	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.96
Ireland	0.95	0.95	0.95	0.95	0.95	0.94	0.93	0.94	0.93	0.94	0.92
Italy	0.96	0.95	0.93	0.93	0.94	0.95	0.95	0.94	0.94	0.95	0.95
Kazakhstan	0.99	0.92	0.98	0.82	0.99	0.98	0.91	0.88	0.95	0.94	0.93
Kosovo	0.86	0.88	0.90	0.80	0.90	0.97	0.90	0.91	0.89	0.90	0.89
Latvia	0.94	0.92	0.94	0.98	0.98	0.96	0.99	0.99	0.94	0.94	0.94
Liechtenstein	0.95	0.94	0.94	0.96	0.97	0.95	0.94	0.93	0.91	0.90	0.92
Lithuania	0.93	0.94	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.90	0.90
Luxembourg	0.94	0.94	0.94	0.94	0.94	0.96	0.96	0.96	0.96	0.95	0.94
Malta	0.94	0.90	0.95	0.97	0.88	0.98	0.98	0.98	0.99	0.99	0.99
Moldova	0.91	0.92	0.88	0.90	0.89	0.94	0.94	0.87	0.87	0.84	0.86
Monaco	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.97
Montenegro	0.90	0.87	0.82	0.75	0.73	0.72	0.62	0.52	0.51	0.72	0.72
Netherlands	0.51	0.94	0.94	0.93	0.92	0.92	0.92	0.93	0.93	0.90	0.91

< > Measles Tetanus Hepatitis B +

We used online searches via Google and partially consulted ChatGPT to fully fill in the missing values for the three diseases across all countries and years.

## 2.2.4 Data Processing for Vaccination Costs

The initial dataset is in the form of a table, with the vaccination costs of different suppliers given in US dollars, based off the number of doses. The prices are provided on a per dose basis, 5 doses, and 10 doses.

The dataset has vaccine prices from countries such as India, Indonesia, France, UK, and Canada.

Measles														
2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
\$0.2150	\$0.2190	\$0.2250	\$0.2300	\$0.2370	\$0.2370	\$0.2370	\$0.2370	\$0.2500	\$0.2600	\$0.2700	\$0.3100	\$0.3200	\$0.3400	\$0.3400
\$0.4250	\$0.4500	\$0.4750	\$0.5000											
\$0.2400	\$0.2520	\$0.2650	\$0.2790	\$0.2790	\$0.308-\$0.318	\$0.3180	\$0.3180	\$0.3500	\$0.3850	\$0.4230				
											\$0.4600	\$0.4600	\$0.4900	\$0.4900
						\$0.3960	\$0.3960	\$0.3960	\$0.4340	\$0.4760	\$0.5220			
												\$0.5700	\$0.5700	\$0.6200
														\$0.6200
2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023				
\$0.1175	\$0.1195	\$0.1225	\$0.1400	\$0.1590	\$0.1670									
						\$0.1600	\$0.1600	\$0.1650	\$0.1650	\$0.1650	\$0.1650	\$0.1750		
												\$0.1750	\$0.1750	\$0.2050
\$0.1100	\$0.1150	\$0.1150												
							\$0.1800	\$0.1800						
\$0.1600	\$0.1600	\$0.1600												
\$0.1730	\$0.1730	\$0.1730	\$0.1750	\$0.1750	\$0.1750	\$0.2500	\$0.2500	\$0.2500	\$0.2500	\$0.2600				
						\$0.2000	\$0.2000	\$0.2000	\$0.2400	\$0.2400	\$0.2400	\$0.2400		
													\$0.2400	
							\$0.3000	\$0.3000	\$0.7000	\$0.7000	\$0.7000	\$0.7000		
													\$0.7000	
														\$0.3300

As this visualization is focused on European countries, we will only take the pricing data from these countries. First, the pricing data that is presented in the form of 5 doses or 10 doses are calculated for their price per dose. Then, the average is calculated from all the European country data available.

Year	HepatitisA	Measles	Tetanus
2013	0.0519	0.024	0.05688
2014	0.0519	0.0252	0.05863
2015	0.0519	0.0265	0.05688
2016	0.0525	0.0279	0.07
2017	0.0525	0.0279	0.0795
2018	0.0525	0.0318	0.08175
2019	0.075	0.0318	0.085
2020	0.075	0.0318	0.08625
2021	0.075	0.035	0.085
2022	0.075	0.0385	0.085
2023	0.078	0.0423	0.095

The data is then arranged as shown in the image above, with the columns showing the years and diseases.

#### 2.2.4 Data Processing for Population European countries

The initial dataset is in World Bank Group website, and require to filter and download.

The screenshot shows the World Bank DataBank interface. At the top, there is a blue header bar with the World Bank Group logo and a button to 'Help us improve this section of the site'. Below the header, the title 'DataBank | Population estimates and proj...' is displayed. A navigation bar at the top right includes icons for 'Variables' (selected), 'Layout', 'Styles', 'Save', 'Share', and 'Embed'. On the left, there is a sidebar with four filter categories: 'Database' (Available 86, Selected 1), 'Country' (Available 266, Selected 0), 'Series' (Available 0, Selected 0), and 'Time' (Available 0, Selected 0). To the right of the filters, there are buttons for 'Clear Selection' and a gear icon for settings.

There are 4 filters that need to be selected.

▼ Database

Available 4 | Selected 1

Database preview

Population estimates and projections

Health Nutrition and Population Statistics

Health Nutrition and Population Statistics by Wealth Quintile

Firstly, need to select the population

Country

Available 4 | Selected 1

Search Rus

B C R

<input type="checkbox"/>	Belarus
<input type="checkbox"/>	Cyprus
<input checked="" type="checkbox"/>	Russian Federation

Second, select the countries needed, I selected all the Russian available (Picture for reference).

Thirdly, select the total population.

▼ Time      Available 91 | Selected 11

Availability Range: Year [1960 - 2050]

Enter Keywords for

VIEW RECENT YEARS 5 10 15 20 25 50

<input type="checkbox"/> 2047	<input type="checkbox"/> 2024	<input type="checkbox"/> 2001	<input type="checkbox"/> 1978
<input type="checkbox"/> 2046	<input checked="" type="checkbox"/> 2023	<input type="checkbox"/> 2000	<input type="checkbox"/> 1977
<input type="checkbox"/> 2045	<input checked="" type="checkbox"/> 2022	<input type="checkbox"/> 1999	<input type="checkbox"/> 1976
<input type="checkbox"/> 2044	<input checked="" type="checkbox"/> 2021	<input type="checkbox"/> 1998	<input type="checkbox"/> 1975
<input type="checkbox"/> 2043	<input checked="" type="checkbox"/> 2020	<input type="checkbox"/> 1997	<input type="checkbox"/> 1974
<input type="checkbox"/> 2042	<input checked="" type="checkbox"/> 2019	<input type="checkbox"/> 1996	<input type="checkbox"/> 1973
<input type="checkbox"/> 2041	<input checked="" type="checkbox"/> 2018	<input type="checkbox"/> 1995	<input type="checkbox"/> 1972

Select the time series from 2013 to 2023.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P		
1	Country	Country	Series	Nar	Series	Coc	2013	[YR2014]	[YR2015]	[YR2016]	[YR2017]	[YR2018]	[YR2019]	[YR2020]	[YR2021]	[YR2022]	[YR2023]
2	France	FRA	Population	SP.POP.TC	66002289	66312067	66548272	66724104	66918020	67158348	67388001	67571107	67764304	67971311	68170228		
3	Poland	POL	Population	SP.POP.TC	38040196	38011735	37986412	37970087	37974826	37974750	37965475	37899070	37747124	36821749	36685849		
4	Luxembou	LUX	Population	SP.POP.TC	543360	556319	569604	582014	596336	607950	620001	630419	640064	653103	668606		
5	Estonia	EST	Population	SP.POP.TC	1317997	1314545	1315407	1315790	1317384	1321977	1326898	1329522	1330932	1348840	1366188		
6	Sweden	SWE	Population	SP.POP.TC	9600379	9696110	9799186	9923085	10057698	10175214	10278887	10353442	10415811	10486941	10536632		
7	Bulgaria	BGR	Population	SP.POP.TC	7265115	7223938	7177991	7127822	7075947	7025037	6975761	6934015	6877743	6465097	6430370		
8	United Kin	GBR	Population	SP.POP.TC	64128273	64602298	65116219	65611593	66058859	66460344	66836327	67081234	67026292	67791000	68350000		
9	Hungary	HUN	Population	SP.POP.TC	9893082	9866468	9843028	9814023	9787966	9775564	9771141	9750149	9709891	9643048	9589872		
10	Germany	DEU	Population	SP.POP.TC	80645605	80982500	81686611	82348669	82657002	82905782	83092962	83160871	83196078	83797985	84482267		
11	Spain	ESP	Population	SP.POP.TC	46620045	46480882	46444832	46484062	46593236	46797754	47134837	47365655	47415794	47778340	48373336		
12	Russian F	RUS	Population	SP.POP.TC	1.44E+08	1.44E+08	1.45E+08	1.44E+08	1.44E+08								
13	Romania	ROU	Population	SP.POP.TC	19983693	19908979	19815616	19702267	19588715	19473970	19371648	19265250	19122059	19047009	19056116		
14	Italy	ITA	Population	SP.POP.TC	60233948	60789140	60730582	60627498	60536709	60421760	59729081	59438851	59133173	58940425	58761146		
15	Greece	GRC	Population	SP.POP.TC	10965211	10892413	10820883	10775971	10754679	10732882	10721582	10698599	10569207	10426919	10361295		

After downloading the csv file, the data contains excess columns such as Country Code (2nd column), Series Name (3rd column), and the Series Code (4th column). The column for the years, the header is not only the years, but it also contains additional and useless information such as [YR2023], [YR2022]. I then delete the unwanted column and rename the attributes to only the year (2013, 2014, 2015....)

A	B	C	D	E	F	G	H	I	J	K	L	
1	Country Name	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2	France	66002289	66312067	66548272	66724104	66918020	67158348	67388001	67571107	67764304	67971311	68170228
3	Poland	38040196	38011735	37986412	37970087	37974826	37974750	37965475	37899070	37747124	36821749	36685849
4	Luxembou	543360	556319	569604	582014	596336	607950	620001	630419	640064	653103	668606
5	Estonia	1317997	1314545	1315407	1315790	1317384	1321977	1326898	1329522	1330932	1348840	1366188
6	Sweden	9600379	9696110	9799186	9923085	10057698	10175214	10278887	10353442	10415811	10486941	10536632
7	Bulgaria	7265115	7223938	7177991	7127822	7075947	7025037	6975761	6934015	6877743	6465097	6430370
8	United Kin	64128273	64602298	65116219	65611593	66058859	66460344	66836327	67081234	67026292	67791000	68350000
9	Hungary	9893082	9866468	9843028	9814023	9787966	9775564	9771141	9750149	9709891	9643048	9589872
10	Germany	80645605	80982500	81686611	82348669	82657002	82905782	83092962	83160871	83196078	83797985	84482267
11	Spain	46620045	46480882	46444832	46484062	46593236	46797754	47134837	47365655	47415794	47778340	48373336
12	Russia	1.44E+08	1.44E+08	1.45E+08	1.44E+08	1.44E+08						
13	Romania	19983693	19908979	19815616	19702267	19588715	19473970	19371648	19265250	19122059	19047009	19056116
14	Italy	60233948	60789140	60730582	60627498	60536709	60421760	59729081	59438851	59133173	58940425	58761146
15	Greece	10965211	10892413	10820883	10775971	10754679	10732882	10721582	10698599	10569207	10426919	10361295
16	Austria	84170823	8516356	8612690	8736668	8797566	8840521	8870020	8916861	8955797	9041851	9132383

This is the final dataset.

## 2.2.4 Data Processing for Healthcare Expenditure

The data for healthcare expenditure is first extracted into an excel file from World Bank Group, as shown below.

Series Name	Se Country Name	Country Code	2017 [YR2017]	2018 [YR2018]	2019 [YR2019]	2020 [YR2020]	2016 [YR2016]
Current health expenditure (% of GDP)	Albania	ALB	6.57848787	6.66844559	6.86214113	7.51920271	6.7293272
Current health expenditure (% of GDP)	Andorra	AND	7.07142639	7.37541723	7.323246	8.78673935	6.90521765
Current health expenditure (% of GDP)	Armenia	ARM	10.36	10.01	11.38	12.24	9.95
Current health expenditure (% of GDP)	Austria	AUT	10.38	10.35	10.49	11.39	10.35
Current health expenditure (% of GDP)	Azerbaijan	AZE	4.07	3.84	4.18	5.85	4.42
Current health expenditure (% of GDP)	Belarus	BLR	5.76	5.53	5.86	6.41	5.91
Current health expenditure (% of GDP)	Belgium	BEL	10.79855728	10.86148262	10.79477787	11.19751263	10.79354668
Current health expenditure (% of GDP)	Bosnia and Herzegovina	BIH	8.82	8.76	8.93	9.7	9.14
Current health expenditure (% of GDP)	Bulgaria	BGR	7.49	7.33	7.09	8.48	7.46
Current health expenditure (% of GDP)	Croatia	HRV	6.66	6.75	6.8	7.72	6.73
Current health expenditure (% of GDP)	Czechia	CZE	7.38071585	7.47048092	7.60336018	9.2136879	7.44554329
Current health expenditure (% of GDP)	Denmark	DNK	10.1	10.1	10.15	10.56	10.25
Current health expenditure (% of GDP)	Estonia	EST	6.59727097	6.6912818	6.81699181	7.57906532	6.70240974
Current health expenditure (% of GDP)	Finland	FIN	9.13	9.05	9.17	9.63	9.38
Current health expenditure (% of GDP)	France	FRA	11.35469437	11.20798969	11.0888586	12.13096142	11.47060013
Current health expenditure (% of GDP)	Georgia	GEO	7.06	7.11	6.66	8.43	8
Current health expenditure (% of GDP)	Germany	DEU	11.33617592	11.48051548	11.71550655	12.69255257	11.241889
Current health expenditure (% of GDP)	Greece	GRC	8.13515854	8.12024307	8.19811249	9.50363827	8.44874668
Current health expenditure (% of GDP)	Hungary	HUN	6.74	6.58	6.28	7.29	6.99
Current health expenditure (% of GDP)	Iceland	ISL	8.26	8.38	8.58	9.61	8.1
Current health expenditure (% of GDP)	Ireland	IRL	7.12621927	6.49550152	6.7090106	7.1091466	7.46859169
Current health expenditure (% of GDP)	Italy	ITA	8.68	8.68	8.66	9.63	8.73

For this dataset, we need to have the data for country, year, disease, GDP, vaccination coverage, and of course healthcare expenditure. The dataset will be produced by combining the data from the various datasets processed previously by our team, into a table with the following structure:

Country	Year	Disease	GDP	Vaccination Coverage	Healthcare Expenditure

The following datasets were used:

## 1. Vaccination Coverage

A	B	C	D	E	F	G	H	I	J	K	L
Percentage	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Countries											
Albania	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.98	0.98	0.96	0.94
Andorra	0.94	0.95	0.94	0.94	0.99	0.98	0.98	0.98	0.98	0.98	0.97
Armenia	0.95	0.93	0.94	0.94	0.94	0.92	0.92	0.92	0.93	0.96	0.96
Austria	0.95	0.98	0.93	0.87	0.90	0.85	0.85	0.85	0.85	0.95	0.88
Azerbaijan	0.93	0.94	0.96	0.97	0.95	0.95	0.94	0.79	0.89	0.94	0.97
Belarus	0.98	0.97	0.99	0.96	0.98	0.98	0.97	0.97	0.98	0.90	0.98
Belgium	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.90
Bosnia and Herzegovina	0.91	0.89	0.82	0.78	0.77	0.80	0.80	0.80	0.80	0.75	0.98
Bulgaria	0.95	0.95	0.92	0.91	0.92	0.85	0.93	0.91	0.89	0.91	0.91
Croatia	0.96	0.95	0.94	0.92	0.92	0.93	0.93	0.91	0.90	0.95	0.92
Czech Republic	0.99	0.99	0.97	0.96	0.94	0.96	0.97	0.96	0.94	0.94	0.94
Denmark	0.97	0.96	0.96	0.97	0.99	0.97	0.97	0.97	0.98	0.97	0.97
Estonia	0.93	0.93	0.91	0.93	0.92	0.93	0.91	0.90	0.84	0.95	0.98
Finland	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.99	0.99
France	0.82	0.83	0.88	0.90	0.90	0.91	0.91	0.91	0.91	0.97	0.95
Georgia	0.96	0.91	0.94	0.92	0.91	0.93	0.94	0.88	0.85	0.85	0.90
Germany	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.87	0.90	0.95
Greece	0.98	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.99	0.99
Hungary	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.97	0.96	0.96	0.96
Iceland	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.96	0.96
Ireland	0.95	0.95	0.95	0.95	0.95	0.94	0.93	0.94	0.93	0.94	0.92
Italy	0.96	0.95	0.93	0.93	0.94	0.95	0.95	0.94	0.94	0.95	0.95
Kazakhstan	0.99	0.92	0.98	0.82	0.99	0.98	0.91	0.88	0.95	0.94	0.93
Kosovo	0.86	0.88	0.90	0.80	0.90	0.97	0.90	0.91	0.89	0.90	0.89
Latvia	0.94	0.92	0.94	0.98	0.98	0.96	0.99	0.99	0.94	0.94	0.94
Liechtenstein	0.95	0.94	0.94	0.96	0.97	0.95	0.94	0.93	0.91	0.90	0.92
Lithuania	0.93	0.94	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.90	0.90
Luxembourg	0.94	0.94	0.94	0.94	0.94	0.96	0.96	0.96	0.96	0.95	0.94
Malta	0.94	0.90	0.95	0.97	0.88	0.98	0.98	0.98	0.99	0.99	0.99
Moldova	0.91	0.92	0.88	0.90	0.89	0.94	0.94	0.87	0.87	0.84	0.86

< > Measles | Tetanus | Hepatitis B | +

## 2. European Country GDPs

Time period	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Countries											
Albania	11361.00	11587.00	11878.00	12292.00	12771.00	13317.00	13653.00	13278.00	14596.00	15492.00	
Andorra											
Armenia	10677.00	11106.00	11506.00	11580.00	12510.00	13231.00	14318.00	13358.00	14207.00	155867.00	
Austria	47936.68	48813.53	49942.06	52665.09	54188.36	56956.11	60590.20	58610.93	63451.49	70889.43	73743.97
Azerbaijan	14652.00	14868.00	14853.00	14232.00	14121.00	14210.00	14442.00	13727.00	14434.00	15094.00	
Belarus	18805.00	19119.00	18363.00	49830.00	18356.00	18975.00	19288.00	19240.00	19873.00	19092.00	
Belgium	43672.71	44929.93	46201.69	48599.20	50442.95	52530.84	56621.43	55729.03	62124.24	68308.21	70830.91
Bosnia and Herzegovina	11483.00	11767.00	12438.00	13001.00	13582.00	14268.00	14852.00	14588.00	15893.00	16737.00	
Bulgaria	18915.00	19203.00	19983.00	20733.00	21458.00	22196.00	23255.00	22467.00	24386.00	26961.00	
Croatia	25484.00	24170.00	24985.00	26056.00	27268.00	28288.00	29412.00	27002.00	32061.00	34302.00	
Czech Republic	31048.12	32810.69	34217.98	36627.61	39620.87	42016.46	46139.56	45675.06	50019.14	53270.20	55803.22
Denmark	46883.13	47880.69	48906.11	51814.24	55270.42	57231.33	60568.74	62700.58	70370.11	78255.73	77223.38
Estonia	27784.71	29375.59	29760.31	31945.12	34553.45	37201.04	40650.01	40685.53	45083.85	49130.00	49652.99
Finland	41492.92	41749.86	42490.21	44934.49	47570.27	49573.26	52569.86	53657.58	57783.83	62590.08	64496.64
France	39772.37	40395.67	41049.73	42983.75	44527.55	46397.54	51119.65	49462.66	53878.48	57860.34	61473.32
Georgia	11739.00	12254.00	12605.00	12964.00	13590.00	14253.00	14989.00	13966.00	15487.00	17078.00	
Germany	44993.67	47011.28	47609.56	50579.48	53071.48	55195.72	58251.74	57905.09	61939.72	66616.05	69329.87
Greece	25986.64	26625.16	26760.28	27511.80	28604.83	29617.52	31611.26	29088.26	32797.28	38364.49	40521.06
Hungary	24547.98	25691.53	26798.85	27941.93	29496.16	31908.86	35152.60	35029.91	38648.00	43394.76	45941.05
Iceland	45243.08	46853.65	50158.55	54477.41	56644.70	58342.55	62031.41	57404.39	63837.75	75834.46	80449.13
Ireland	48878.66	52700.50	71682.51	73170.44	80556.53	86433.67	92189.16	97903.15	116741.57	135774.00	128156.55

The first step in the process was to look at the rows in the healthcare expenditure files that were extracted from the World Bank Group, and extract the list of countries, as well as their years and healthcare expenditure.

country	year	disease	gdp_per_capita	vaccination_coverage	health_expenditure_percentage
Albania	2016	measles			6.7
Andorra	2016	measles			6.9
Armenia	2016	measles			10.9
Austria	2016	measles			10.4
Azerbaijan	2016	measles			4.4
Belarus	2016	measles			5.9
Belgium	2016	measles			10.8
Bosnia and Herzegovina	2016	measles			9.1
Bulgaria	2016	measles			7.5
Croatia	2016	measles			6.7
Czech Rep	2016	measles			7.4
Denmark	2016	measles			10.3
Estonia	2016	measles			6.7
Finland	2016	measles			9.4
France	2016	measles			11.5
Georgia	2016	measles			8
Germany	2016	measles			11.2
Greece	2016	measles			8.4
Hungary	2016	measles			7
Iceland	2016	measles			8.1
Ireland	2016	measles			7.5

Next, we compare each row to the European country GDPs and vaccination coverage files to fill in the rest of the chart.

country	year	disease	gdp_per_capita	vaccination_coverage	health_expenditure_percentage
Albania	2016	measles	12292	0.96	6.7
Andorra	2016	measles	11580	0.97	6.9
Armenia	2016	measles	52665.09	0.97	10.9
Austria	2016	measles	14232	0.95	10.4
Azerbaijan	2016	measles	49830	0.98	4.4
Belarus	2016	measles	48599.2	0.98	5.9
Belgium	2016	measles	13001	0.96	10.8
Bosnia and Herzegovina	2016	measles	20733	0.68	9.1
Bulgaria	2016	measles	26056	0.92	7.5
Croatia	2016	measles	36627.61	0.9	6.7
Czech Rep	2016	measles	51814.24	0.98	7.4
Denmark	2016	measles	31945.12	0.94	10.3
Estonia	2016	measles	44934.49	0.93	6.7
Finland	2016	measles	42983.75	0.94	9.4
France	2016	measles	12964	0.9	11.5
Georgia	2016	measles	50579.48	0.93	8
Germany	2016	measles	27511.8	0.97	11.2
Greece	2016	measles	27941.93	0.97	8.4
Hungary	2016	measles	54477.41	0.99	7
Iceland	2016	measles	73170.44	0.91	8.1

Finally, we limited the decimals in the healthcare expenditure column to 2 decimal places by selecting the Number Format option on Excel and selecting more formats. Here, we set it to two decimal places.



This is how the data looks before and after.

	2016	measles	25491.00	0.98	8.23
Russia	2016	measles	58433.00	0.82	8.4219532
Slovenia	2016	measles	16183.00	0.82	8.45890999
Spain	2016	measles	29737.53	0.95	7.09
Sweden	2016	measles	33581.83	0.92	8.46
Switzerland	2016	measles	37333.06	0.97	8.94727325
Turkey	2016	measles	50289.79	0.97	10.85
Ukraine	2016	measles	67350.74	0.94	10.9900341
United Kingdom	2016	measles	26695.91	0.98	4.28
	2016	measles	11536.00	0.42	7.55
	2016	measles	44057.69	0.92	9.72899723
	2016	measles	25491.00	0.98	5.29
Before	2016	measles	58433.00	0.82	8.42
Slovenia	2016	measles	16183.00	0.82	8.45
Spain	2016	measles	29737.53	0.95	7.09
Sweden	2016	measles	33581.83	0.92	8.46
Switzerland	2016	measles	37333.06	0.97	8.95
Turkey	2016	measles	50289.79	0.97	10.85
Ukraine	2016	measles	67350.74	0.94	10.99
United Kingdom	2016	measles	26695.91	0.98	4.28
	2016	measles	11536.00	0.42	7.55
	2016	measles	44057.69	0.92	9.73
	2016	measles	25491.00	0.98	5.29
After	2016	measles	58433.00	0.82	8.42
Slovenia	2016	measles	16183.00	0.82	8.45
Spain	2016	measles	29737.53	0.95	7.09
Sweden	2016	measles	33581.83	0.92	8.46
Switzerland	2016	measles	37333.06	0.97	8.95
Turkey	2016	measles	50289.79	0.97	10.85
Ukraine	2016	measles	67350.74	0.94	10.99
United Kingdom	2016	measles	26695.91	0.98	4.28
	2016	measles	11536.00	0.42	7.55
	2016	measles	44057.69	0.92	9.73

The final dataset has 679 rows of data.

country	year	disease	gdp_per_capita	vaccination_coverage	health_expenditure_percentage	
Albania	2016	measles	12292	0.96	6.70	
Andorra	2016	measles	11580	0.97	6.90	
Armenia	2016	measles	52665.09	0.97	10.90	
Austria	2016	measles	14232	0.95	10.40	
Azerbaijan	2016	measles	49830	0.98	4.40	
Belarus	2016	measles	48593.2	0.98	5.90	
Belgium	2016	measles	13001	0.96	10.80	
Bosnia and Herzegovina	2016	measles	20733	0.68	9.10	
Bulgaria	2016	measles	26056	0.92	7.50	
Croatia	2016	measles	36627.61	0.9	6.70	
Czech Republic	2016	measles	51814.24	0.98	7.40	
Denmark	2016	measles	31945.12	0.94	10.30	
Estonia	2016	measles	44934.49	0.93	6.70	
Finland	2016	measles	42983.75	0.94	9.40	
France	2016	measles	12964	0.9	11.50	
Georgia	2016	measles	50579.48	0.93	8.00	
Germany	2016	measles	27511.8	0.97	11.20	
Greece	2016	measles	27941.93	0.97	8.40	
Hungary	2016	measles	54477.41	0.99	7.00	
Iceland	2016	measles	73170.44	0.91	8.10	
Ireland	2016	measles	40267.22	0.92	7.50	
Italy	2016	measles	24211	0.87	8.70	
Kazakhstan	2016	measles	10031	0.99	3.40	
Latvia	2016	measles	26724.54	0.93	6.10	
Lithuania	2016	measles	30925.26	0.94	6.60	
Luxembourg	2016	measles	112955.47	0.99	5.10	
Malta	2016	measles	40319	0.93	9.00	
Moldova	2016	measles	10816	0.88	7.50	
Montenegro	2016	measles	18798	0.47	8.60	
Netherlands	2016	measles	53163.28	0.94	10.06	
North Macedonia	2016	measles	15554	0.82	6.38	
Norway	2016	measles	59263.43	0.96	10.53	
Poland	2016	measles	27830.93	0.96	6.59	
Portugal	2016	measles	31607.76	0.98	9.39	
Romania	2016	measles	24759	0.86	5.08	
Russia	2016	measles	25491	0.98	5.29	
San Marino	2016	measles	58433	0.82	8.42	
Serbia	2016	measles	16183	0.82	8.45	
Slovakia	2016	measles	29737.53	0.95	7.09	
Slovenia	2016	measles	33581.83	0.92	8.46	
Spain	2016	measles	37333.06	0.97	8.95	
Sweden	2016	measles	50289.79	0.97	10.85	
Switzerland	2016	measles	67350.74	0.94	10.99	
Turkey	2016	measles	26695.91	0.98	4.28	

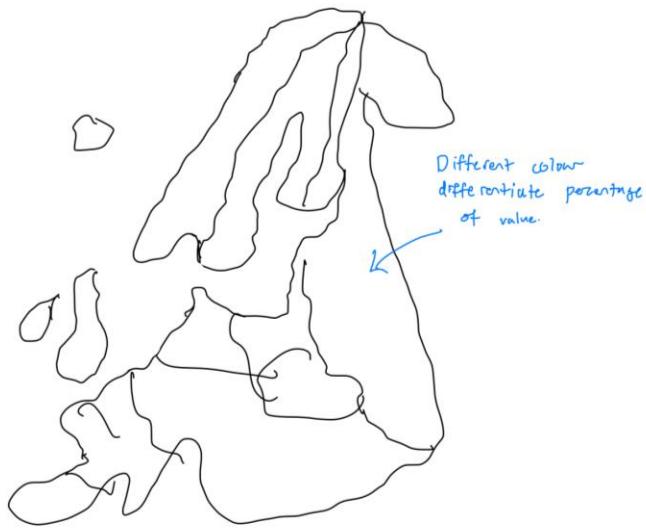
## 2.2.5 Data Processing for Incidence Rate

The dataset takes the three files extracted

### **3. Visualization Design**

#### **3.1 Low-Fidelity Design Sketching**

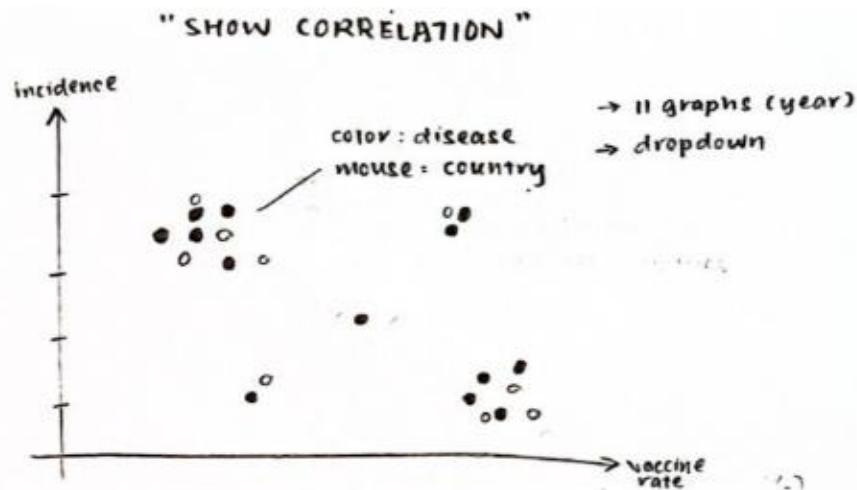
##### **3.1.1 Map for European Countries**



This is a preliminary sketch of the Europe map, designed to visualize vaccination coverage across European countries. The map will use a color gradient to represent varying levels of vaccination coverage, with darker shades indicating higher vaccination percentages. The color intensity will increase as the coverage percentage rises, allowing for a clear comparison of vaccine distribution across the region.

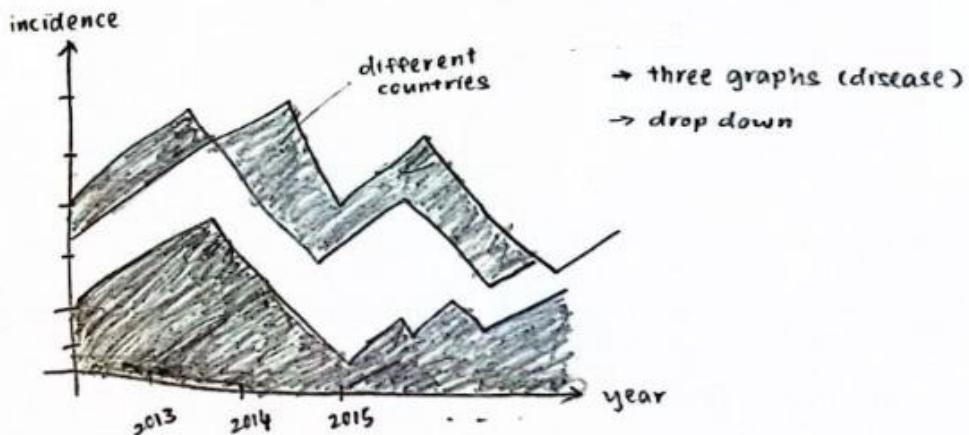
### 3.1.2 Vaccination Rates in European Countries

#### Design 1: Scatter Plot



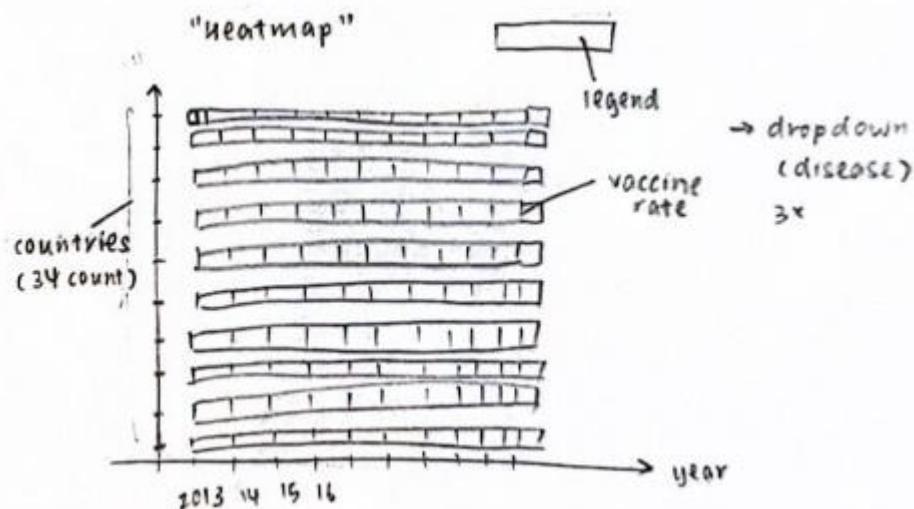
The initial design for visualizing vaccination rates in each country was to use a scatter plot that also displayed the correlation between vaccination rates with the number of reported incidences for each disease from 2013 to 2023. The y-axis represents the number of reported incidences, while the x-axis represents the vaccine rates. This design would include a total of 11 graphs, it would allow users to select the desired years from a drop-down menu. The points on the chart represented countries, with colors differentiating the diseases. Additionally, a mouse-over effect was included to display the country names for each point.

#### Design 2: Area Chart

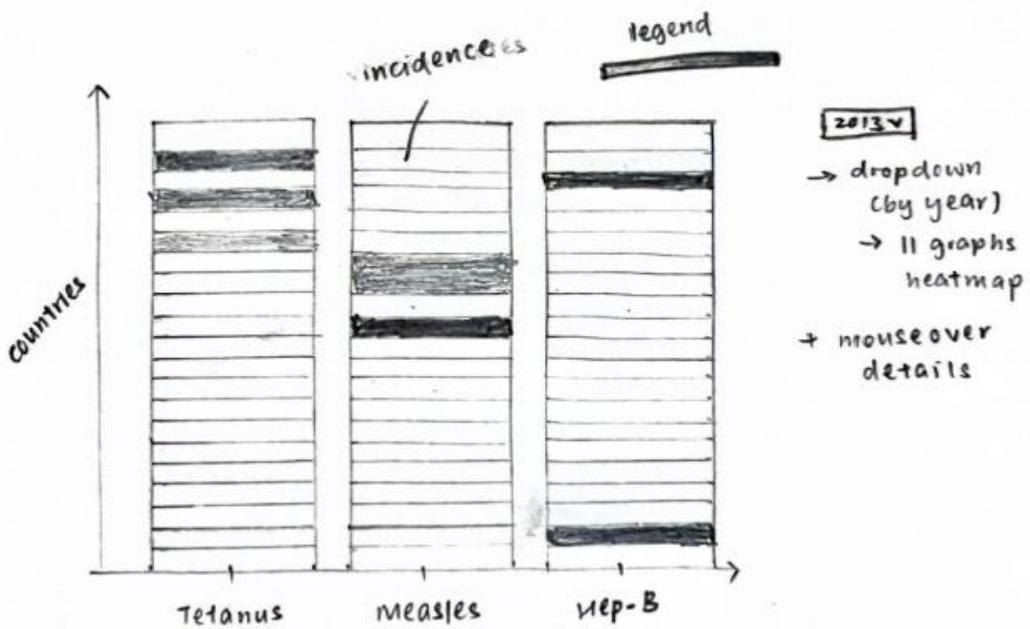


The second design option we considered was to visualize the number of reported incidences over the years in different countries using area charts. The design planned to have the number of reported incidences scaled on the y-axis, while the x-axis displayed the years from 2013 to 2023. The colors on the area charts would represent different countries, possibly labeled with their names. Additionally, there would be three separate graphs, one for each disease, selectable from a drop-down menu.

### *Design 3: Heatmap*



The third design option we considered for visualizing the vaccination rates dataset was a heatmap. However, the concept evolved after we started coding it. The initial draft of the heatmap was designed with countries on the y-axis and years on the x-axis, where each cell displayed a color tone representing the vaccination rates. A color legend was included to help users interpret the heatmap. Additionally, a drop-down menu was provided with three options, allowing users to select the disease they wanted to visualize.

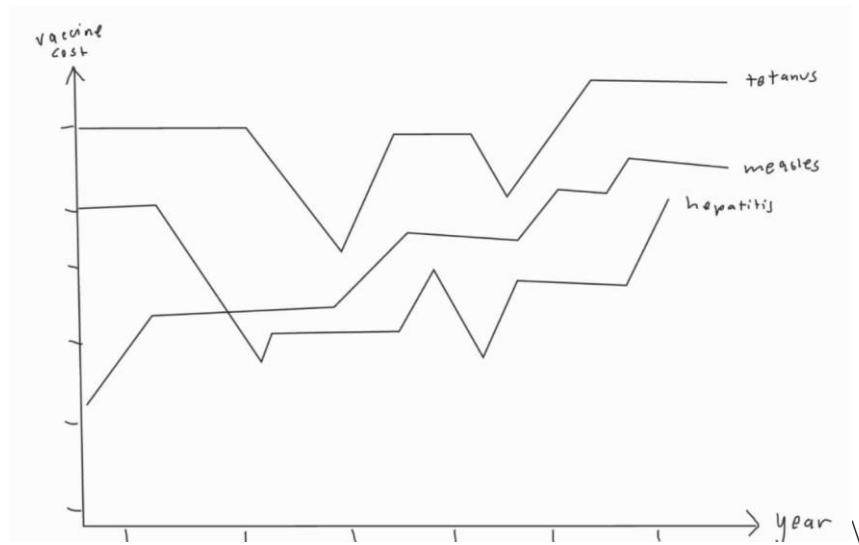


The second draft, which is also our final version of the heatmap, is shown above. The y-axis still represents countries, but the x-axis has been changed to display diseases. Additionally, after realizing that similar data was presented in the Europe map, we decided to modify the cells in the heatmap to indicate reported incidences instead of vaccination rates, using color tones. A color legend has been positioned in the top right corner to help users interpret the data. This final draft includes 11 maps, each representing data for a specific year from 2013 to 2023. Notably, in certain years, particularly the earlier ones, only two diseases are represented. Furthermore, the design features a mouse-over effect that allows users to view detailed information when hovering over each cell, including the country name, vaccination rate, disease, and number of reported incidences.

### 3.1.3 Vaccination Costs Over Time

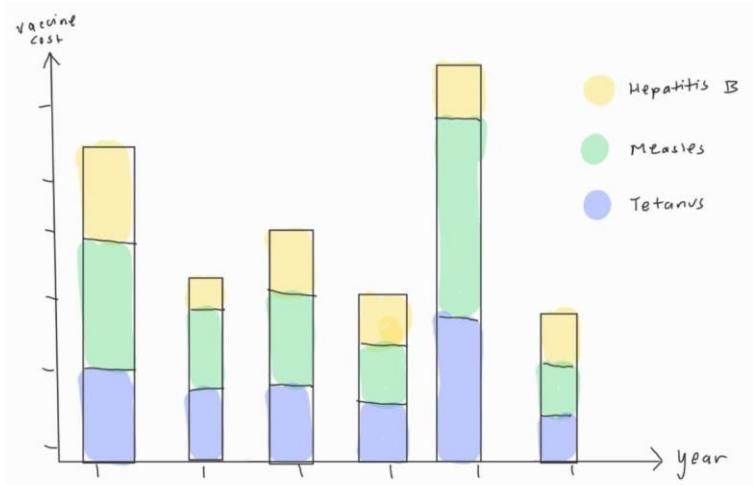
To effectively represent vaccine costs over time, we considered multiple visualization designs, including a line chart and a stacked bar chart.

*Design 1: Line Chart*



The line chart features year on the x-axis and vaccine costs on the y-axis, with distinct lines representing different vaccines. This design effectively uses position as a visual encoding to reveal trends over time, such as increases, decreases, or periodic fluctuations. Line charts are intuitive for time-series data and make it easy to compare patterns across categories.

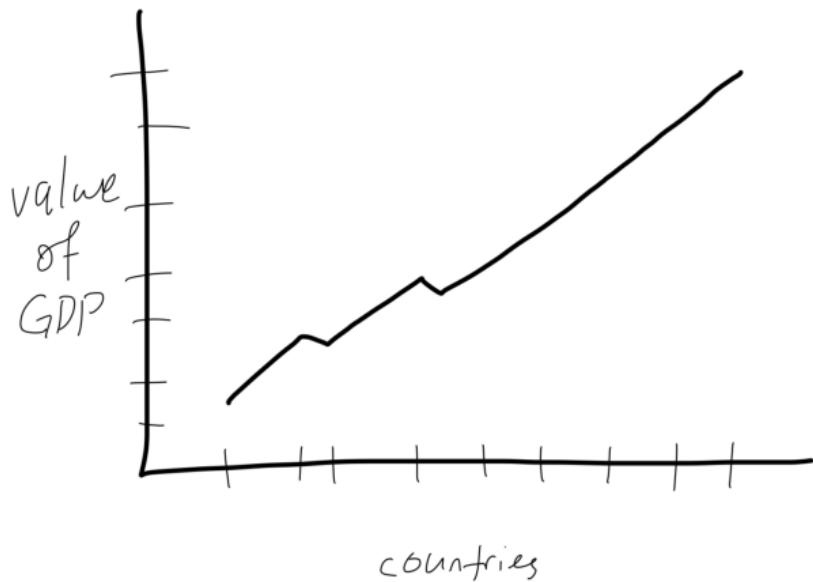
*Design 2: Stacked Bar Chart*



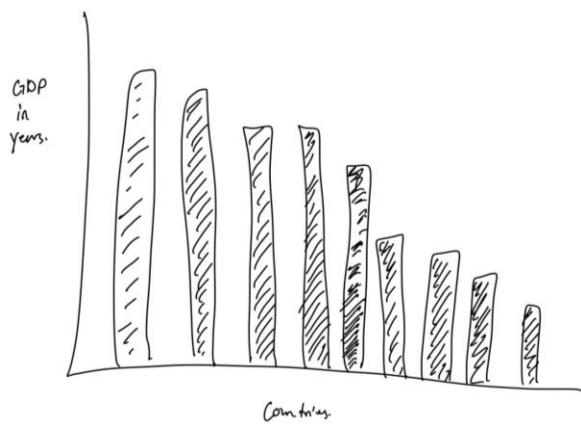
The second design we considered, the stacked bar chart, places time on the x-axis and total vaccine costs on the y-axis, with bars segmented by vaccine type. This design uses height to encode total costs and color to show the contribution of each vaccine to the overall figure.

Stacked bar charts are particularly effective for understanding proportional contributions and tracking cumulative trends over time. While less effective at highlighting trends within individual vaccine types, this chart type excels in showing how different categories contribute to overall costs.

### 3.1.4 Country GDP Over the Years



Line chart is being considered to represent the flow of GDP. The y-axis is to represent the value of GDP, and the x-axis display the countries in Europe. It is then change to bar chart because there are many countries to be present at x-axis. If there are too many data points or lines, the chart can become cluttered and hard to read.

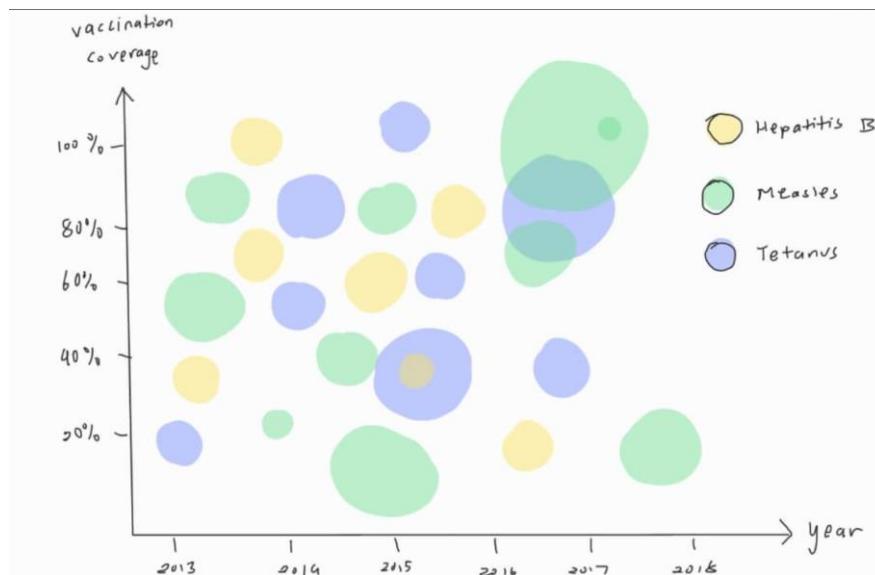


This is a sketch of a bar chart designed to visualize the GDP of European countries over the years. The y-axis represents the GDP values, with the scale increasing as the GDP rises. The x-axis lists the countries, showing the GDP for each country across different years. However, the design of this chart was updated in Section 3.2.3 to improve its visual clarity and effectiveness.

### **3.1.5 Health Expenditure**

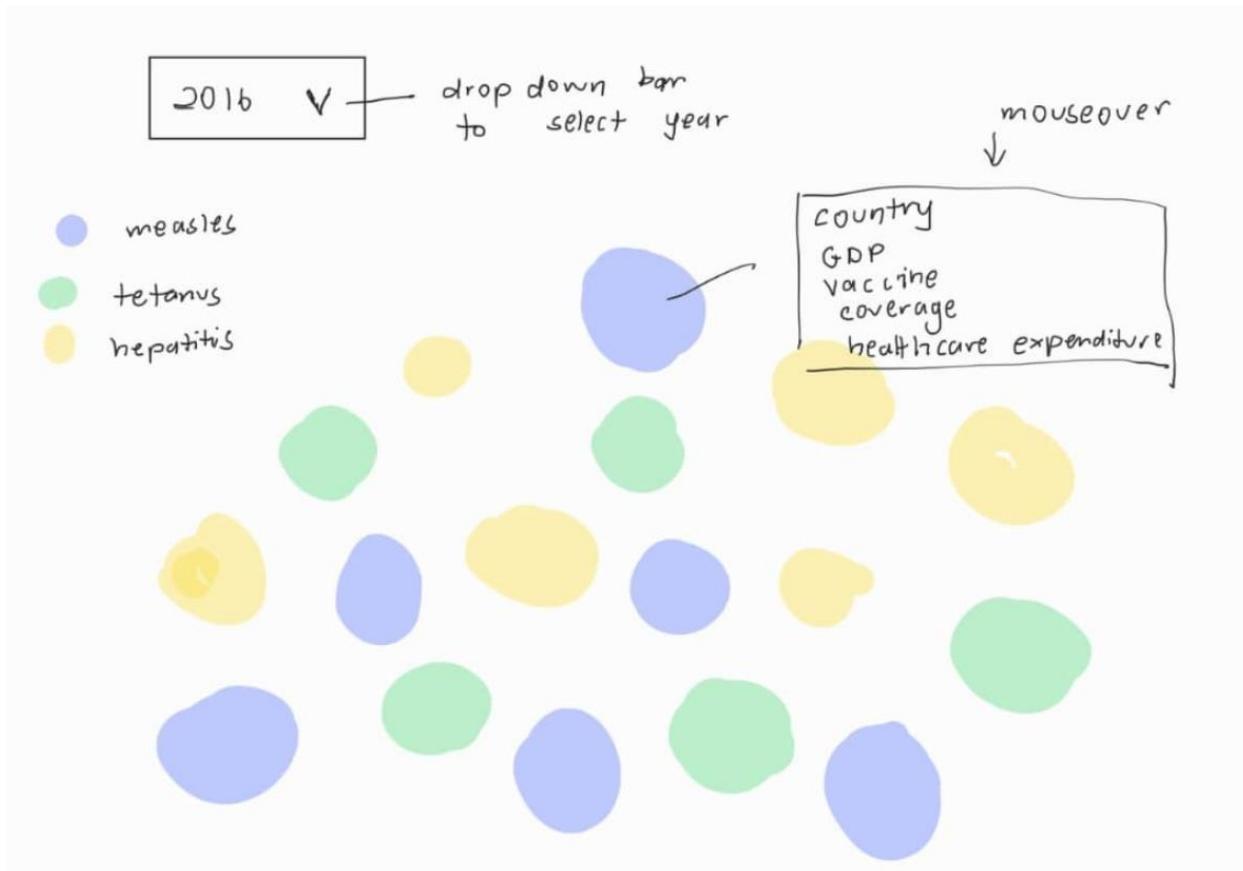
To represent healthcare expenditure effectively, we explored several visualization designs to highlight patterns and relationships in the data.

#### *Design 1: Bubble Chart (Option 1)*



The first design uses a bubble chart, where the x-axis represents the year, the y-axis represents vaccination coverage, and the size of the bubbles encodes healthcare expenditure. This design is particularly effective for illustrating the relationship between healthcare spending and vaccination coverage over time. Larger bubbles indicate higher expenditures, making it easy to identify variations in spending and their potential impact on coverage rates. Additionally, the chart helps to reveal trends or correlations, such as whether increased spending corresponds to higher vaccination coverage or if there are periods of stagnation or decline despite changes in expenditure.

#### *Design 2: Bubble Chart (Option 2)*



The second design is also a bubble chart, but instead of representing multiple years on a single chart, it focuses on one year at a time. The years can be changed via a dropdown menu. In this design, there are no axes; instead, the bubbles for all three diseases are categorized by color, with each color representing a different disease. The size of the bubbles encodes healthcare expenditure, providing a clear visual cue for how much is spent on each disease. Additionally, each bubble includes information such as the country and its GDP, which are displayed directly on the bubble for easy reference. Vaccination coverage data will be made available through a tooltip that appears when hovering over the bubbles, allowing users to explore the relationship between expenditure and coverage for each disease without overcrowding the chart with too much information. This approach provides a more focused view of healthcare spending and vaccination coverage for individual years, while also allowing users to access detailed information interactively.

### 3.2 Design Evolutions

#### 3.2.1 Map for European Countries

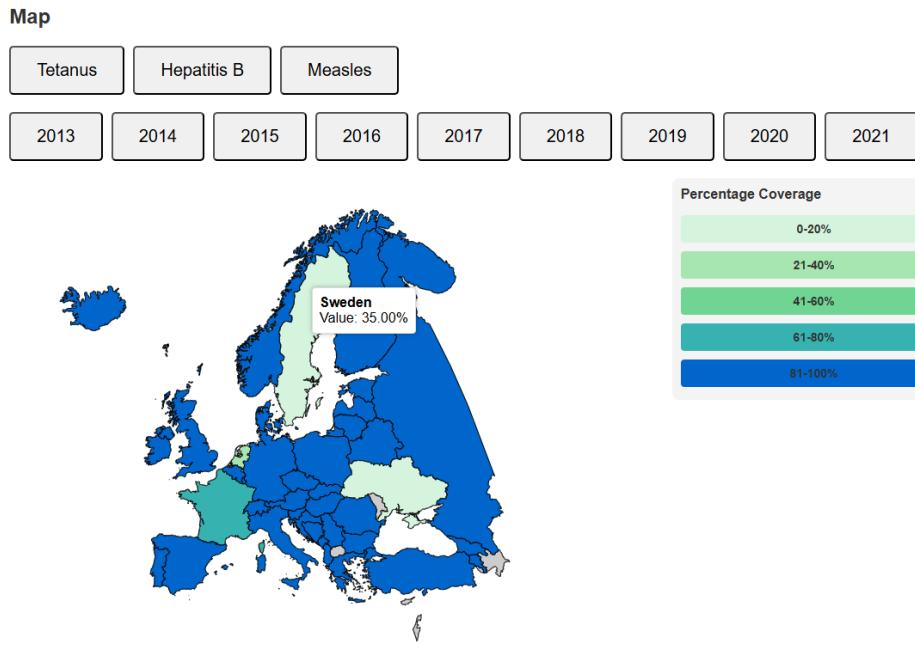
## The D3 journey starts here...

COS30045 Data Visualisation  
Lim Chi Yuen



Our initial draft of the GeoMap aimed to implement a basic European map using GeoJSON data, focusing on displaying vaccination coverage across Europe. To start, we downloaded the Europe GeoJSON from online sources and attempted to integrate it based on the techniques taught in lab classes. This initial design featured a simple color gradient from 'light blue to dark blue,' which we explored to differentiate vaccination coverage levels.

During this early phase, our team also considered several alternative chart types, including basic heatmaps and choropleth maps, to find the most effective way of visualizing the data. These iterations provided foundational insights into how different map types and color schemes would impact readability and user interaction, setting the stage for further refinements.



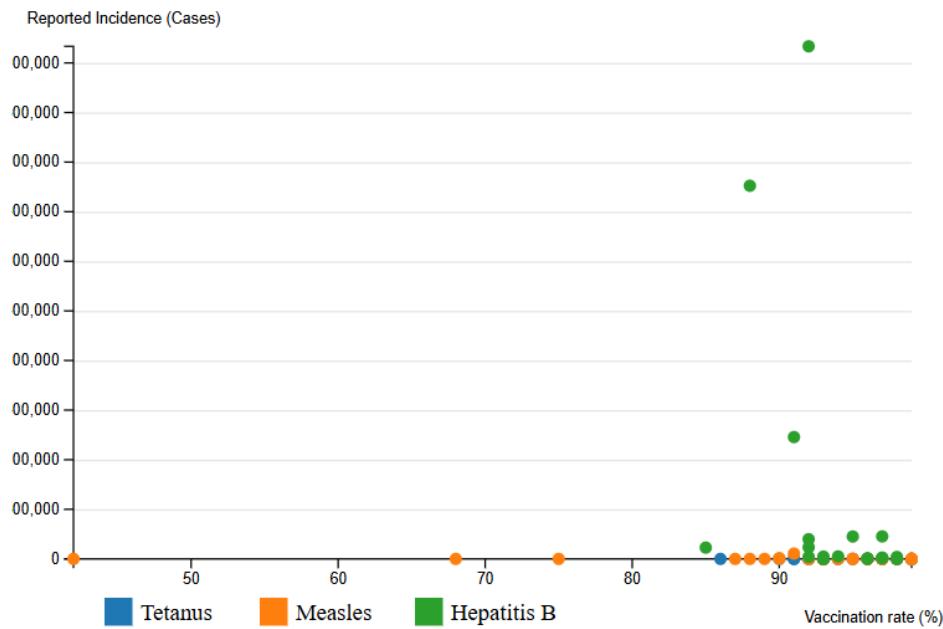
After refining the code and enhancing the GeoMap design, we implemented several new features based on an iterative design process and user feedback. The map now reads CSV data containing vaccination coverage information, allowing for more precise data integration. We updated the color gradient from 'light blue to dark blue' to 'light green to blue' to enhance readability, choosing this scheme after user testing showed that a green-to-blue scale offered higher contrast and clearer data interpretation.

To improve user interaction, we added buttons for selecting diseases and years, providing a quick and intuitive way for users to switch views without losing context. Additionally, hovering over any country now reveals detailed vaccination percentages, a feature added after user evaluations highlighted the need for easy access to exact figures.

A legend was incorporated at the bottom of the map to clarify the color scale, showing which colors correspond to specific percentage ranges. This enhancement, informed by user feedback, supports intuitive data interpretation and rounds out the design for a clear and accessible user experience.

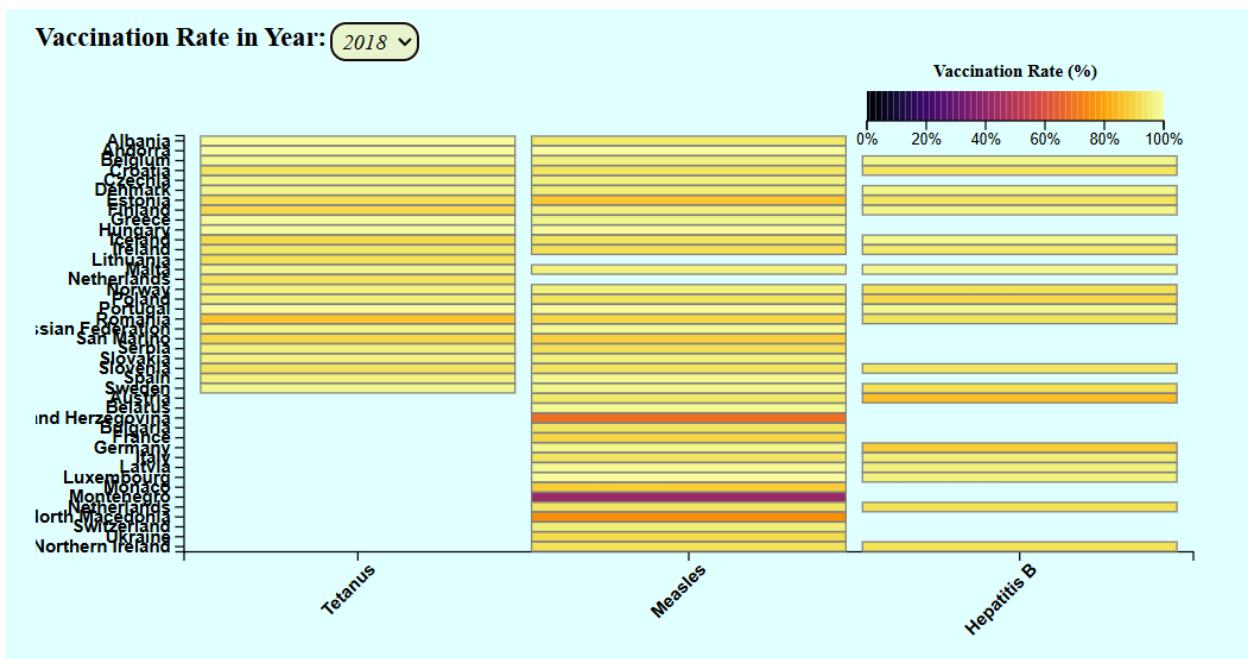
### ***3.2.2 Disease Number of Reported Incidences in European Countries***

# Vaccination Rate vs Diseases Incidence 2017



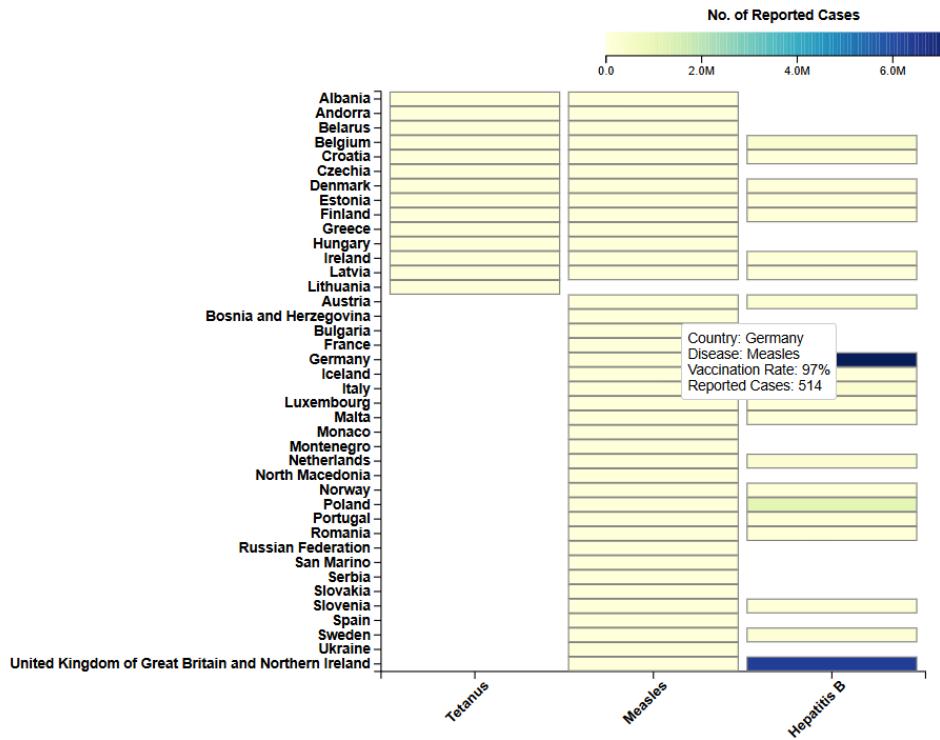
COS30045 Data Visualisation Group

Initially, our group decided to use scatter plots to present the data, with the goal of showing the correlation between vaccination rates and the number of disease incidences across European countries from 2013 to 2023 (11 graphs). The plan was to scale the y-axis to represent the number of disease incidences, while the x-axis represented the vaccination rates, with a mouse-over effect on each point to display the names of the countries. Additionally, the diseases were differentiated using D3 color features. However, after plotting the points on the chart, we realized that most of the data points were clustered around the 80-90% range of the x-axis. Moreover, due to significant differences in the number of incidences each country had, inconsistencies appeared in each year's graph, with some cases exceeding 100,000 and others having only 2 or 3 cases. This also affected the data presentation, making it difficult to fit all the data within the plots.



Our group later decided to change our visualization to a heatmap, instead of using scatter plots. We chose not to display all the information on the axes, focusing instead on presenting the vaccination rates of each country for different diseases. The figure above shows the visualization using heatmap, which provides more consistent and clearer data compared to the scatter plots. The map includes a color legend with scales to give users an idea of the vaccination rates in each country. Additionally, there is a dropdown menu on the top left corner that allows users to select the year of data they wish to visualize.

Disease Reported Incidences in Year: 2019



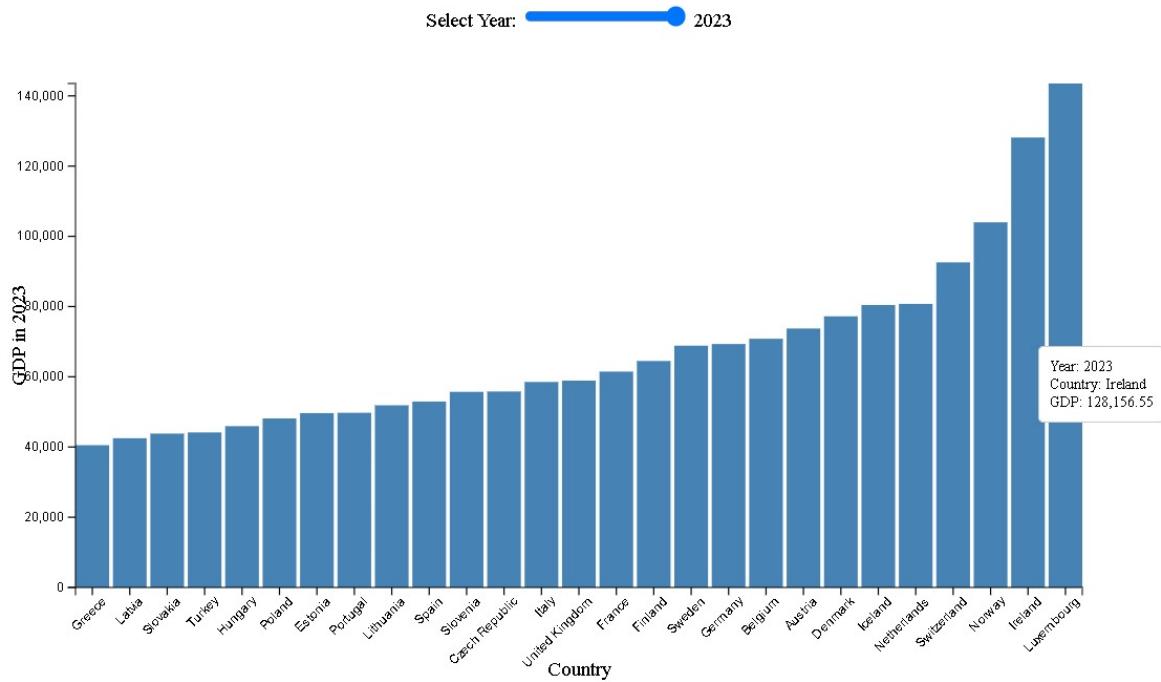
We realized that the data presented in the heatmap was similar to that shown on the Europe map. Consequently, we decided to finalize our heatmap to display reported incidences in each country. Initially, handling the significant range on the scale posed a challenge, as the color legend needed to accommodate a minimum value in single digits and a maximum value in eight digits. However, after conducting online research and consulting AI tools, we managed to scale the values on the legend by dividing the number of cases by 100.

Additionally, the heatmap now includes a mouse-over effect, enabling users to view detailed information when hovering over each cell. These details include the country name, disease type, vaccination rate, and the number of reported cases of the disease for that year. This addition fulfilled our initial goal of showcasing both vaccination rates and reported cases of each disease within a country for each year.

Finally, adjustments were made to the left margin to ensure that country names were fully visible on the y-axis. The height of the graph was also increased to make each cell taller,

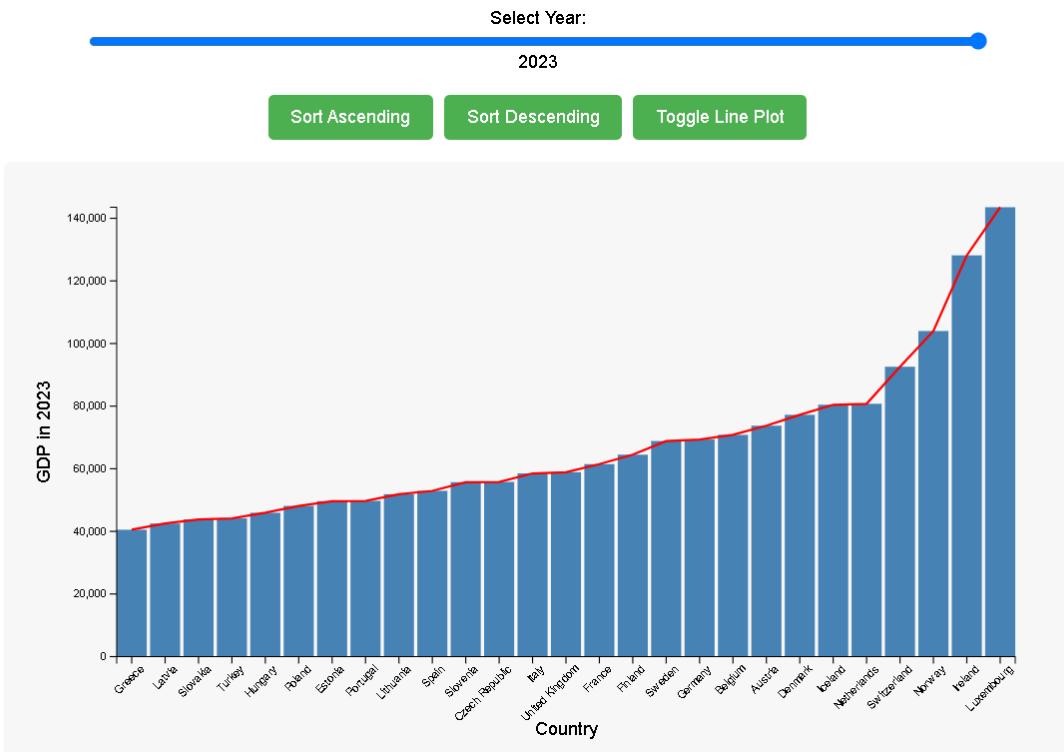
preventing them from appearing too flat when stacked, which previously made it difficult for users to view and hover over each cell for details.

### 3.2.3 Country GDP Over the Years



Our initial bar chart sketch aimed to present GDP data across European countries, with years initially represented along the y-axis. After testing this layout, we found that it restricted readability and flexibility in comparing GDP values across countries, especially when selecting different years. Based on early user feedback, we reoriented the y-axis to display GDP values in dollars, while the x-axis was updated to represent individual countries.

We also considered various chart types, such as line charts and stacked bar charts, but ultimately chose a bar chart due to its clarity in representing discrete data per country and year. Initial user evaluations confirmed that this approach helped users make direct comparisons between countries. Additionally, a hover function was incorporated to display details like the year, country, and GDP for each bar, providing users with exact information without overcrowding the chart.



Building on the initial design, we refined the bar chart to enhance interactivity and accessibility, based on iterative feedback from users and our own design assessments. Key features added include ‘Sort Ascending’ and ‘Sort Descending’ buttons, allowing users to reorder bars by GDP, which simplifies comparison by arranging countries in either ascending or descending order. This design choice was implemented after user evaluations suggested that dynamic sorting would help with identifying high and low GDP values more easily.

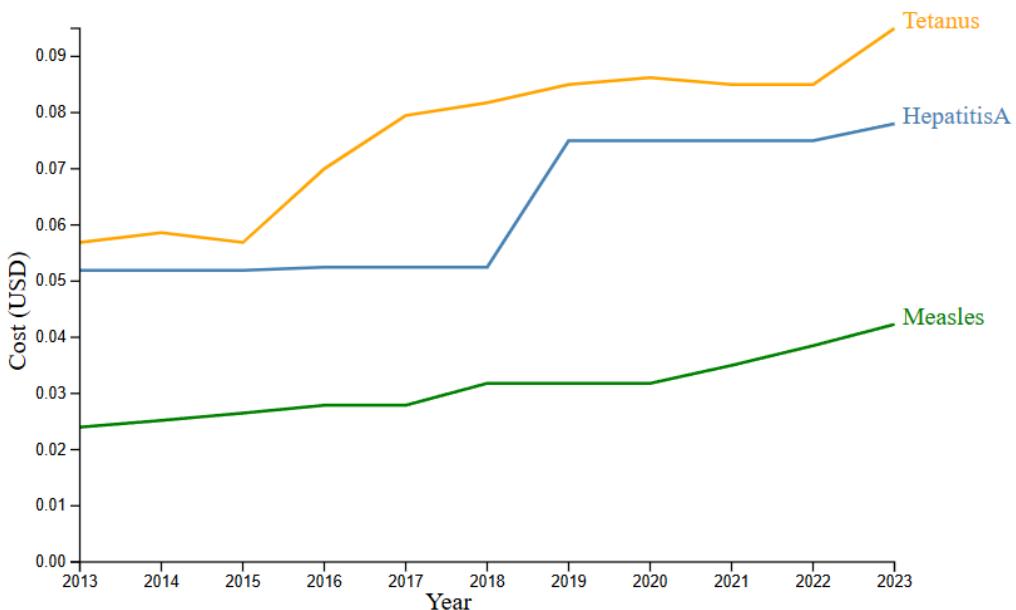
In addition, we introduced a ‘Toggle Line Plot’ option that overlays a line graph on the bars, providing a more holistic view of GDP trends across years. This addition was inspired by feedback indicating that users wanted an easier way to track patterns over time.

We also expanded the sliding bar at the top, enabling smooth year selection. This feature was improved for more precise control and usability, based on user testing that highlighted the importance of flexibility in year selection. Finally, the color scheme and layout were adjusted for readability, and a legend was added for clarity, helping users interpret the data intuitively and explore GDP trends with minimal effort.

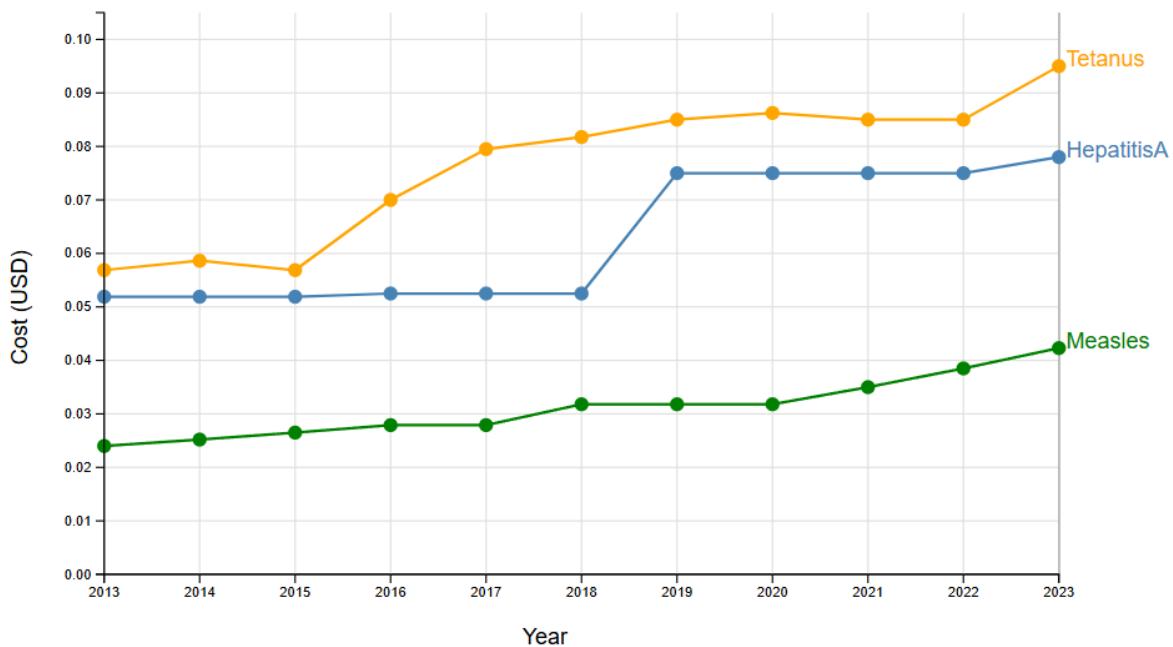
### 3.2.4 Vaccination Costs Over Time

For our visualization of vaccination costs over time, our group decided to use a line chart as the main goal was to clearly show how costs changed over time. The initial design featured a simple chart with three lines, each representing a different vaccination type. To distinguish between the types, the lines were assigned different colors, and their labels were placed at the end of the respective lines for clarity.

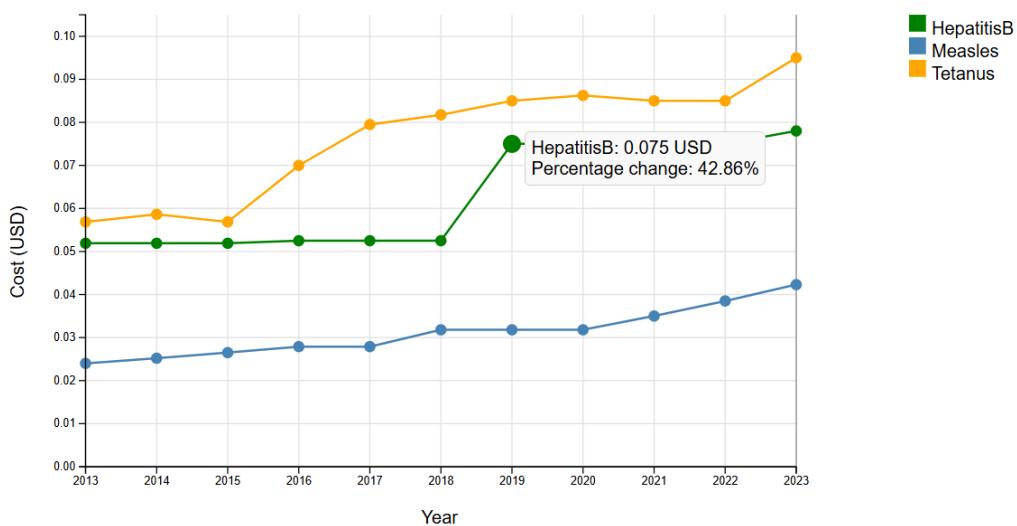
## Vaccination Costs Over Time



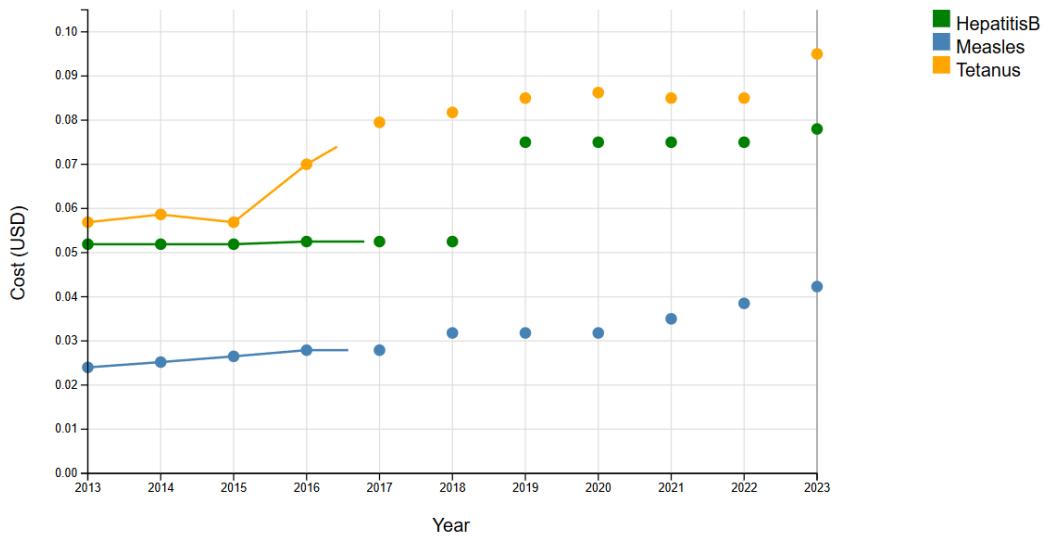
To enhance the clarity and readability of the chart, we incorporated points (dots) at each data point, making it easier for viewers to identify exact values. Additionally, we added grid lines to the chart. These grid lines improve the user experience by helping readers align the data points with the axes, ensuring they can more accurately interpret the values. For example, they allow for quicker comparisons of costs between specific years and vaccines. We also implemented a mouse-over effect for each point, which provides interactivity and allows users to view precise values by hovering over the data points.



As the design evolved, we decided that representing vaccine types using a legend instead of labels at the end of the lines would make the visualization look neater and more polished. This adjustment streamlined the chart's appearance, reducing clutter and improving its overall aesthetic. Additionally, we enhanced the mouse-over functionality by including the percentage increase in vaccine costs compared to the previous year. This added layer of information provides users with more insight into year-over-year trends, making the chart more informative.



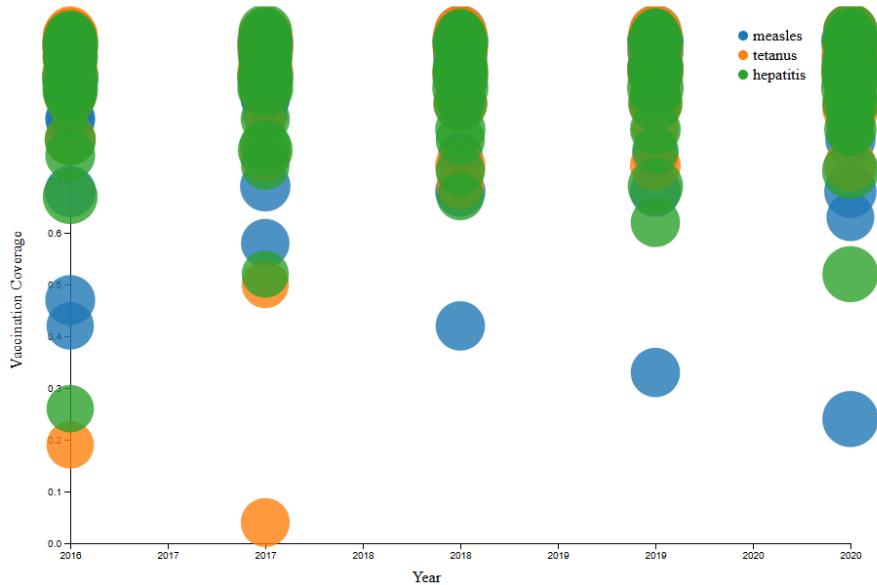
Finally, to make the visualization more engaging, we incorporated a transition effect that animates the drawing of the lines. This subtle animation adds a dynamic touch, capturing the viewer's attention while maintaining the professional presentation of the data. These iterative refinements improved both the usability and appeal of our line chart, ensuring that it effectively communicates the trends in vaccination costs over time.



### 3.2.5 Health Expenditure

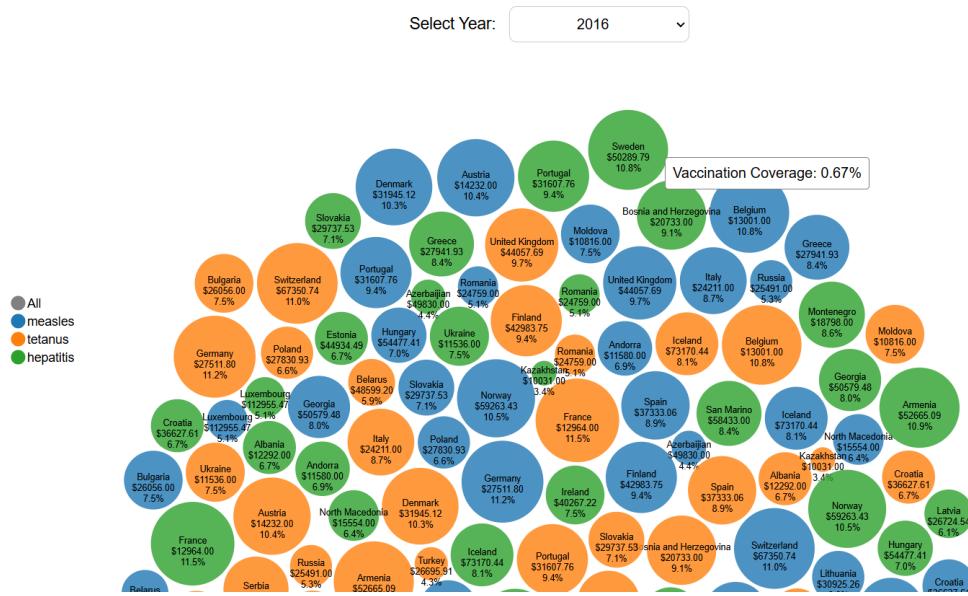
Initially, our group decided to use the first bubble chart option with axes, as it would allow all data across the years to be shown simultaneously, providing a more comprehensive overview. However, after coding it, we quickly realized that many of the data bubbles overlapped due to the density of the dataset. Since the x-axis represented the years, we had expected the bubbles to spread more evenly across the chart. Instead, they were arranged in columns corresponding to each year tick, which created a cluttered, hard-to-read visualization. The overlapping bubbles hindered the clarity of the trends, making it difficult to distinguish between data points.

### Vaccination Bubble Chart (2016–2020)

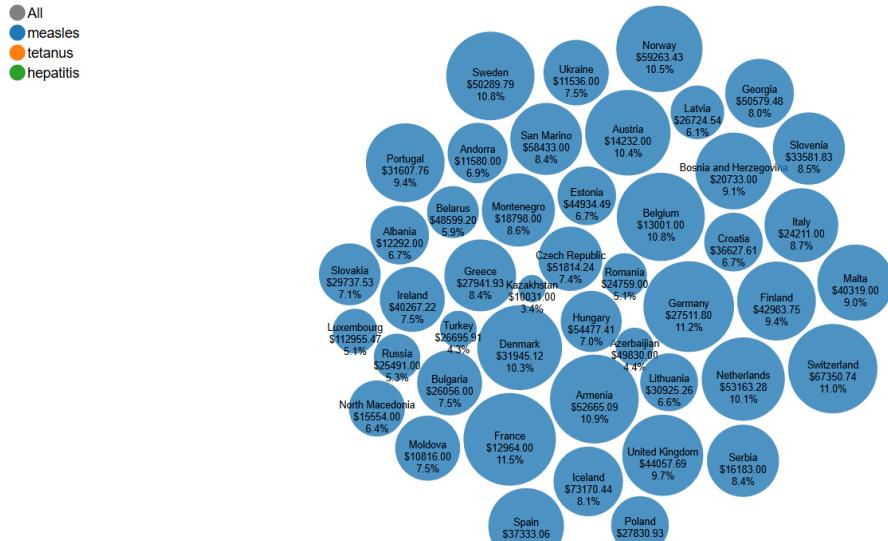


As a result, we switched to the second option. The first iteration of this design, shown below, included drag and force interactions for the bubbles. We also implemented a solution to prevent overlapping by using **d3.forceCollide**, which automatically arranges the bubbles without overlap when the chart loads. This approach not only improved the clarity but also provided an engaging, interactive experience for the viewer. Users could drag the bubbles around the chart, and the other bubbles would adjust accordingly, creating a dynamic and fun visual effect.

Additionally, we incorporated a **dropdown menu** that allows users to select individual years. This feature helps to focus on one specific year at a time, making it easier to compare the data for that period. The **size of each bubble** represents the healthcare expenditure for that year, with larger bubbles indicating higher spending. For further context, the **tooltip** displays the vaccination coverage for each disease, providing the viewer with more detailed information when they hover over a bubble. These interactive elements enhance the overall user experience, allowing for both deeper exploration and clearer visual presentation.

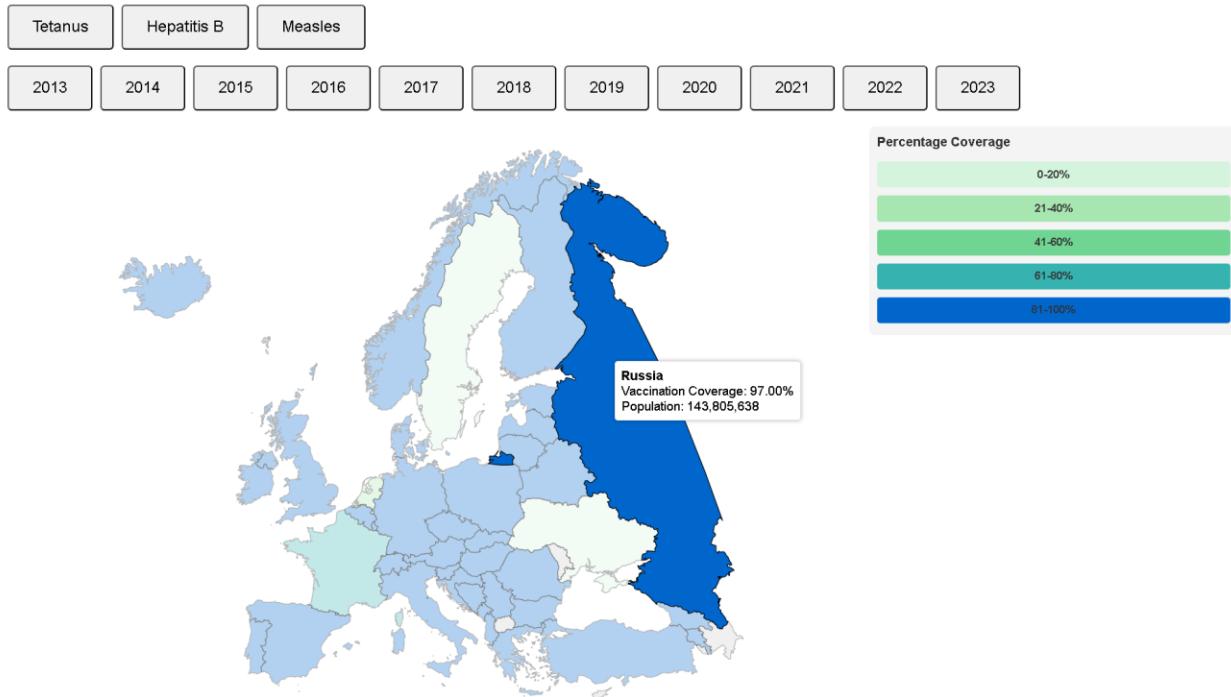


However, we soon realized that displaying all three diseases simultaneously could overwhelm the viewer or create a messy chart. To address this, we introduced a filtering function, allowing users to select the specific disease they wanted to view. We made the legend clickable, so users could easily filter by one disease at a time, improving the focus and readability of the data.

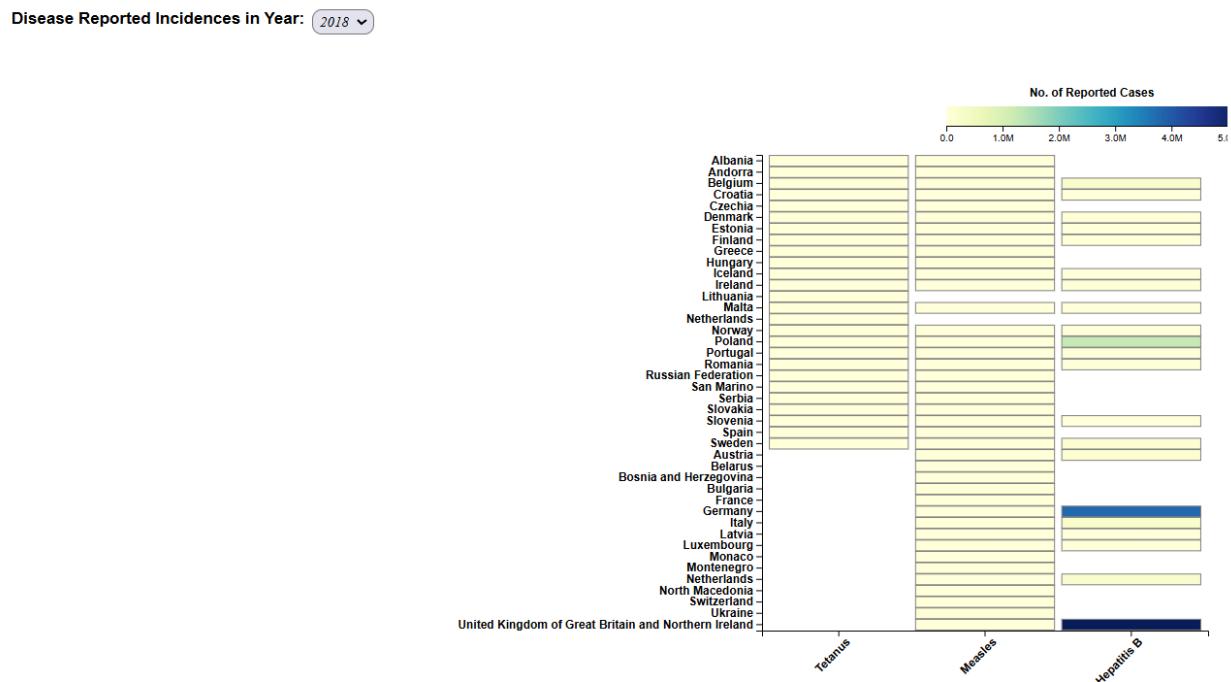


### 3.3 Final Design on Website

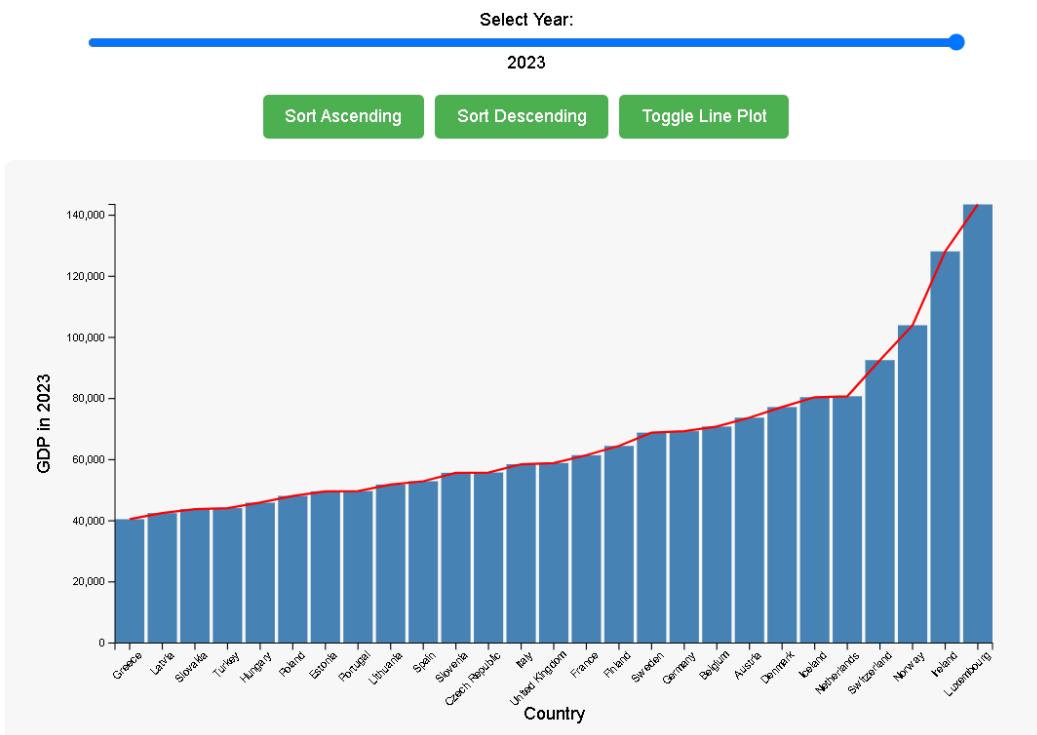
#### 3.3.1 Map for European Countries



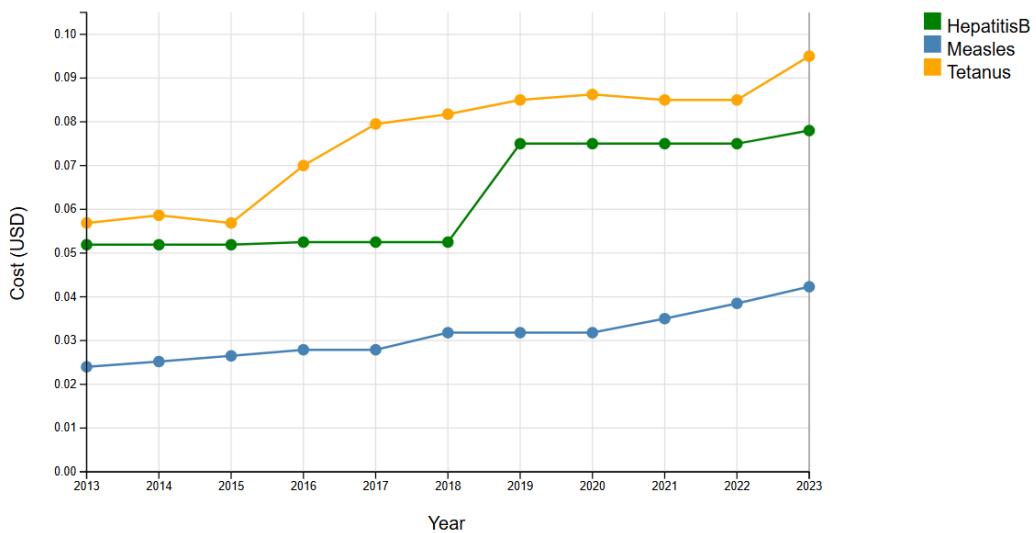
### **3.3.2 Vaccination Rates in European Countries using Heatmap**



### **3.3.3 Country GDP Over the Years using Bar Chart**



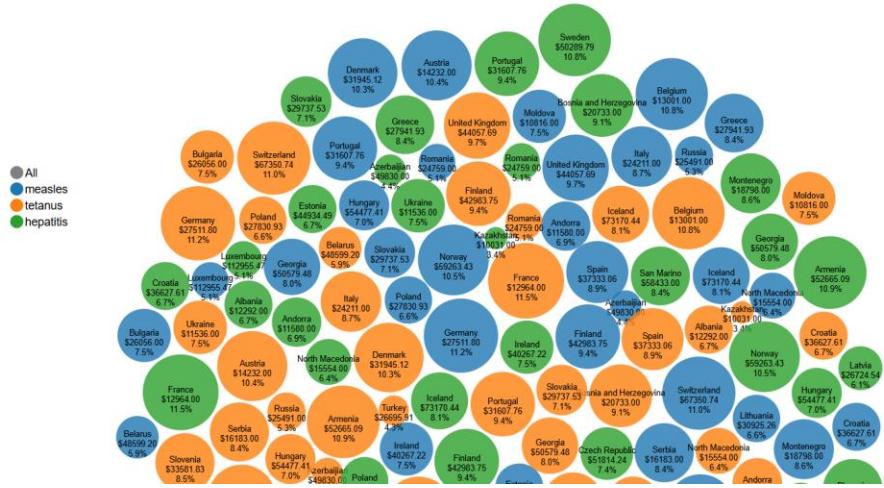
### 3.3.4 Vaccination Costs Over Time using Line Chart



### 3.3.5 Health Expenditure using Bubble Chart

Click to go back, click to see history

Select Year: 2016



## 4. Validation

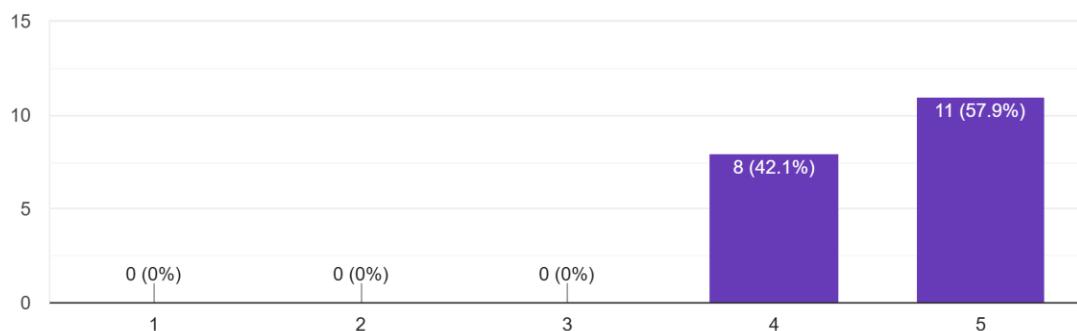
Our group conducted a survey using Google Forms to validate users' experiences with the website we created. The objective of this survey was to collect users' opinions on the data visualizations and gather feedback for further improvements to enhance future visualizations. The survey is divided into three sections, with questions focusing on rating the overall experience, assessing user-friendliness, evaluating the design of each chart, and gathering user feedback for future enhancements.

### Section 1: General Users Experience

#### *Question 1*

1. How would you rate your overall experience when browsing the visualization graphs and charts on the website? (1 = Poor, 5 = Overall Good)

19 responses

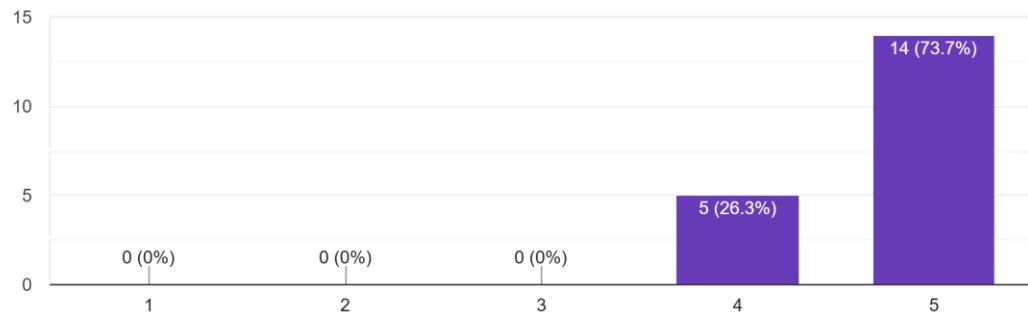


The first question asked how users would rate their overall experience with the graphs and charts we have created on the website, as well as interactivity. Users were required to give a rating from 0, indicating a poor experience, to 5, indicating an excellent experience. As shown in the bar chart above, we can conclude that users rated their overall experience as above average: 11 out of 19 respondents gave a rating of 5, while the remaining 8 rated it a 4.

#### *Question 2*

2. How would you rate the user-friendliness of the website?(1 = Poor, 5 = Overall Good)

19 responses

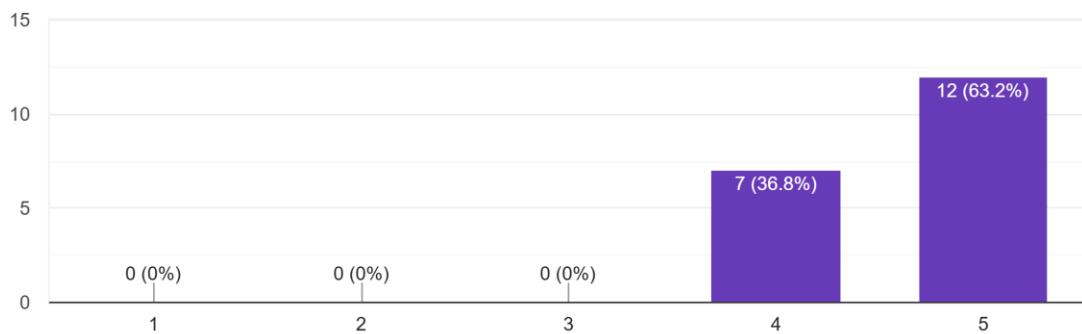


The next question asked users to rate the website's user-friendliness, which included aspects such as mouse interactivity, navigation buttons, font sizes, content, and other user-interaction features. Users were required to give a rating from 0, indicating the website is not user-friendly, to 5, indicating perfect user-friendliness. As shown in the bar chart above, the majority of users gave a rating of 5, acknowledging the website's high level of user-friendliness.

### *Question 3*

3. How would you rate the level of understanding provided by the graphs? (1 = I don't understand, 5 = Easy to understand)

19 responses



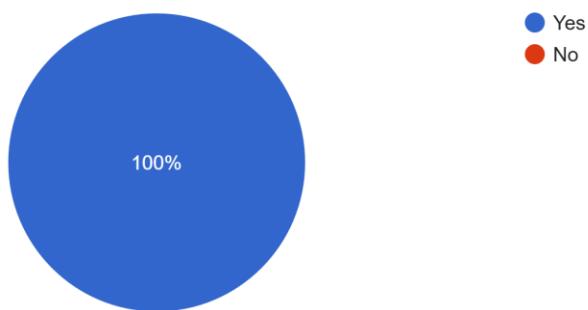
This question asked users to rate the clarity of overall content delivery, specifically whether the presented visualizations were complicated or easy to understand. Users were required to give a

rating from 0, indicating the content was hard to understand, to 5, indicating it was easy to understand. The results, with most ratings at 4 or 5, demonstrate that the content is clear and understandable to users.

#### *Question 4*

4. Did the data presented seem meaningful and provide you with better insight into vaccinations?

19 responses



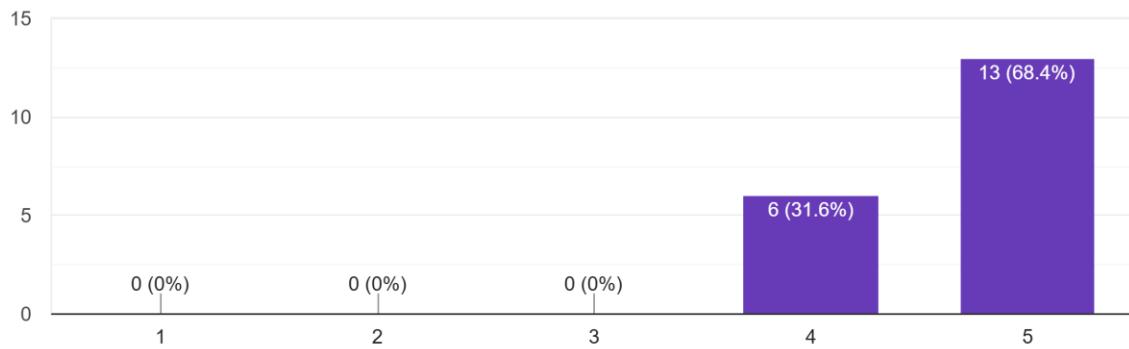
The last question of the first section aimed to determine whether the data visualizations were beneficial to users and if they provided better insight into the purpose of vaccinations. As shown above, 100% of the users—19 out of 19—agreed that the content was helpful and informative for understanding more about vaccinations.

## **Section 2: Design Evaluation**

## *Visualization 1 – Vaccination Coverage Across European Countries (Europe Map)*

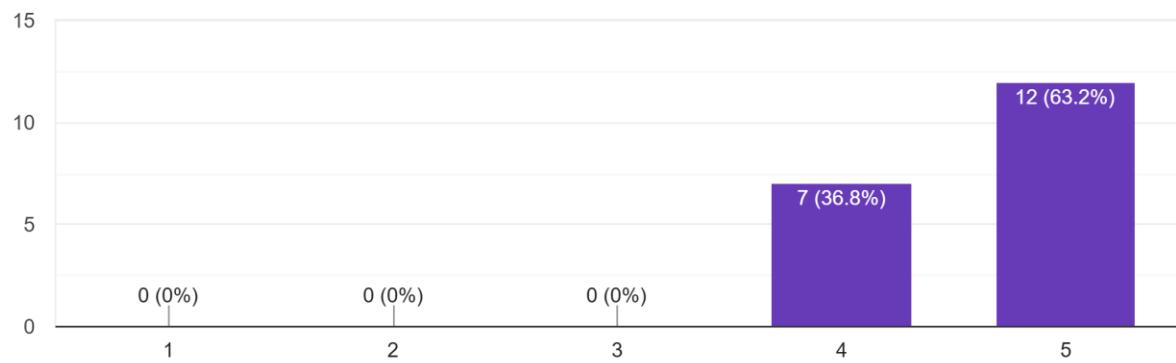
1. How would you rate the map visualization in terms of user interactivity? (1 = Poor, 5 = Overall Good)

19 responses



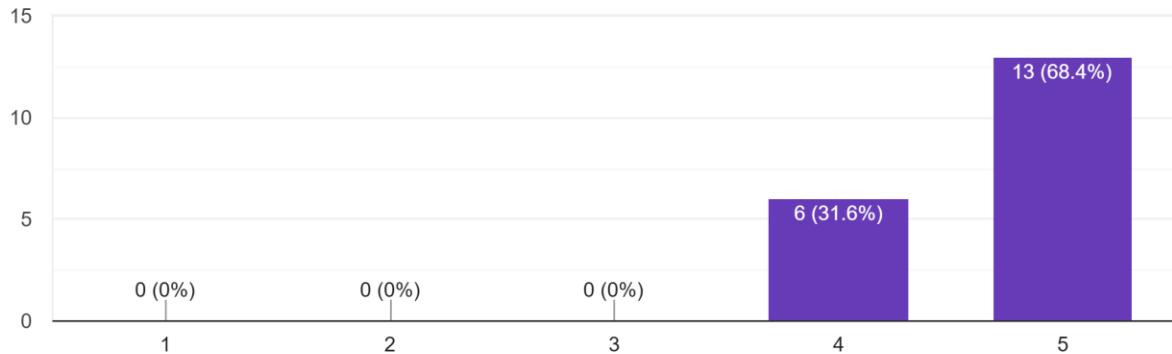
2. How would you rate the map visualization in terms of color tone? (1 = Poor, 5 = Overall Good)

19 responses



3. How would you rate the map visualization in terms of content representation? (1 = Poor, 5 = Easy to understand)

19 responses

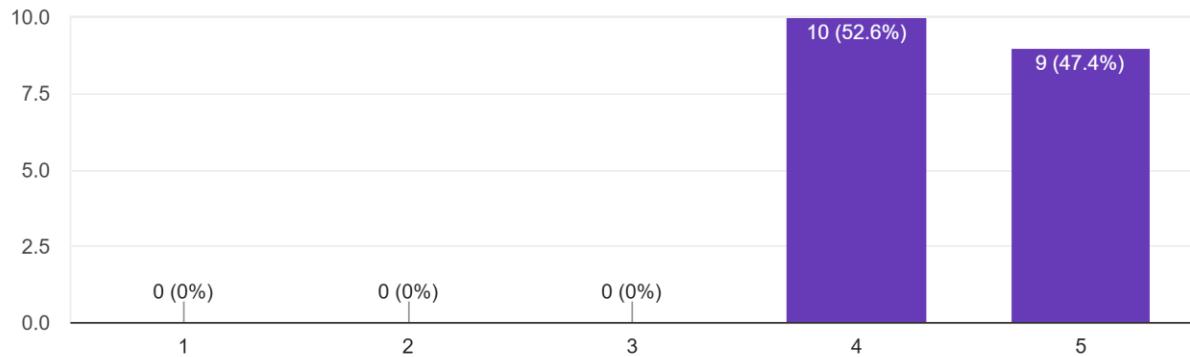


For the visualization of Vaccination Coverage Across European Countries, which utilized a Europe map with hover effects and filters for diseases and years, users provided positive ratings regarding the visualization design. According to the results shown in the charts above, 13 out of 19 users gave full ratings for user interactivity on the map and content representation. This indicates that the map design was above average, with users appreciating the provided interactivity and being able to understand the conveyed content. Additionally, for the color tone, 12 out of 19 respondents rated it 5 out of 5, while the remaining respondents gave it a 4 out of 5.

## *Visualization 2 – Number of Reported Incidence Across European Countries (Heatmap)*

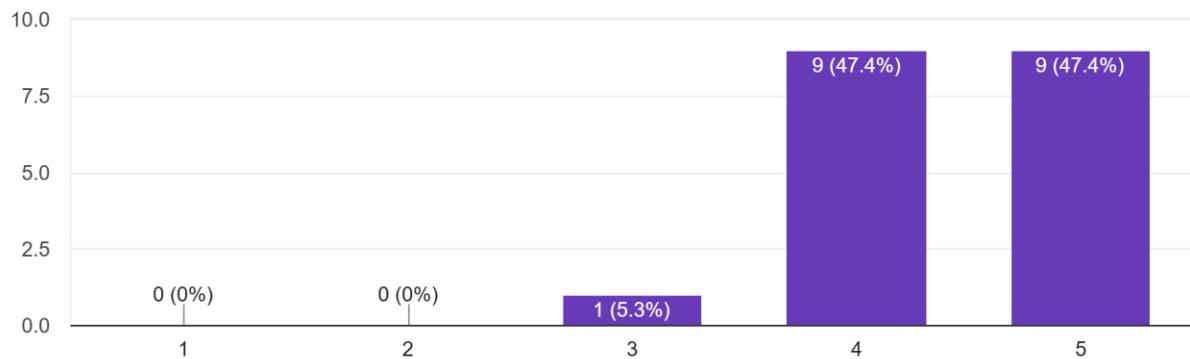
4. How would you rate the heatmap visualization in terms of user interactivity? (1 = Poor, 5 = Overall Good)

19 responses



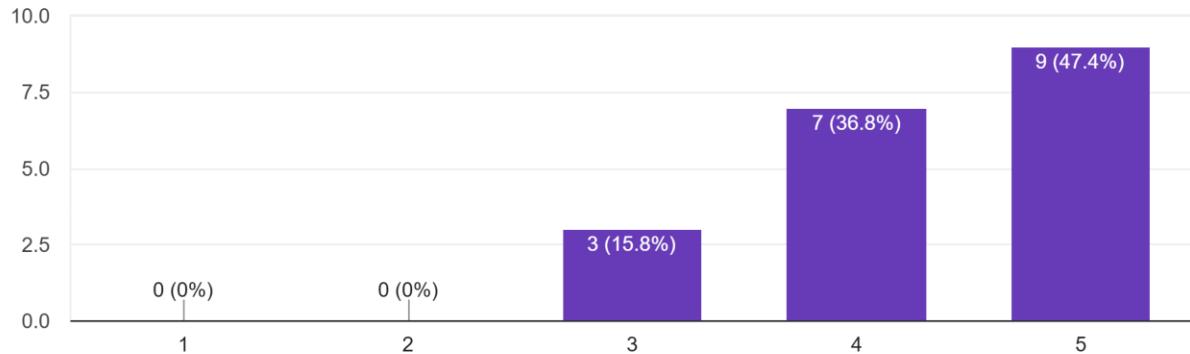
5. How would you rate the heatmap visualization in terms of color tone? (1 = Poor, 5 = Overall Good)

19 responses



6. How would you rate the heatmap visualization in terms of content representation? (1 = Poor, 5 = Easy to understand)

19 responses

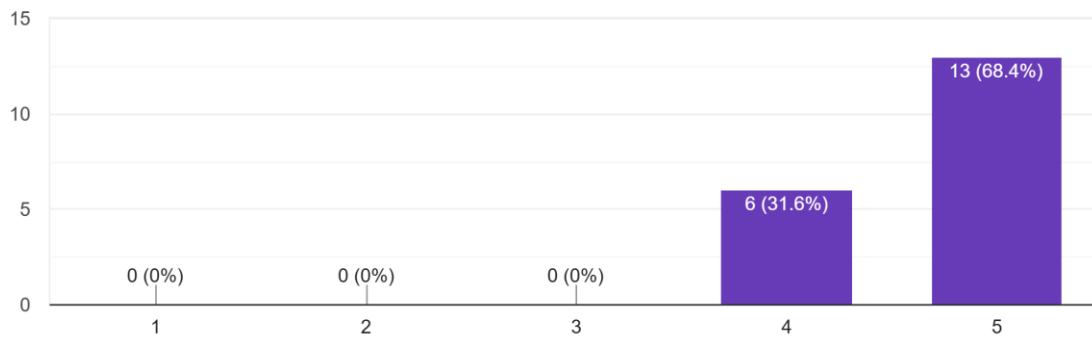


Next, the heatmap, which was used to visualize the number of reported incidences across European countries with a hover effect for details and a drop-down menu allowing users to select the year, also received an above-average rating for user interactivity. Additionally, the color tone was rated above average, although one respondent rated it 3 out of 5, while the rest rated it between 4 and 5. Lastly, for content presentation, the heatmap was rated slightly lower than the other visualizations. We believe this may be due to the level of detail not meeting users' expectations. This aspect will be taken into consideration for future improvements.

### *Visualization 3 – Country GDPs Over the Years (Bar Chart)*

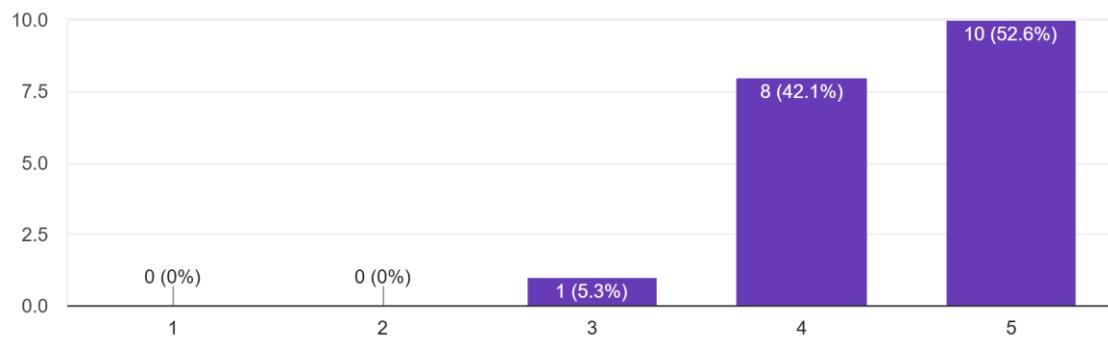
7. How would you rate the bar chart visualization in terms of user interactivity? (1 = Poor, 5 = Overall Good)

19 responses



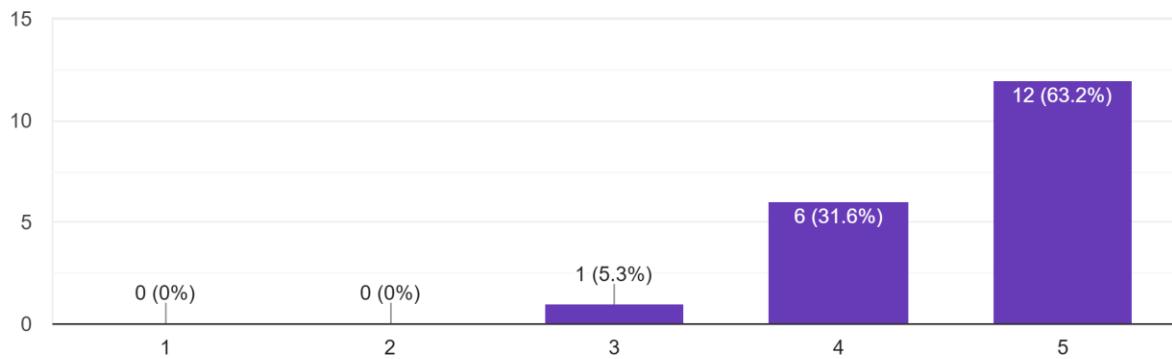
8. How would you rate the bar chart visualization in terms of color tone? (1 = Poor, 5 = Overall Good)

19 responses



9. How would you rate the bar chart visualization in terms of content representation? (1 = Poor, 5 = Easy to understand)

19 responses

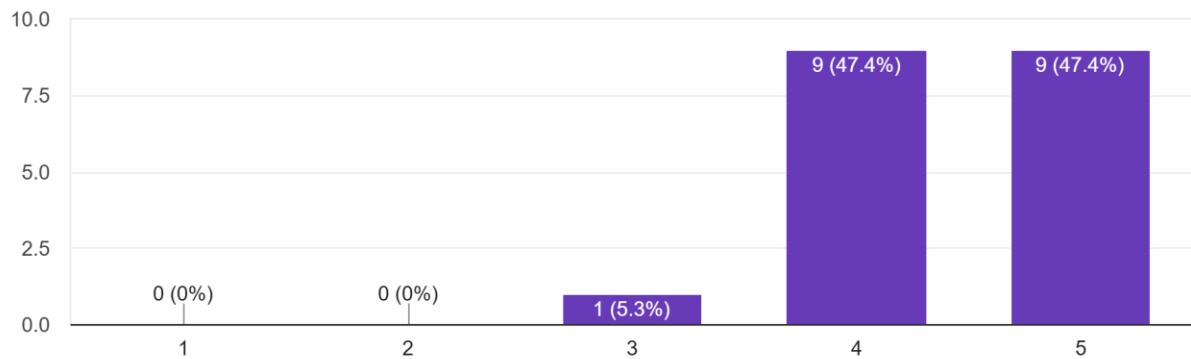


The third visualization is a bar chart depicting Country GDPs Over the Years, featuring a toggled line for enhanced visualization. It also provides users with buttons to sort the bars in either ascending or descending order. Additionally, a slider above the buttons allows users to adjust the view over different years to observe changes in country GDPs over time. The bar chart received a rating of 5 out of 5 from 13 respondents, while the remaining six rated it 4 out of 5 for user interactivity. Furthermore, the color tone of the chart was rated above average by most users, and positive ratings were also given for content representation. These ratings indicate overall positive user satisfaction with the visualization chart.

#### *Visualization 4 – Vaccination Costs Over Time (Line Chart)*

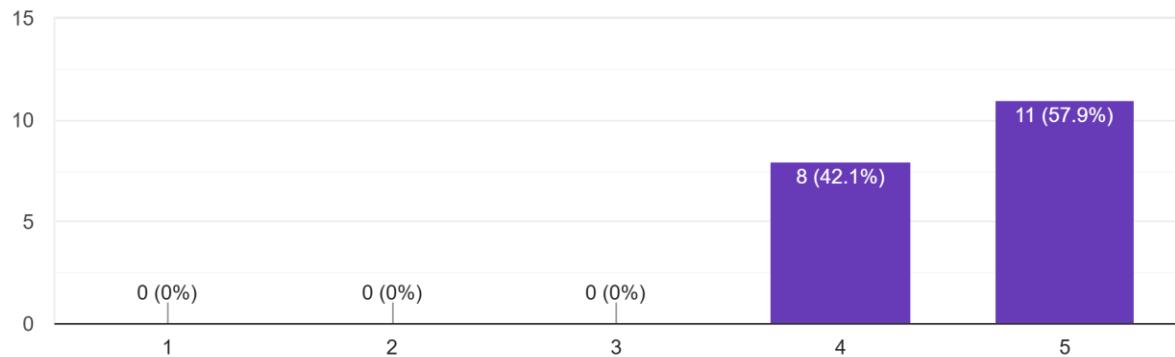
10. How would you rate the line chart visualization in terms of user interactivity? (1 = Poor, 5 = Overall Good)

19 responses



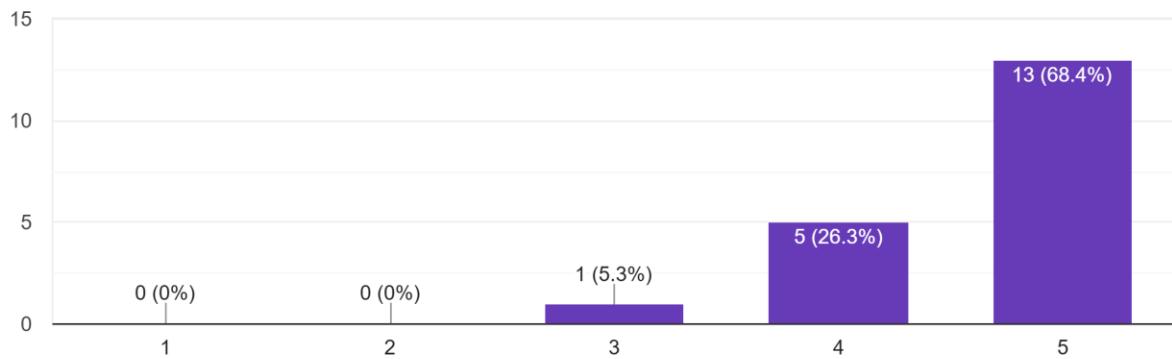
11. How would you rate the line chart visualization in terms of color tone? (1 = Poor, 5 = Overall Good)

19 responses



12. How would you rate the line chart visualization in terms of content representation? (1 = Poor, 5 = Easy to understand)

19 responses

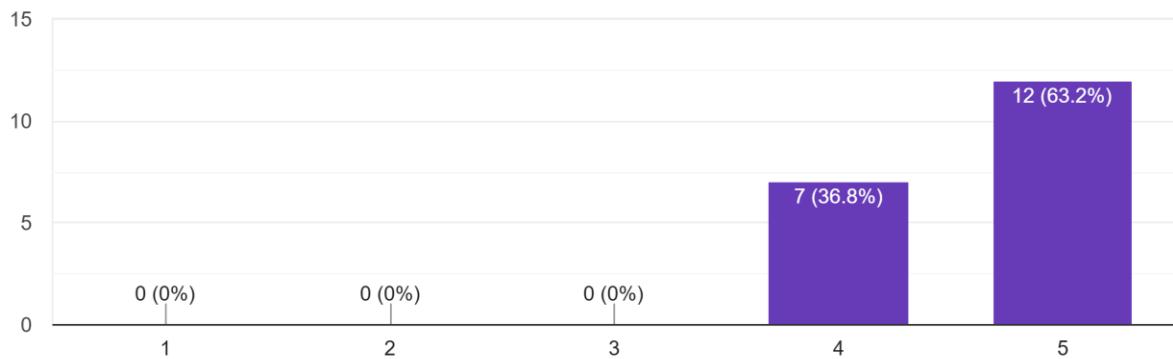


The line chart's interactivity received an average rating of 3 out of 5, with 9 votes each for ratings 4 and 5, indicating a generally positive response. The color tone used in the line chart was rated 5 by 57.9% of respondents and 4 by 42.1%, showing a majority positive reception with more than half giving the highest rating. For content representation, the line chart received a rating of 5 from 13 out of 19 respondents (68.4%), with 5 respondents rating it 4, and 1 respondent rating it 3, reflecting strong overall approval.

### *Visualization 5 – Health Expenditure (Bubble Chart)*

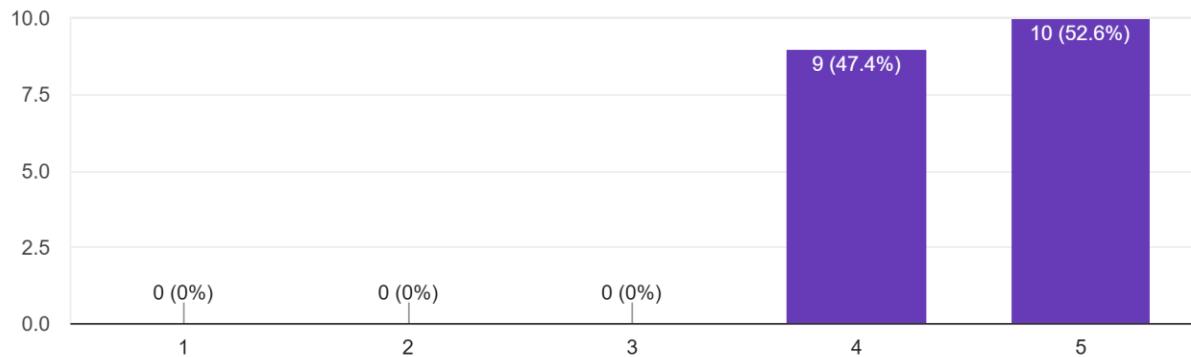
13. How would you rate the bubble chart visualization in terms of user interactivity? (1 = Poor, 5 = Overall Good)

19 responses



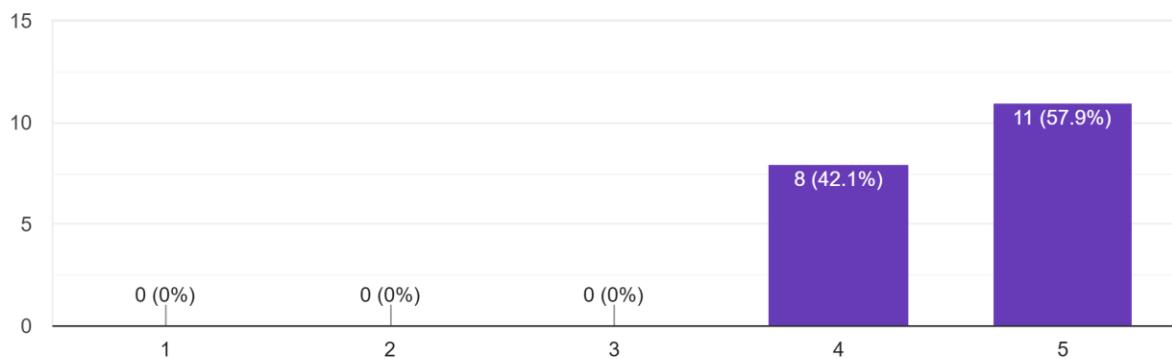
14. How would you rate the bubble chart visualization in terms of color tone? (1 = Poor, 5 = Overall Good)

19 responses



15. How would you rate the bubble chart visualization in terms of content representation? (1 = Poor, 5 = Easy to understand)

19 responses



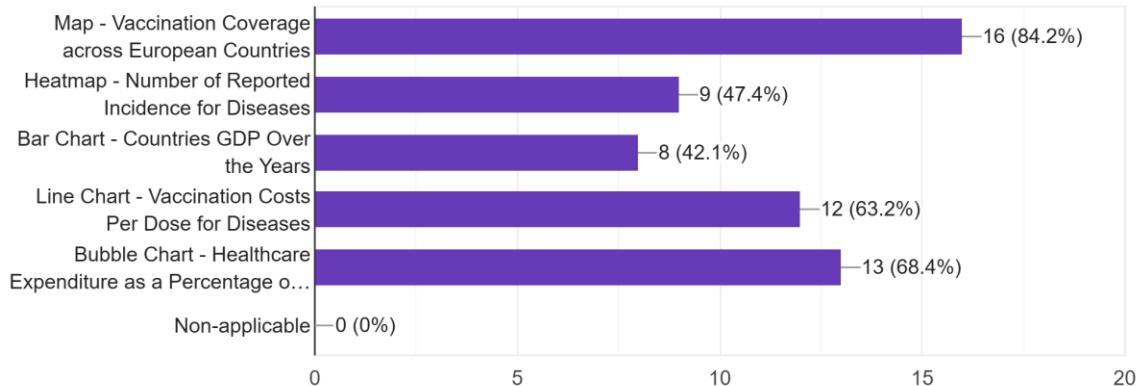
The bubble chart, which aimed to visualize Health Expenditure in each country, also received positive ratings from users. According to the results shown in the charts above, 12 out of 19 respondents gave a rating of 5 out of 5 for user interactivity on the bubble chart. Additionally, the color tone of the chart was rated above average, with 10 out of 19 respondents giving it a 5 out of 5, while the remaining respondents rated it 4 out of 5. Lastly, for content representation, 11 respondents rated the bubble chart 5 out of 5, while the others rated it 4 out of 5. Overall, the ratings for the bubble chart visualization are positive, indicating user satisfaction with the chart.

## Section 3: Design Feedback

### Question 1, 2 – Good and Poor Visualization Feedback

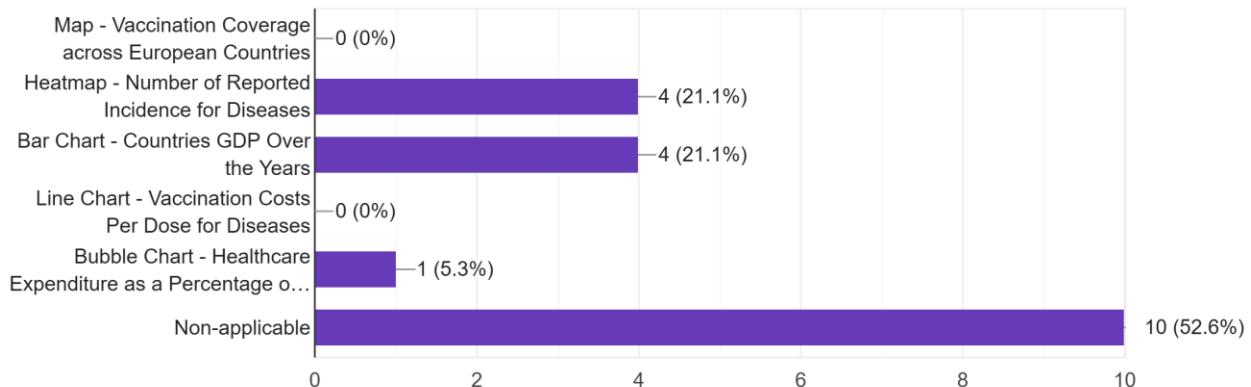
- Choose the graphs/charts that you think present good visualizations.

19 responses



- Choose the graphs/charts that you think do not present good visualizations.

19 responses

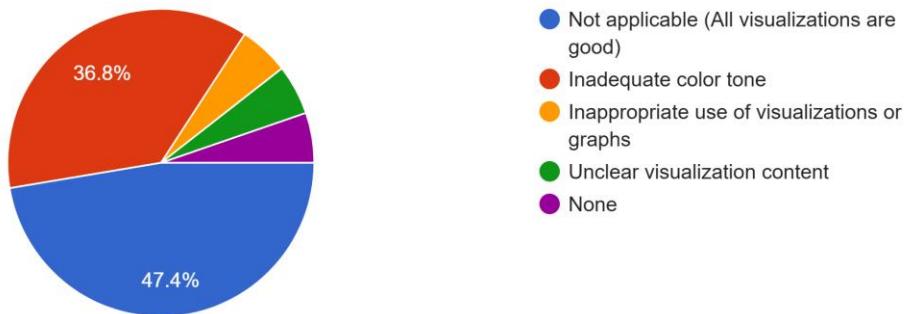


According to the first chart above, the Europe Map visualization received the highest number of votes as a good visualization, with 16 votes, followed by the bubble chart with 13 votes and the line chart with 12 votes. In contrast, the second chart shows that both the heatmap and bar chart received 4 votes each for not being well-received as good visualizations. Therefore, we will further investigate the reasons behind these charts not resonating well with users and work on solutions for future improvements in data visualizations.

### *Question 3 – Reasons of Poor Visualization*

3. The reason the above charts do not present a good visualization.

19 responses



Before proposing solutions for the previously mentioned results, our group also inquired about the potential factors influencing users' feedback on the less effective visualizations. As shown in the pie chart above, 36.8% of users indicated that the color tone on the visualizations was inadequate. Recognizing that the presentation was impacted by the color tone, we will prioritize finding a better dataset and applying improved scaling to make the color tone more appealing and less dull. Additionally, a minority of users cited the inappropriate use of visualization types and unclear content. We will also address these issues to enhance our data visualization skills in the future.

#### *Question 4 – Users' Feedback for Improvements*

4. How can we further enhance our visualization in terms of graph design, color contrast, user interactivity, and other aspects?

19 responses

Very good. Don't have to worry

More data especially for line chart

add the vaccination coverage to the bar chart

Tone cam be better

use a more significant color contrast

overall is fine

Not sure

descriptions alongside changing data

more details to describe the graphs and charts

Looks simple and straightforward. Easy to understand.

Can remove bar chart while displaying the line, but overall is good

Increase users interactivity

Maybe more details but overall is simple to understand.

Good, more interactive designs

Maybe allow to select only certain countries for heatmap

Heatmap could've been better but very impressive work overall

more data needed to be shown

Better color choice for bar chart..

The last question in our survey sought users' opinions on how we could improve our visualizations in terms of graph design, color contrast, user interaction, and other aspects. We received positive feedback and appreciated the advice provided by all the respondents, as shown above. All these opinions will be taken into consideration to ensure that future visualizations are improved and can offer better insights to users.

## 5. Conclusion

This project successfully developed interactive visualizations exploring vaccination rates and related factors across European countries. Through an iterative design process, including user feedback and data analysis, we created a website with multiple visualizations that effectively communicate vaccination coverage, disease incidence, GDP, vaccination costs, and healthcare expenditure. User evaluations confirmed the website's clarity, user-friendliness, and ability to provide valuable insights into vaccination trends and their impact on public health. This website can be a valuable resource for public health officials, policymakers, and researchers to understand vaccination patterns, identify areas for improvement, and make informed decisions to improve vaccination efforts across Europe.

## 6. References

- [1] *World Health Organization*. (2024). *Vaccines and immunization*. World Health Organization.  
[https://www.who.int/health-topics/vaccines-and-immunization#tab=tab\\_1](https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1)
- [2] *D3 by Observable | The JavaScript library for bespoke data visualization*. (n.d.).  
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<https://geographyfieldwork.com/DataPresentationBarCharts.htm>
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- [5] *Flourish | Data Visualization & Storytelling*. (n.d.). Flourish. <https://flourish.studio/#>