Vaccination in the UK

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Contents

1 Introduction

Hello. My name is Elena, and I am a Data Scientist.

When I came to Bristol in May 2021, I decided to be vaccinated because, in my opinion, this is a safer way to live my normal life. So, I started my long research about Covid vaccination. And now I am ready to show you interesting facts.

I live in Bristol. What do I know about Bristol?

- This city is a part of the UK, England, and South West.
- There are two universities.

So, I am interested in data about the UK, England, South West, and Bristol.

Question 0: Are there dependencies between academic year events and vaccination waves? Does the vaccination depend on holidays?

I was vaccinated by the first, the second, and booster doses on 8 August 2021, 3 October 2021, 8 January 2022, respectively.

Question 1: How many people got their jabs with me?

I got the first and the second jabs on Sunday. There were fewer people in the vaccination centre. When I got the third jab on Saturday, there was a big queue.

Question 2: When do people prefer to get a jab: weekdays or weekends/Saturdays or Sundays?

Question 3: Is there something illogical in data?

Overall, I need to find datasets to answer my questions.

- Data is about the UK, England, South West, and Bristol.
- Data is about new people who got the jabs by dates.

And I was lucky to find the website “Coronavirus (COVID-19) in the UK”.

2 Choosing datasets

- Create a list of metrics for each dataset
- Look at the metrics

newPeopleVaccinatedFirstDoseByPublishDate
newPeopleVaccinatedFirstDoseByVaccinationDate
newPeopleVaccinatedSecondDoseByPublishDate
newPeopleVaccinatedSecondDoseByVaccinationDate
newPeopleVaccinatedThirdInjectionByPublishDate
newPeopleVaccinatedThirdInjectionByVaccinationDate

Table 1: Lower Tier Local Authority (LTLA)

newPeopleVaccinatedBoosterDoseByPublishDate
newPeopleVaccinatedFirstDoseByPublishDate
newPeopleVaccinatedFirstDoseByVaccinationDate
newPeopleVaccinatedSecondDoseByPublishDate
newPeopleVaccinatedSecondDoseByVaccinationDate
newPeopleVaccinatedThirdDoseByPublishDate
newPeopleVaccinatedThirdInjectionByPublishDate
newPeopleVaccinatedThirdInjectionByVaccinationDate
newVaccinesGivenByPublishDate

Table 2: Nation

So, as we can see, **some metrics are common**. I suggest finding out which metrics are the same for all datasets.

- Add new metrics in a common list
- Build zero-matrix, which dimension is the count of metrics x the count of area types
- Show links

- Look at the result

	ltla	msoa	nation	nhsRegion	nhsTrust	overview	region	utla
newPeopleReceivingFirstDose	0	0	0	0	0	0	0	0
newPeopleReceivingSecondDose	0	0	0	0	0	0	0	0
newPeopleVaccinatedBoosterDoseByPublishDate	0	0	1	0	0	0	0	0
newPeopleVaccinatedFirstDoseByPublishDate	1	0	1	0	0	1	0	1
newPeopleVaccinatedFirstDoseByVaccinationDate	1	0	1	0	0	0	1	1
newPeopleVaccinatedSecondDoseByPublishDate	1	0	1	0	0	1	0	1
newPeopleVaccinatedSecondDoseByVaccinationDate	1	0	1	0	0	0	1	1
newPeopleVaccinatedThirdDoseByPublishDate	0	0	1	0	0	0	0	0
newPeopleVaccinatedThirdInjectionByPublishDate	1	0	1	0	0	1	0	1
newPeopleVaccinatedThirdInjectionByVaccinationDate	1	0	1	0	0	0	1	1
newVaccinesGivenByPublishDate	0	0	1	0	0	1	0	0

First of all, I am interested in data about the **first jab**. **So, I need to look at the datasets:**

Lower Tier Local Authority (LTLA)
Nation
Overview
Region
Upper Tier Local Authority (UTLA)

3 Step 3 Look at the datasets

3.1 South West

As we can see on the website, Region metrics are available for regions of England. I am interested in the South West and metrics that start with "New":

areaCode
areaName
areaType
date
newPeopleVaccinatedFirstDoseByVaccinationDate
newPeopleVaccinatedSecondDoseByVaccinationDate
newPeopleVaccinatedThirdInjectionByVaccinationDate

We have additional columns. Let's look at them.

- For **areaCode** unique value is $E12000009$,
- for **areaName** unique value is $SouthWest$,
- for **areaType** unique value is *region*.

So, we do not need to look at them in the future because these columns are used for filtering that we have already done on the website.

Let's prepare data for the plotting.

- Rename columns and columns
- Add the column MonthYear
- Create long table

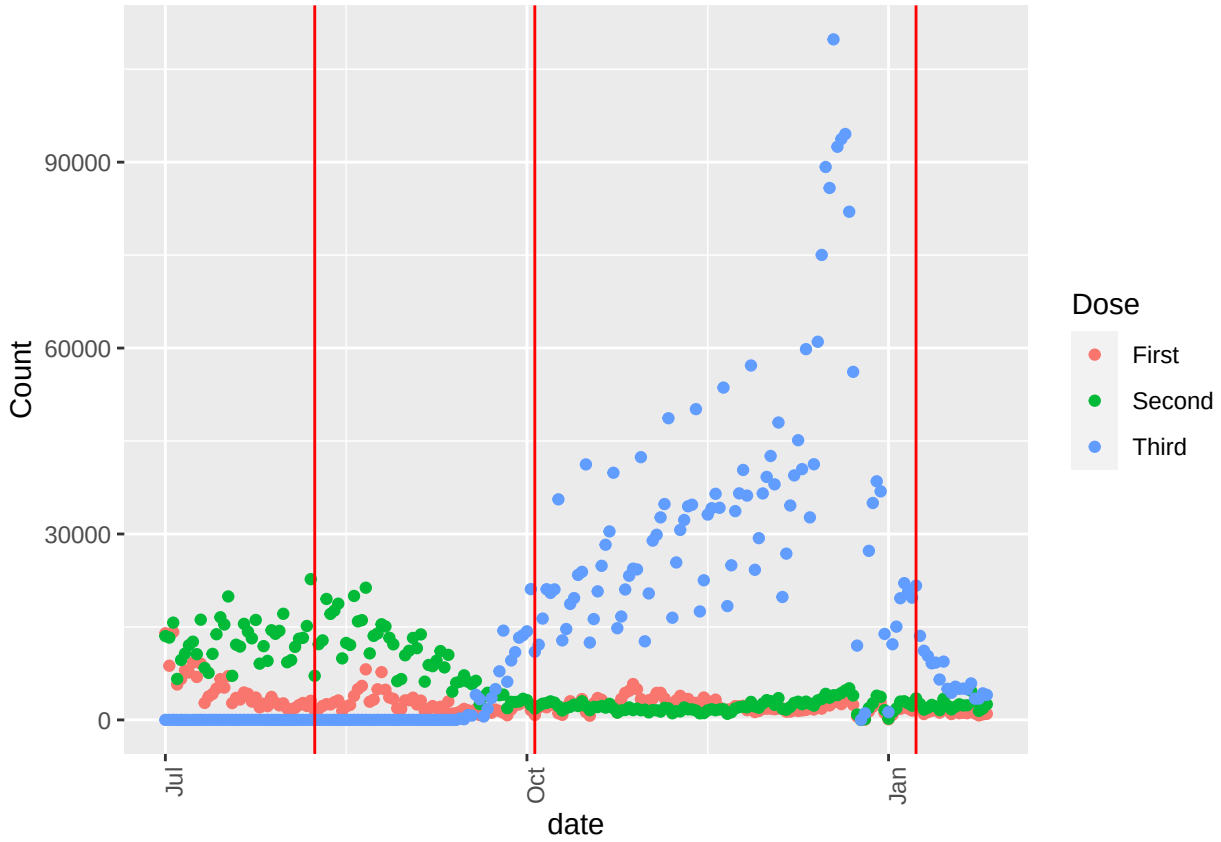
date	MonthYear	Dose	Count
2022-01-26	1.2022	First	986
2022-01-25	1.2022	First	899
2022-01-24	1.2022	First	723
2022-01-23	1.2022	First	1035
2022-01-22	1.2022	First	1822
2022-01-21	1.2022	First	1085

Let's plot something.

3.1.1 Question 0

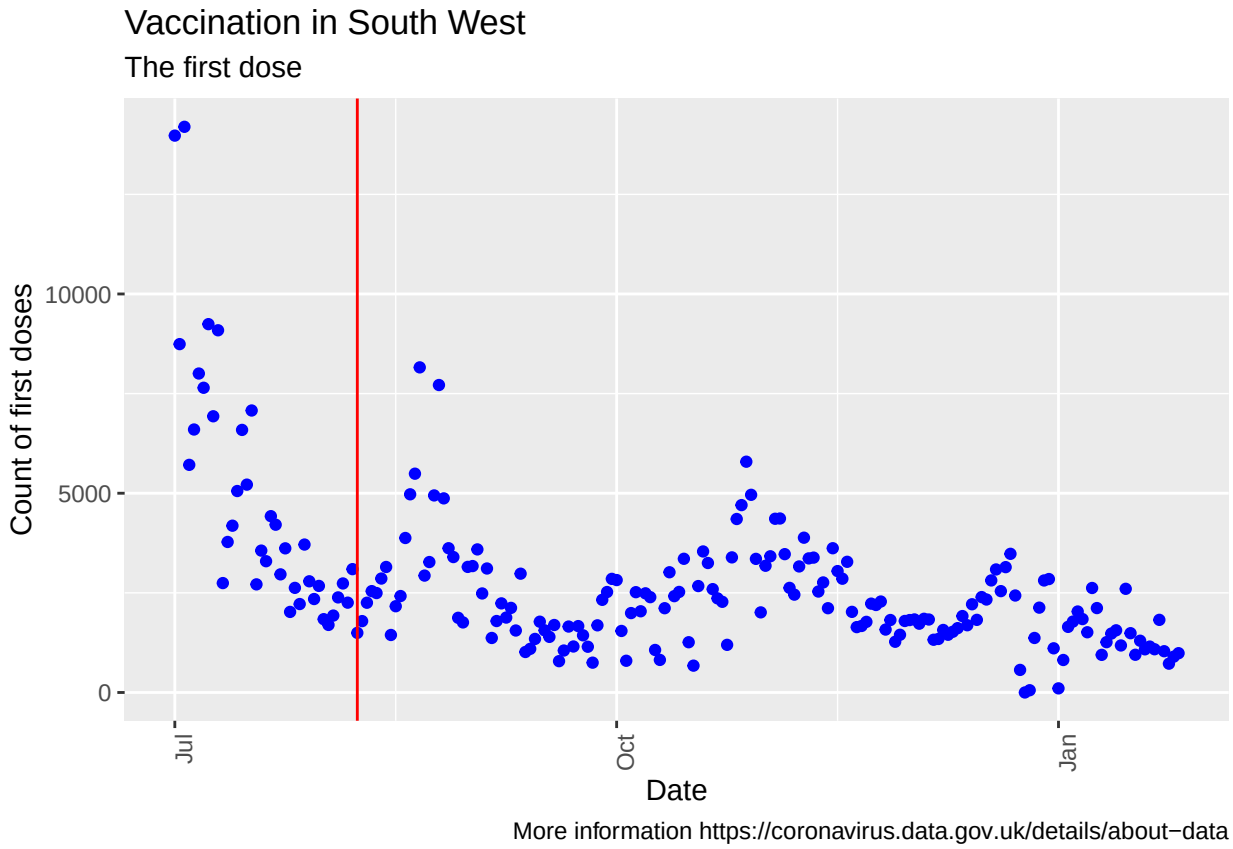
Are there dependencies between academic year events and vaccination waves? Does the vaccination depend on holidays?

Figure 1: My caption

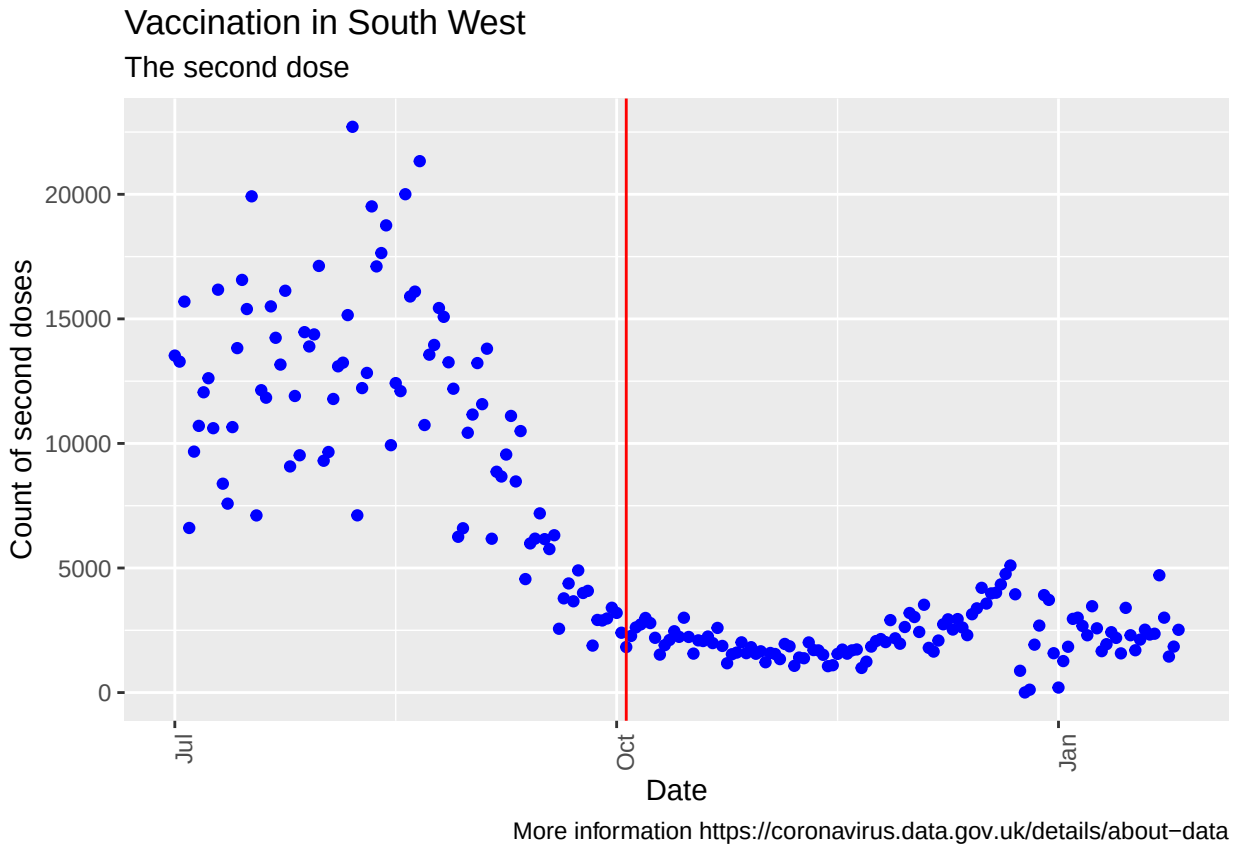


The result is not beautiful because of the active growth of the third jabs count at the end of 2021.

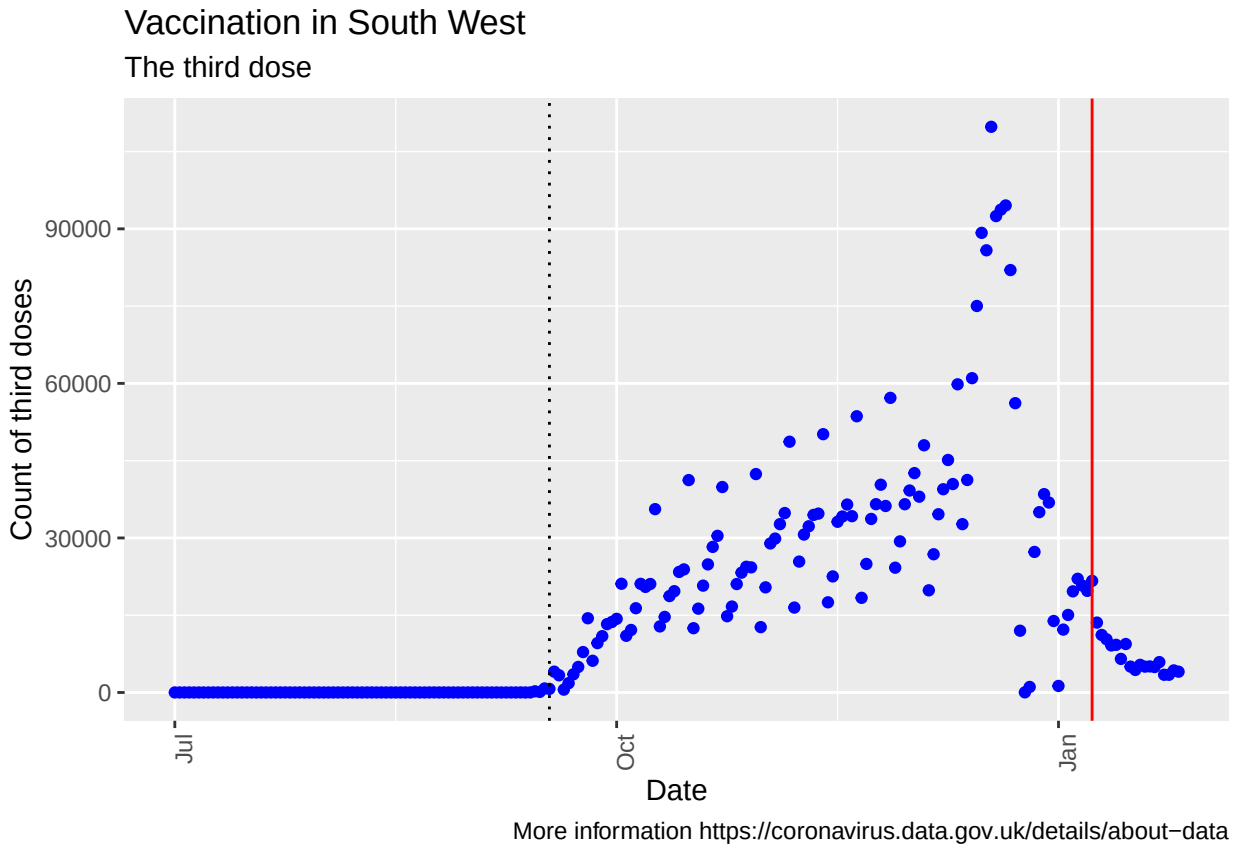
Let's plot them separately.



It is so interesting why the graph is wavy. 1496 people got their first jabs with me.



1828 people got their second jabs with me.

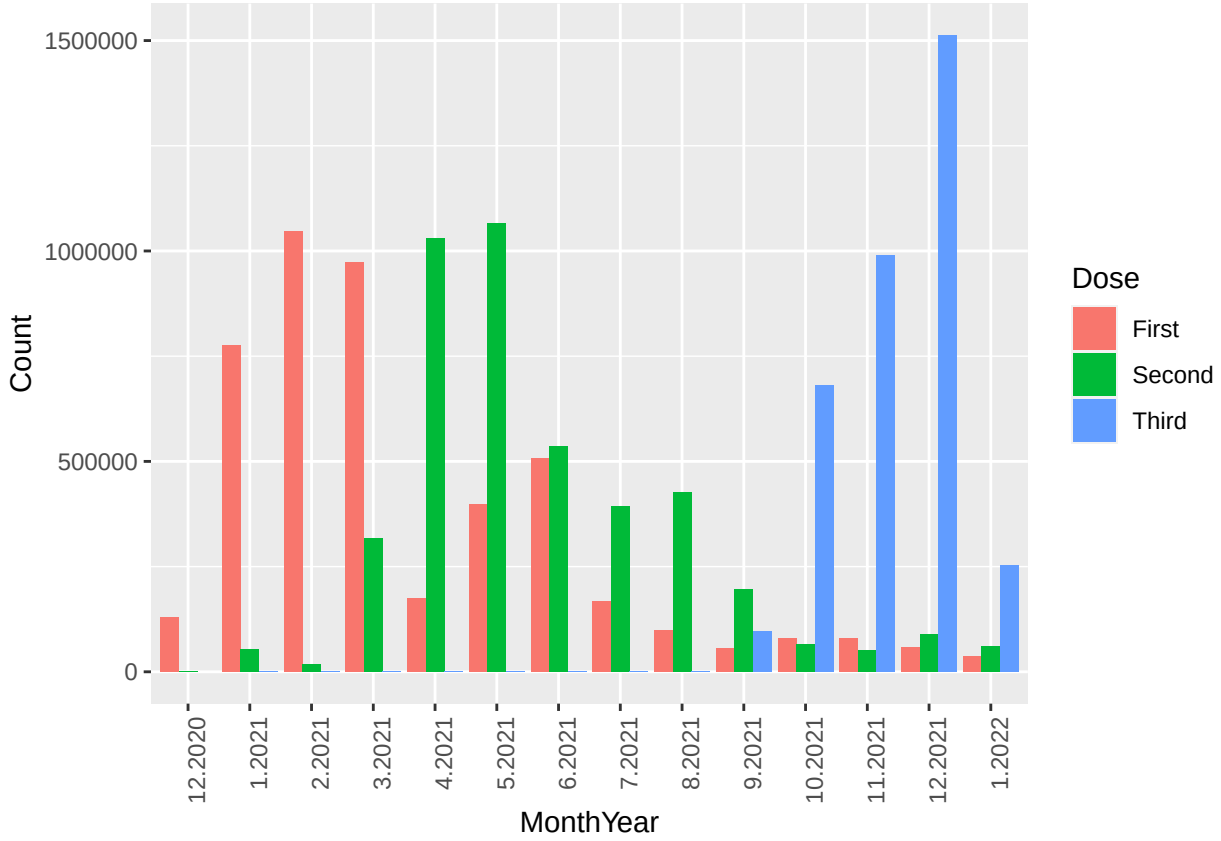


21664 people got their third jabs with me. We can see when the active phase of vaccination by the third dose started.

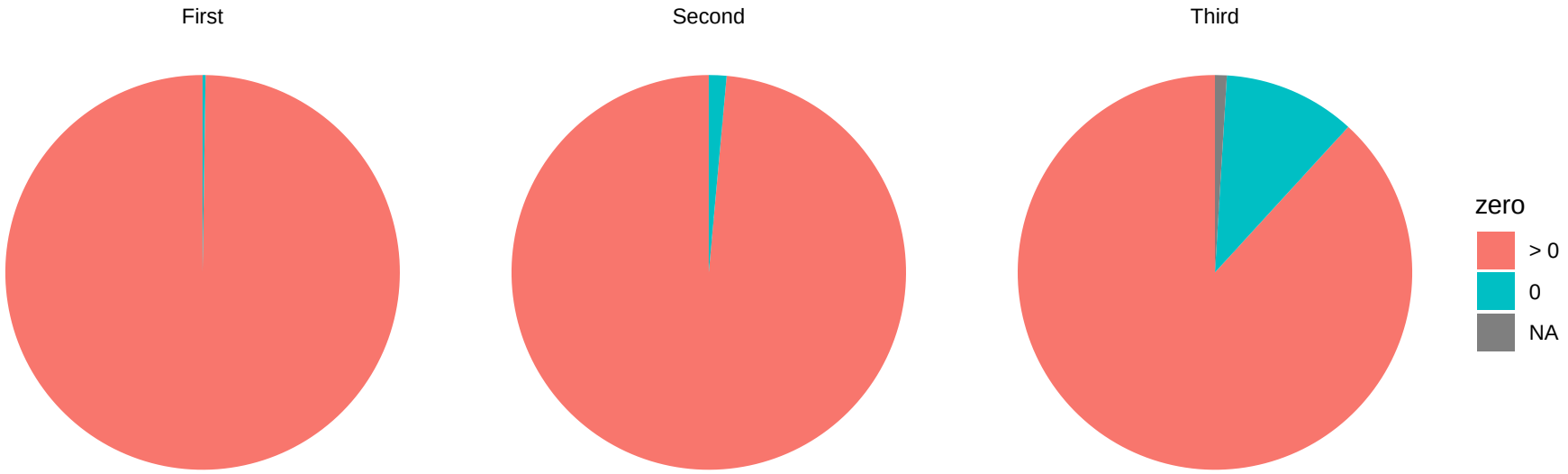
Let's calculate the date. ("2021-09-17")

```
## Warning: Removed 1 rows containing missing values (geom_col).
```

Figure 2: My caption



3.1.2 Zeroes



The column “Third” has more zero values than “First” and “Second; but, I think, it won’t influence models’ accuracy. Also, we can see missing values for the column”Third”; in our case, missing values mean that nobody got the third jab. I suggest replacing them with zeroes.

Replace missing values.

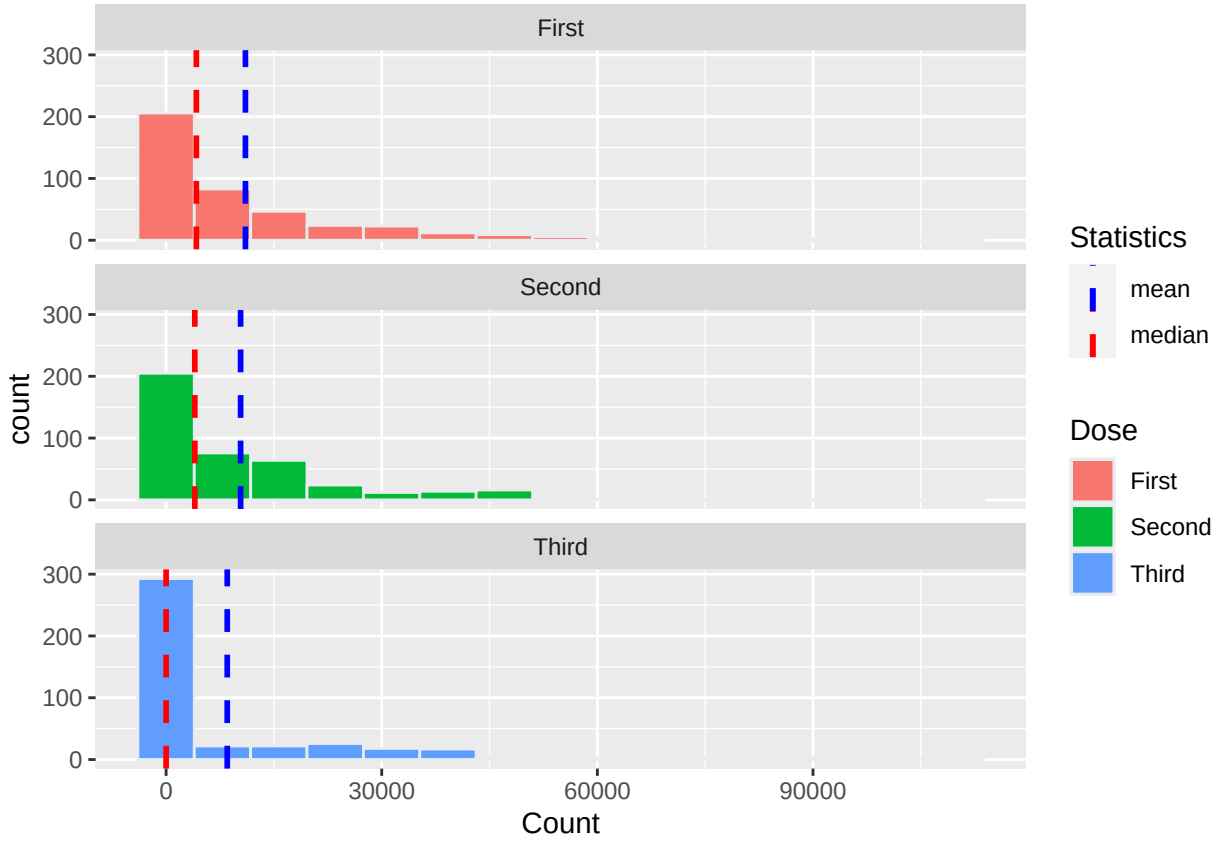
3.1.3 Data description

Median, percentiles and mean

	mean	median	Q0.25	Q0.75	Q0.9
First	11037.614	4210	2072.0	14213.0	31224.6
Second	10367.352	3998	1659.5	13708.5	28700.6
Third	8589.925	6	2.0	10629.5	33689.0

What can I say?

- Mean and median have a visible difference. So, there are large extreme values.
- For the Third dose, half of the values are below 6. That is not surprised. In the beginning, people needed to get two jabs.
- If we look at "Q0.25", "Q0.75", "Q0.90", we find out that the Third dose's wave caught up with other doses' waves quickly. We already saw this fact on the plot 1.



Standard deviation (sd), IQR and range

	sd	range	IQR
First	13971.58	84537	12141.0
Second	13477.22	78425	12049.0
Third	17512.10	109810	10627.5

IQR and standard deviation for each dose are big, consequently, the data spread out. Also, we can see the difference between largest and smallest values in the column "range".

3.2 Bristol

The dataset's columns:

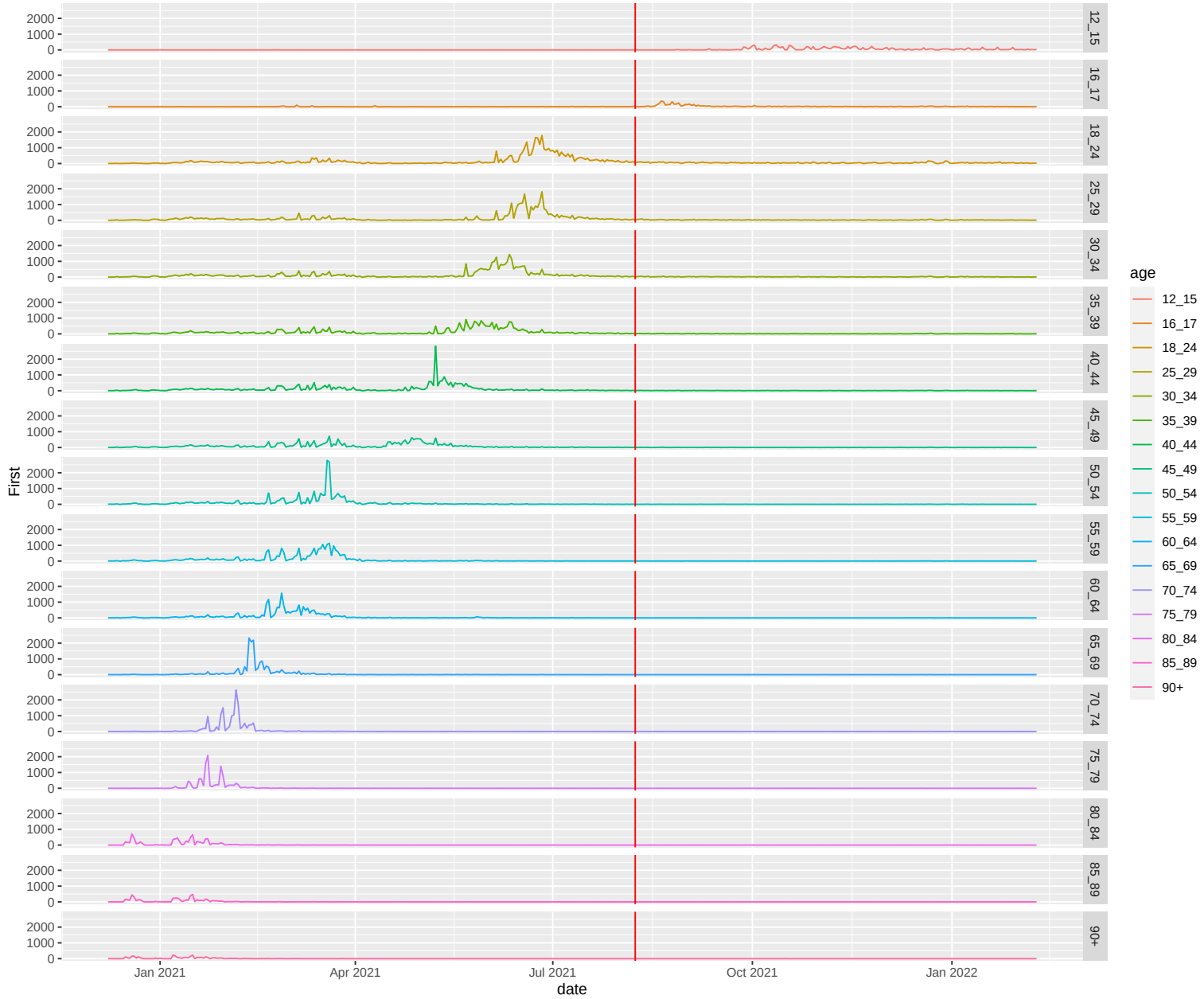
areaCode
areaName
areaType
date
age
VaccineRegisterPopulationByVaccinationDate
cumPeopleVaccinatedCompleteByVaccinationDate
newPeopleVaccinatedCompleteByVaccinationDate
cumPeopleVaccinatedFirstDoseByVaccinationDate
newPeopleVaccinatedFirstDoseByVaccinationDate
cumPeopleVaccinatedSecondDoseByVaccinationDate
newPeopleVaccinatedSecondDoseByVaccinationDate
cumPeopleVaccinatedThirdInjectionByVaccinationDate
newPeopleVaccinatedThirdInjectionByVaccinationDate
cumVaccinationFirstDoseUptakeByVaccinationDatePercentage
cumVaccinationSecondDoseUptakeByVaccinationDatePercentage
cumVaccinationThirdInjectionUptakeByVaccinationDatePercentage
cumVaccinationCompleteCoverageByVaccinationDatePercentage

We have additional columns. Let's look at them.

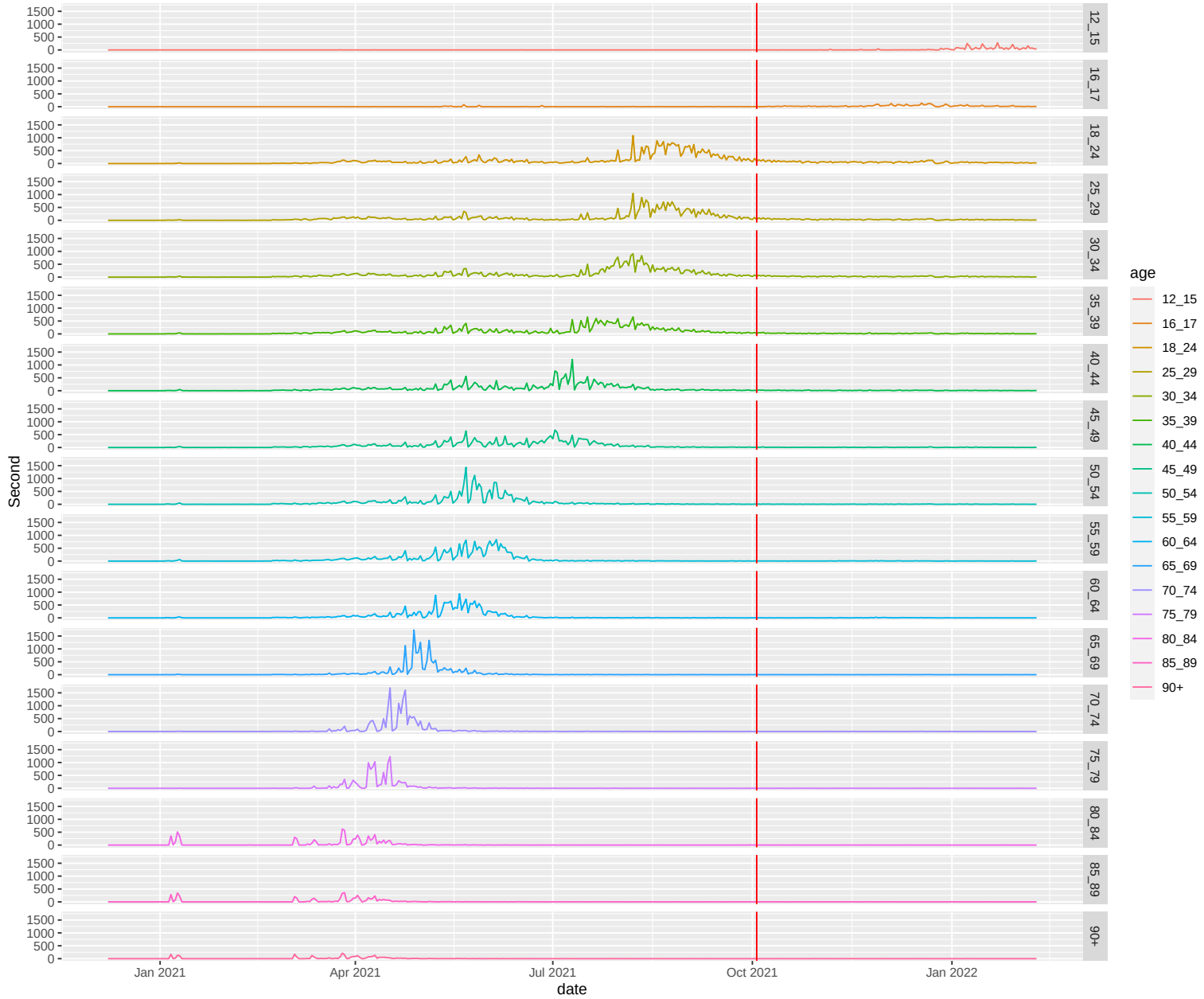
There are 1 unique value for **areaCode**, 1 unique value for **areaName**, and 1 unique value for **areaType** as well. So, we do not need to look at them in the future because these columns are used for filtering that we have already done on the website.

Just rename columns and we will move on to answer the questions.

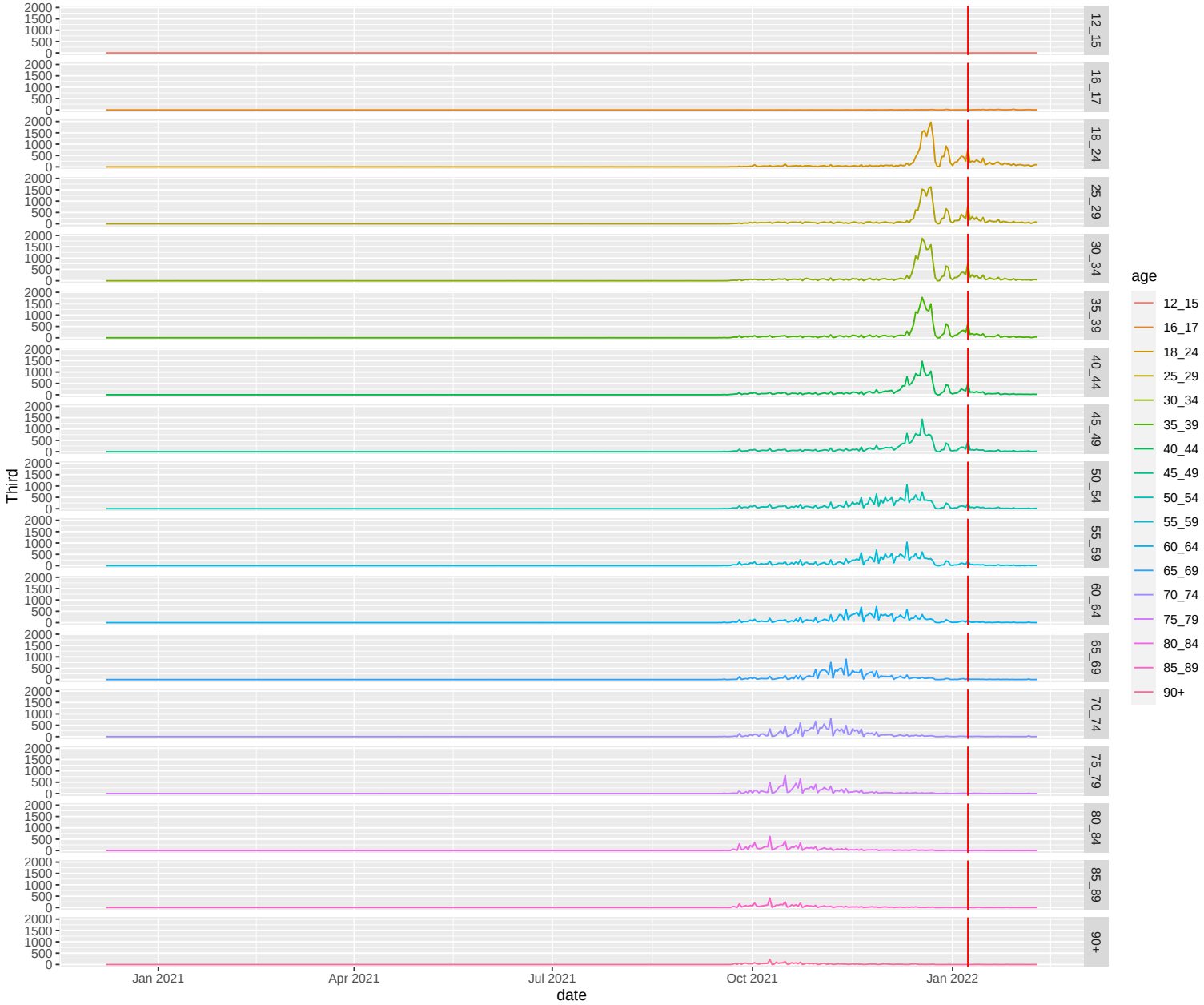
age	date	First	Second	Third
12_15	2022-02-09	28	45	0
16_17	2022-02-09	4	8	6
18_24	2022-02-09	25	18	83
25_29	2022-02-09	11	8	48
30_34	2022-02-09	4	10	37
35_39	2022-02-09	3	8	26


First
2000
1000
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

16 people in my age group got their First jabs with me in Bristol.

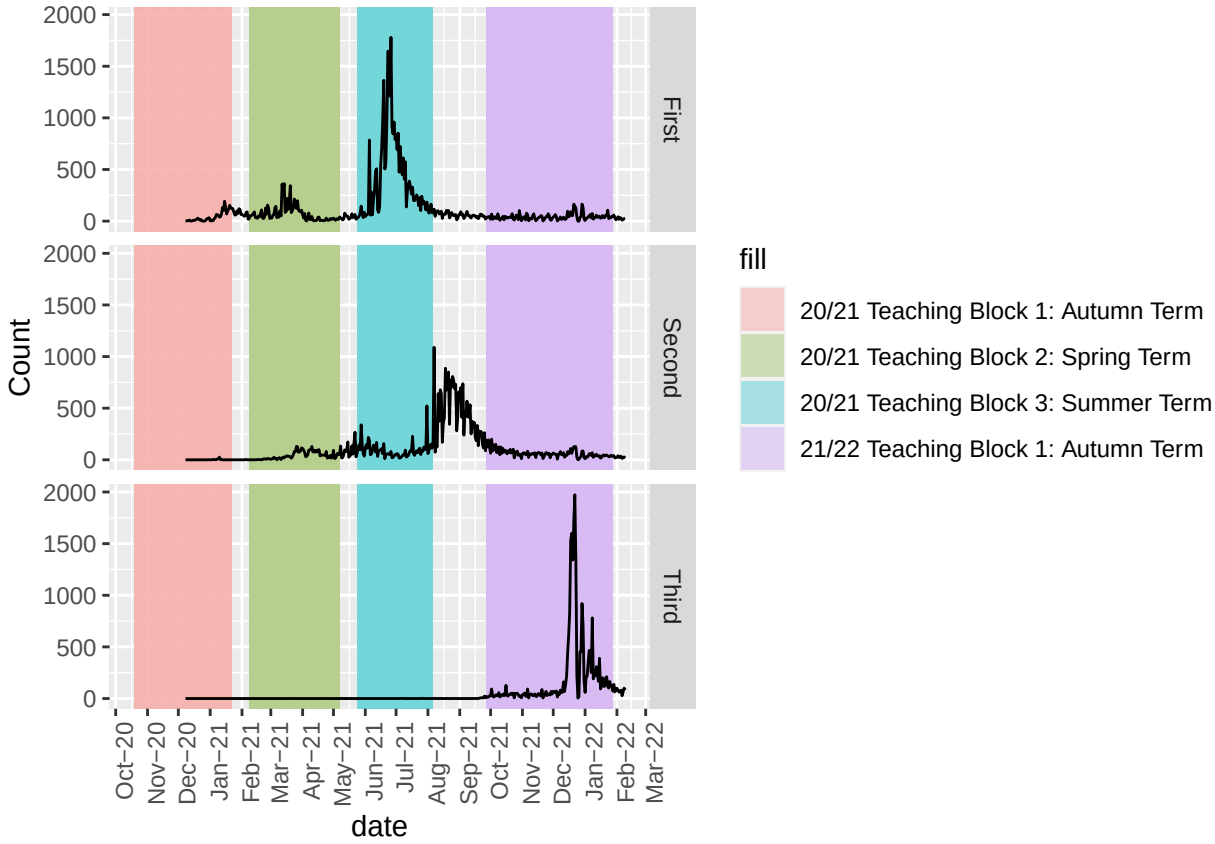

Second
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

37 people in my age group got their Second jabs with me in Bristol.


Third
2000
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

806 people in my age group got their Third jabs with me in Bristol.

Students



https://www.uwe.ac.uk/study/term-dates/2020-21-term-dates

https://www.uwe.ac.uk/study/term-dates/2021-22-term-dates

https://www.uwe.ac.uk/study/term-dates/2022-23-term-dates

3.3 England

Look at the dataset's columns.

areaCode
areaName
areaType
date
newPeopleVaccinatedFirstDoseByVaccinationDate
newPeopleVaccinatedSecondDoseByVaccinationDate
newPeopleVaccinatedThirdInjectionByVaccinationDate

We are not going to look at the columns areaCode, areaName, areaType, because these columns have one unique value ($E92000001$ for areaCode, *England* for areaName, *nation* for areaType), they are used for filtering on the website.

Rename columns and exclude unnecessary columns.

	Date	First	Second	Third
457	2020-12-08	5370	146	NA
456	2020-12-09	9648	137	2
455	2020-12-10	11888	119	1
454	2020-12-11	12516	82	1
453	2020-12-12	10565	23	3
452	2020-12-13	6134	30	0

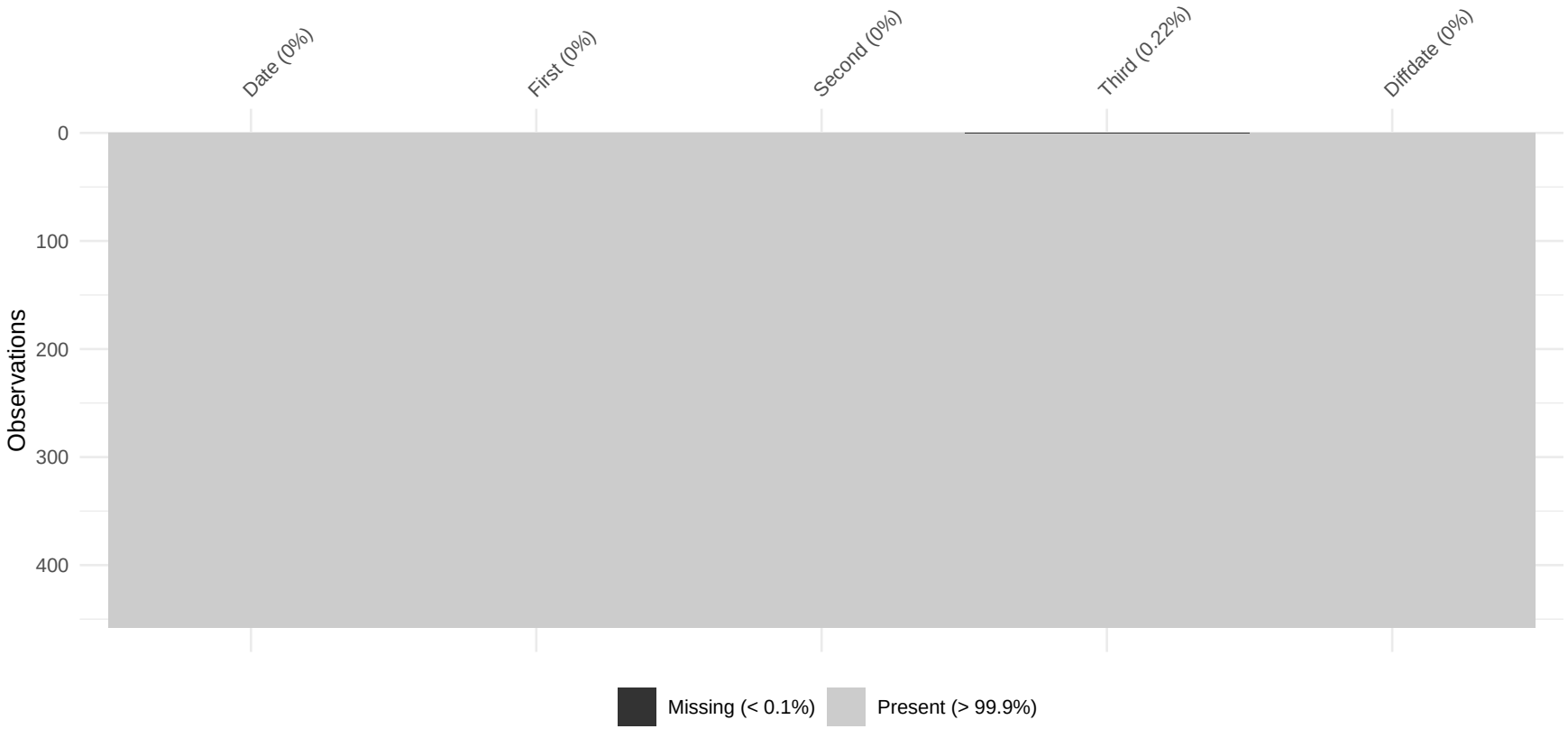
I want to be sure that the file has statistics for every day.

- Add the column with difference between the date and the previous date within the table.

The difference between dates is 1. So, we have full statistics by date.

Do we have missing values?

Date	0
First	0
Second	0
Third	1
Diffdate	0

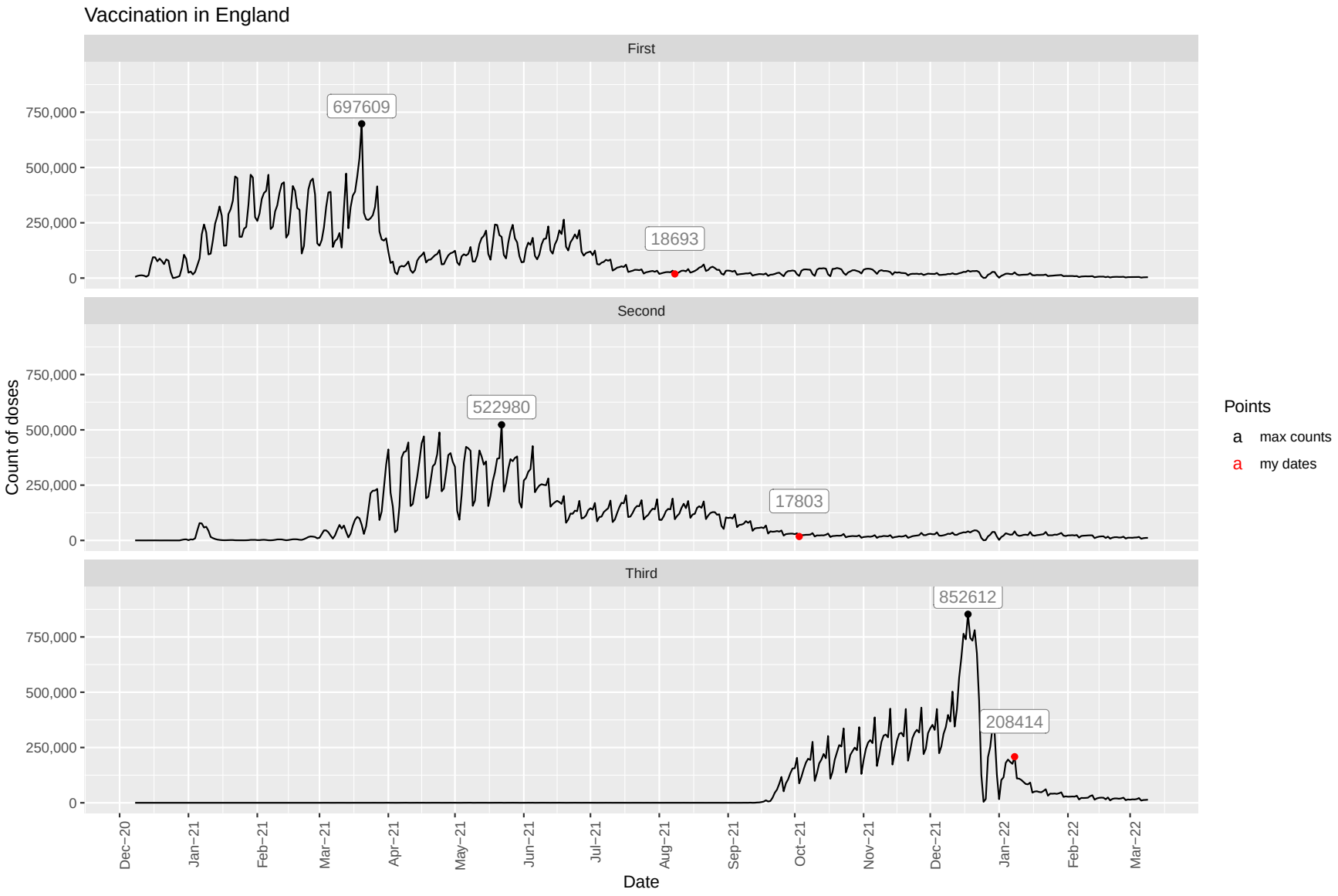


Yes, we have missing values in the column “Third”. In this case, missing values and zeroes are equivalent.

Replace by zero.

I have a question.

How many people got their jabs with me?


Vaccination in England
First
Second
Third
697609
18693
522980
17803
852612
208414
750,000
500,000
250,000
0
Count of doses
Dec−20
Jan−21
Feb−21
Mar−21
Apr−21
May−21
Jun−21
Jul−21
Aug−21
Sep−21
Oct−21
Nov−21
Dec−21
Jan−22
Feb−22
Mar−22
Date
Points
a max counts
a my dates

4 Step 4 Machine learning

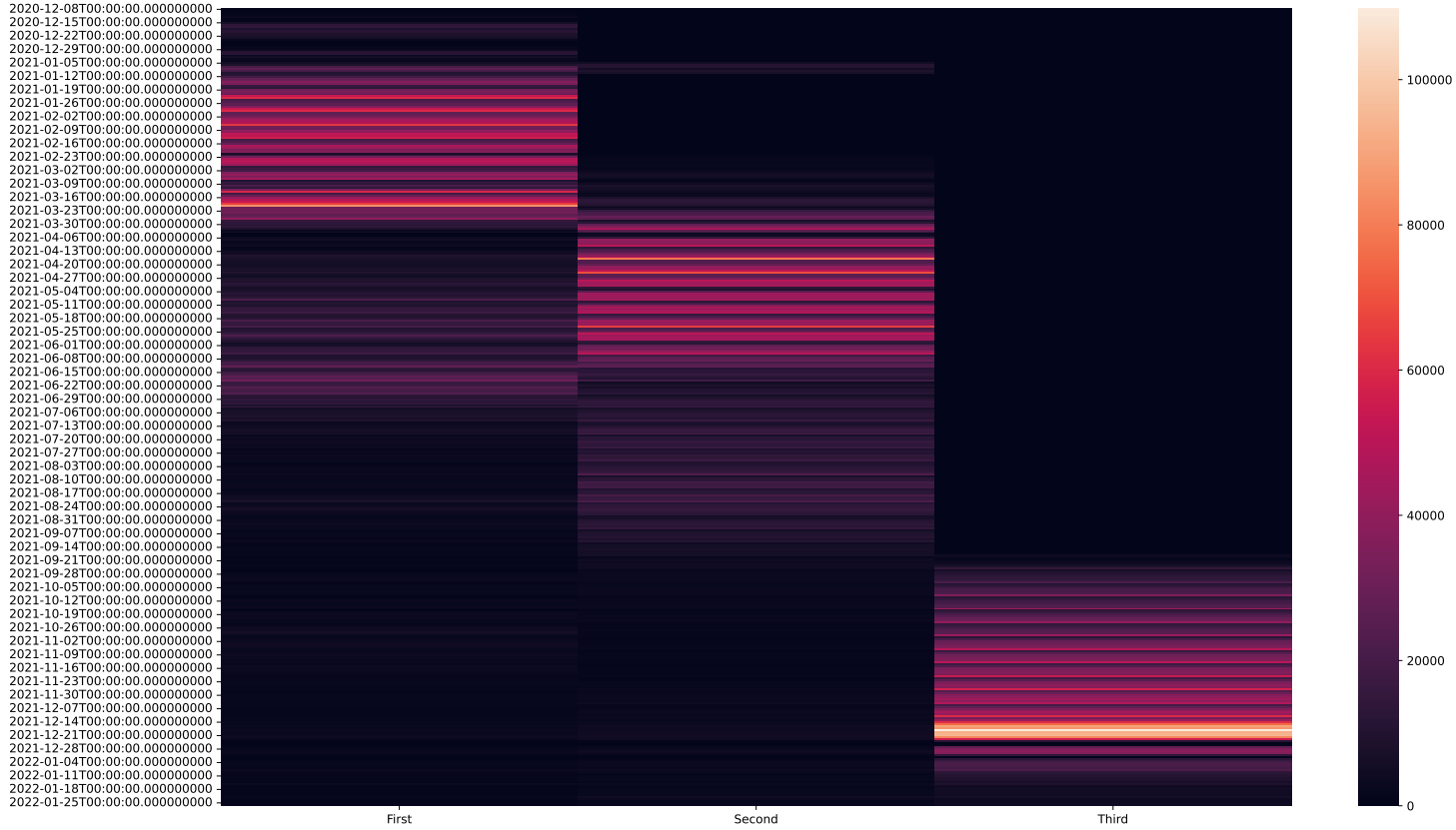
4.1 South West

4.1.1 Look at and Modify the dataset

So, I am curious. Can I predict vaccination data?

I will work with the South West's vaccination data.

	First	Second	Third
2022-01-26	986	2520	4034
2022-01-25	899	1845	4283
2022-01-24	723	1445	3441
2022-01-23	1035	3007	3439
2022-01-22	1822	4709	5896
2022-01-21	1085	2362	4944
2022-01-20	1152	2330	5058
2022-01-19	1083	2524	5017
2022-01-18	1298	2126	5359
2022-01-17	946	1699	4374



As we discuss earlier 2, there are waves. So, the count of jabs depends on dates.

Let's get features: 1) Year 2) Month 3) Day etc.

	First	Second	Third	Year	Month	Day	DayOfYear	Weekday	Quarter	IsMonthStart	IsMonthEnd
2022-01-26	986	2520	4034	2022	1	26	26	2	1	FALSE	FALSE
2022-01-25	899	1845	4283	2022	1	25	25	1	1	FALSE	FALSE
2022-01-24	723	1445	3441	2022	1	24	24	0	1	FALSE	FALSE
2022-01-23	1035	3007	3439	2022	1	23	23	6	1	FALSE	FALSE
2022-01-22	1822	4709	5896	2022	1	22	22	5	1	FALSE	FALSE
2022-01-21	1085	2362	4944	2022	1	21	21	4	1	FALSE	FALSE
2022-01-20	1152	2330	5058	2022	1	20	20	3	1	FALSE	FALSE
2022-01-19	1083	2524	5017	2022	1	19	19	2	1	FALSE	FALSE
2022-01-18	1298	2126	5359	2022	1	18	18	1	1	FALSE	FALSE
2022-01-17	946	1699	4374	2022	1	17	17	0	1	FALSE	FALSE

First of all, I am going to use Regression Machine Learning models:

- Decision Tree
- Random Forest.

What is my plan?

1. Read data

I already did this step.

2. Understand statistics about the data

It will be helpful to choose the right features for better results.

- Work with missing data and categorical variables
- Work with outliers or not completed data.

5. Store prediction target (y) in a Series, selecting multiple features by providing a list of column names inside brackets, define X (subset with features), check the X summary.
6. Choose the library
7. Build and use the model What type of model will it be? Capture patterns from provided data. Predict Evaluate = Determine how accurate the model's predictions are

Let's look at the dataset carefully.

4.1.2 Explore the dataset

In the previous chapter 3.1, we already looked at the South West's data. Do we need to know something else? Yes.

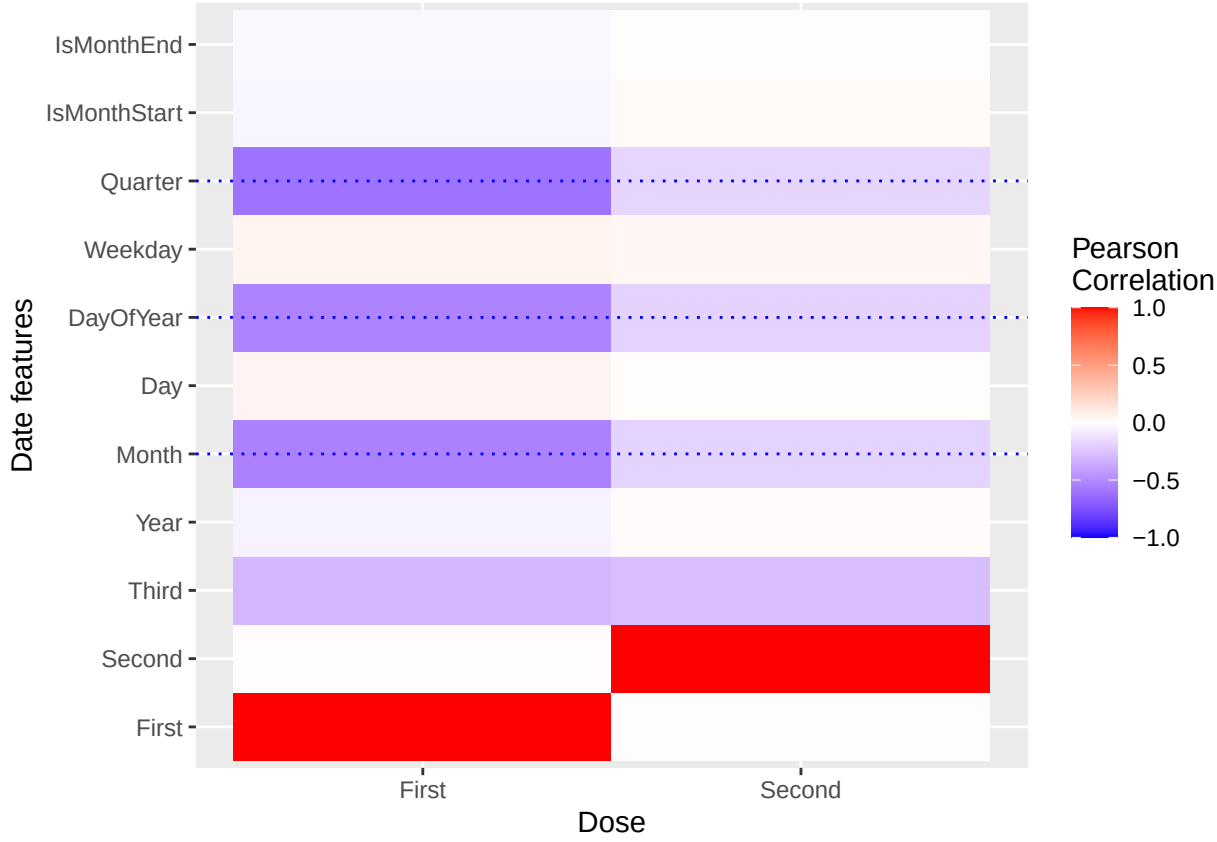
4.1.2.1 Data types It is important to know which types of data columns have. Sometimes we don't realise what we see: the string or the number.

First	double
Second	double
Third	double
Year	double
Month	double
Day	double
DayOfYear	double
Weekday	double
Quarter	double
IsMonthStart	logical
IsMonthEnd	logical

The good news is I don't need to convert my variables because they fit into Regression Machine Learning models.

We will move on to correlations.

4.1.2.2 Correlations What do we need to remember? Correlation does not imply causation. So, the columns that have a strong relationship may show low accuracy in the model.

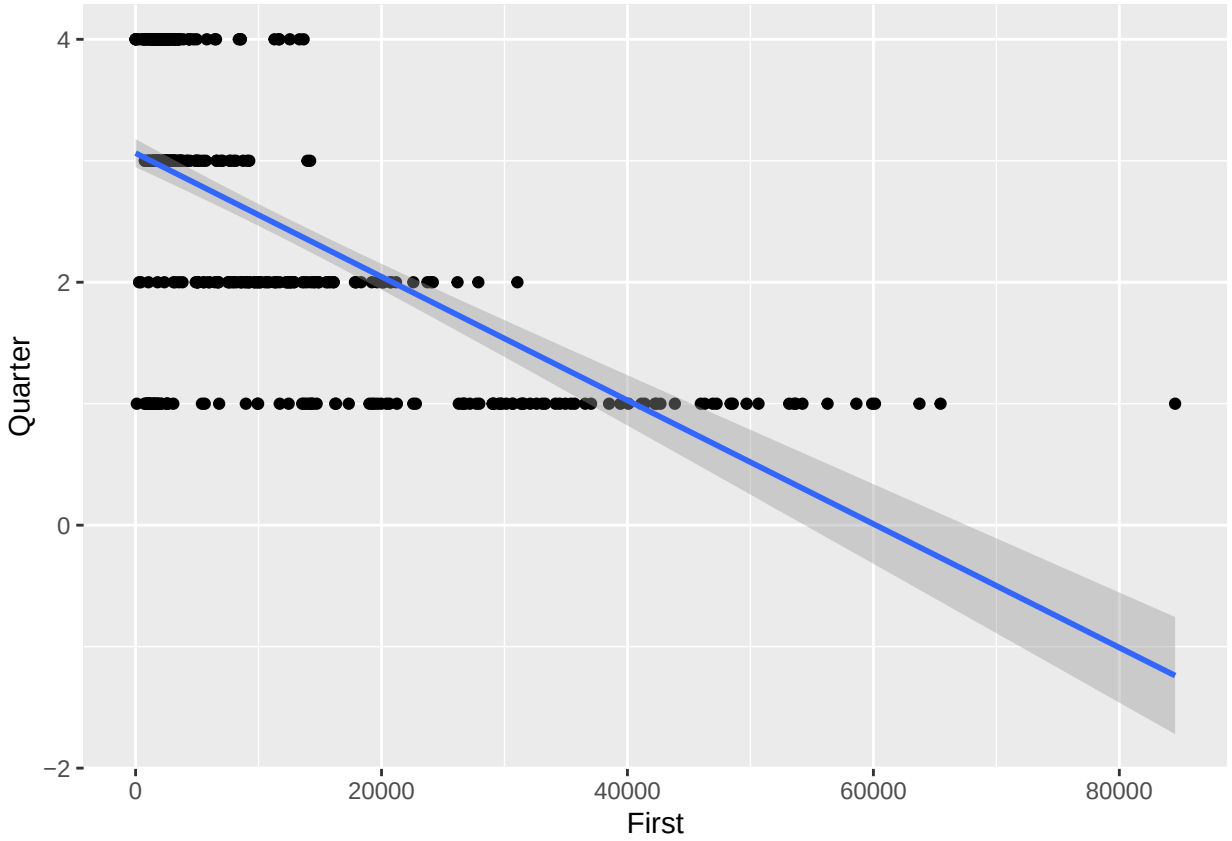


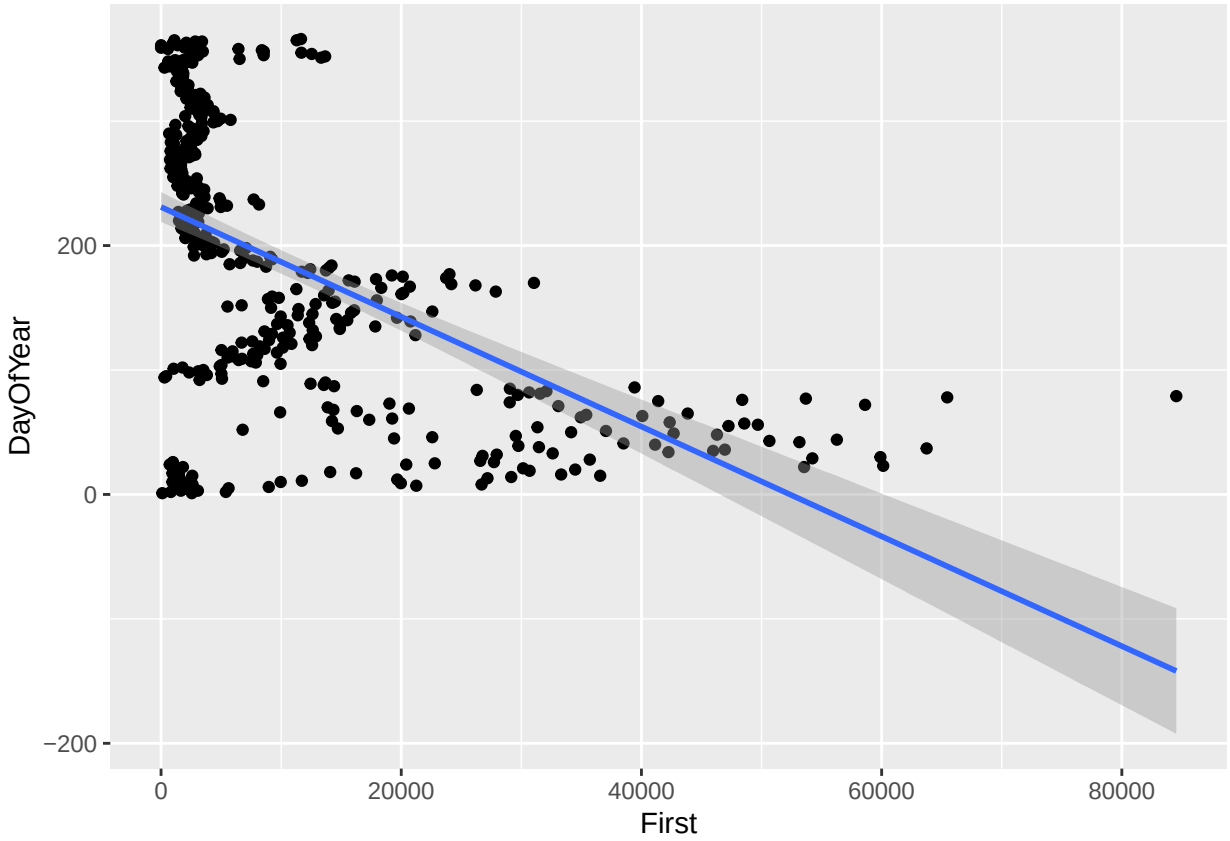
In the table below, we can see the numeric values.

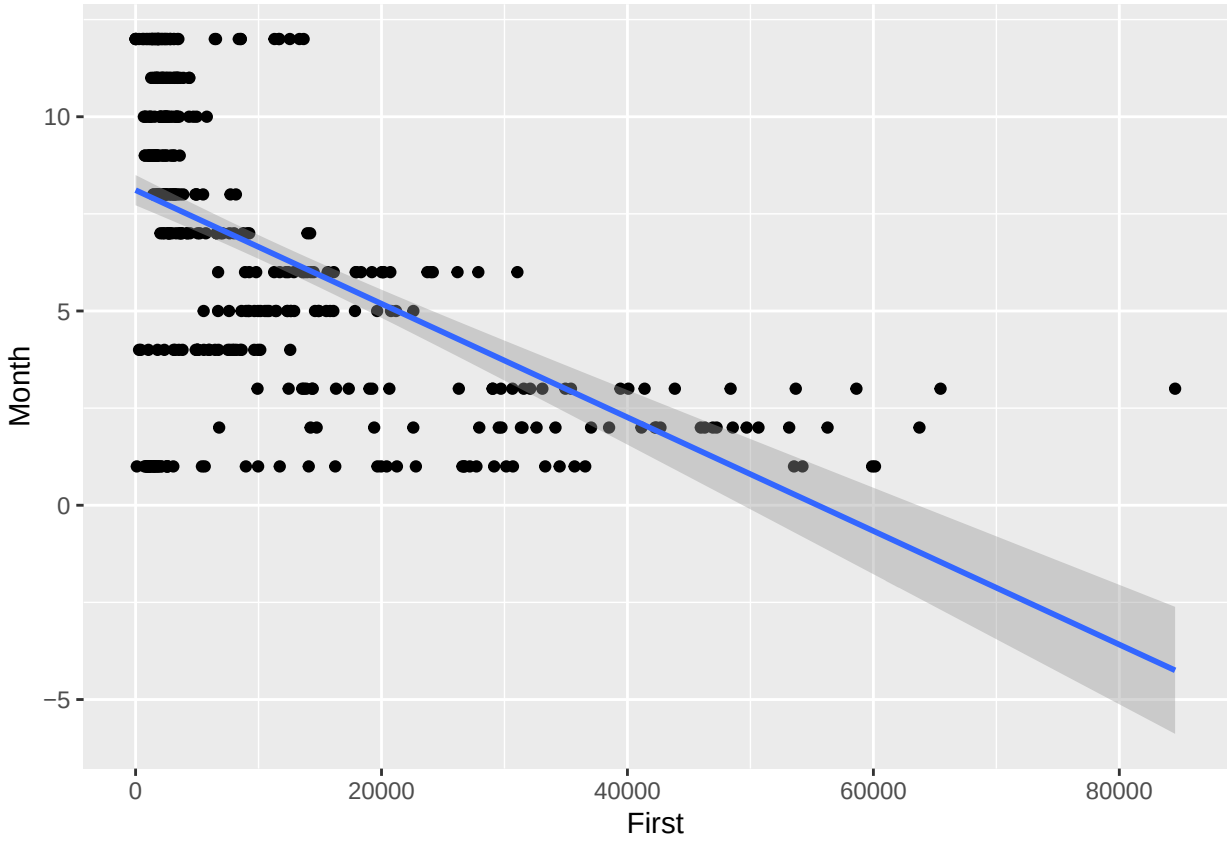
First	Month	-0.5432969
Second	Month	-0.1888013
First	DayOfYear	-0.5343244
Second	DayOfYear	-0.1901012
First	Quarter	-0.6070344
Second	Quarter	-0.1799906

As we can see, the column “First” has a strong relationship with

- “Quarter”,
- “DayOfYear”,
- “Month”.



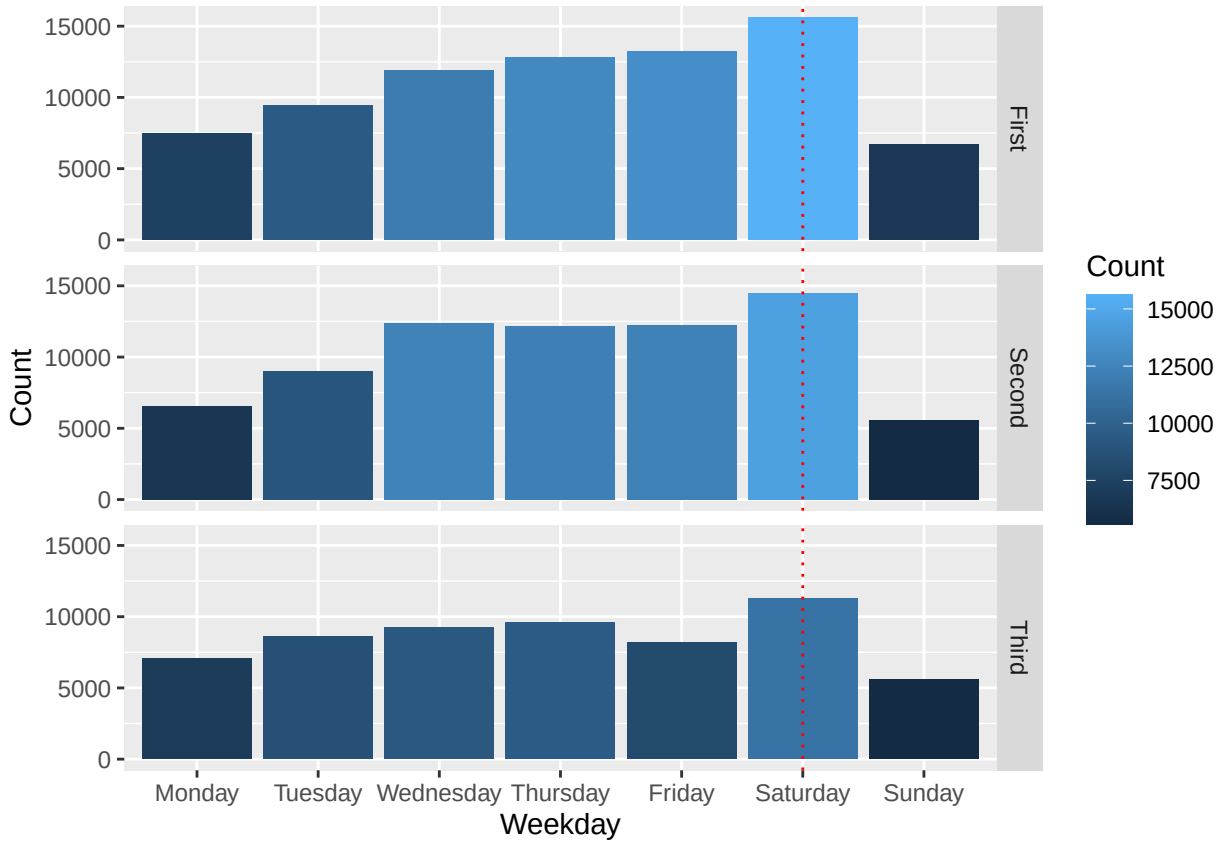

DayOfYear
200
0
−200
0
20000
40000
60000
80000
First



At the same time, the column “Second” doesn’t have strong relationships; but we can use the same columns.

4.1.2.3 Weekdays As you remember, I have a question. When do people prefer to get a jab: weekdays or weekends/Saturdays or Sundays? It may be helpful to choose the right features.

Let's answer.



So, most of South West's people prefer to get a jab on Saturdays. That is not illogical because, for example, for me, the side effects go away during the weekend.

4.1.2.4 Missing values As we already saw in the previous chapter 3.1, the column "Third" has missing values, but we can replace them with zeroes. Do we have the dates when nobody got the jab?

Calculate a count of dates in the dataset.

```
## 415
```

Calculate a count of dates between maximum and minimum dates.

```
## 415
```

There are no missing dates.

So, we have finished the dataset exploring. The next steps are about the models.

4.1.3 Split sets, train a Machine Learning Model and Evaluate performance

Define necessary variables

First of all, I will use all columns that I have.

Year
Month
Day
DayOfYear
Weekday
Quarter
IsMonthStart
IsMonthEnd

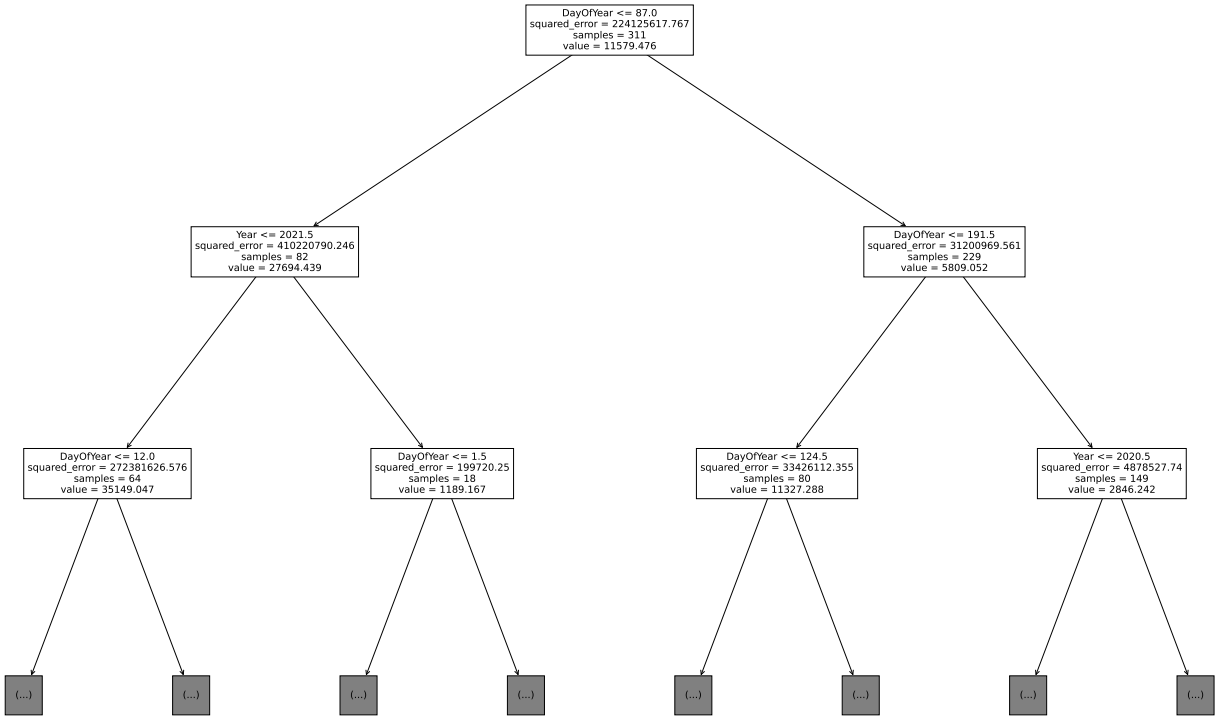
Prepare sets and train models using parameters.

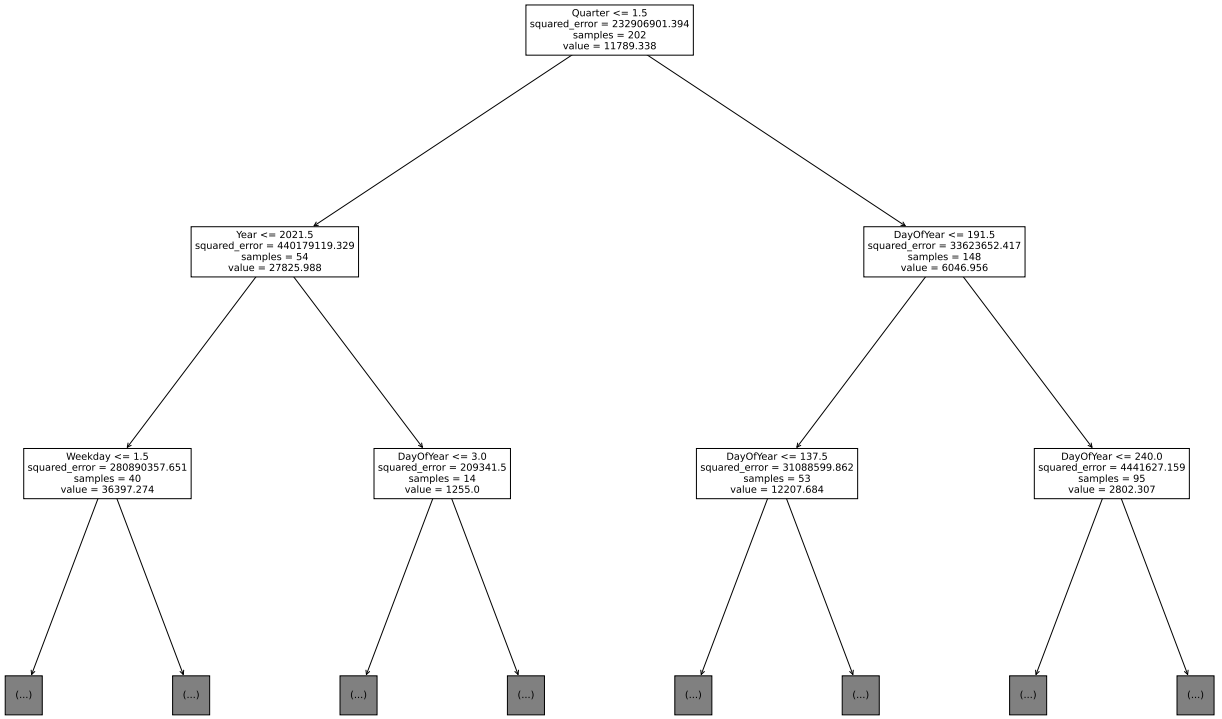
The first column that I will predict is "First".

```
## DecisionTree:  0.719657929335243
```

```
## RandomForest:  0.774580856609961
```

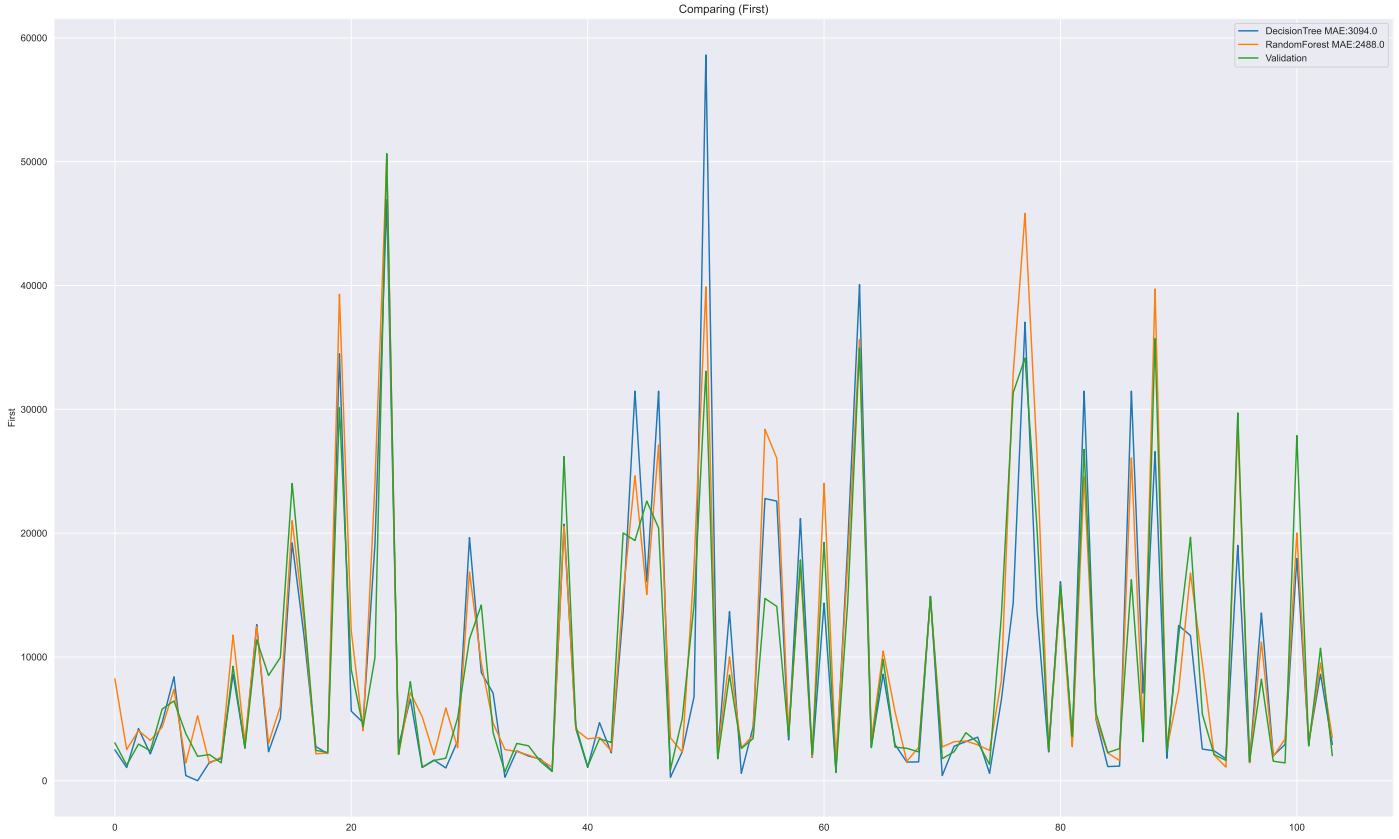
Look at the tree


DayOfYear <= 87.0
squared_error = 224125617.767
samples = 311
value = 11579.476
Year <= 2021.5
squared_error = 410220790.246
samples = 82
value = 27694.439
DayOfYear <= 191.5
squared_error = 31200969.561
samples = 229
value = 5809.052
DayOfYear <= 12.0
squared_error = 272381626.576
samples = 64
value = 35149.047
DayOfYear <= 1.5
squared_error = 199720.25
samples = 18
value = 1189.167
DayOfYear <= 124.5
squared_error = 33426112.355
samples = 80
value = 11327.288
Year <= 2020.5
squared_error = 4878527.74
samples = 149
value = 2846.242
(...)
(...)
(...)
(...)
(...)
(...)
(...)
(...)



What can we see?

Finally, look at the result.



In my opinion, the result is good.

- The waves were recognized.

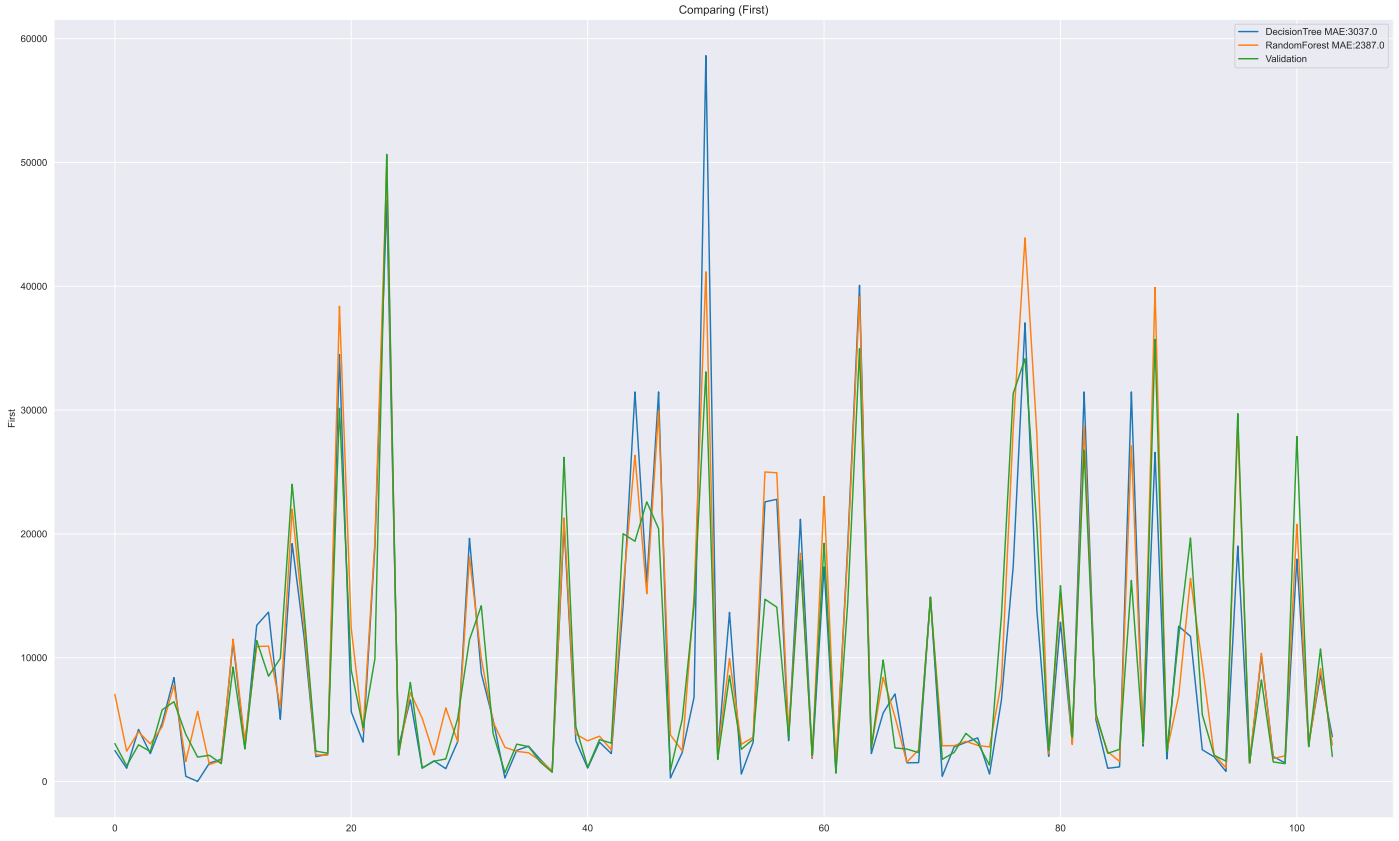
- The extreme values are bigger than in real data.

Let's work with the columns that I chose during the dataset exploring.

- "Weekday" that we discussed in this chapter influences the wave during the week.
- "Year" is the logical key because of the vaccination steps.
- DayOfYear was chosen because of the dependency on dates.

```
## DecisionTree:  0.7248630326024768
```

```
## RandomForest:  0.7837038702898657
```

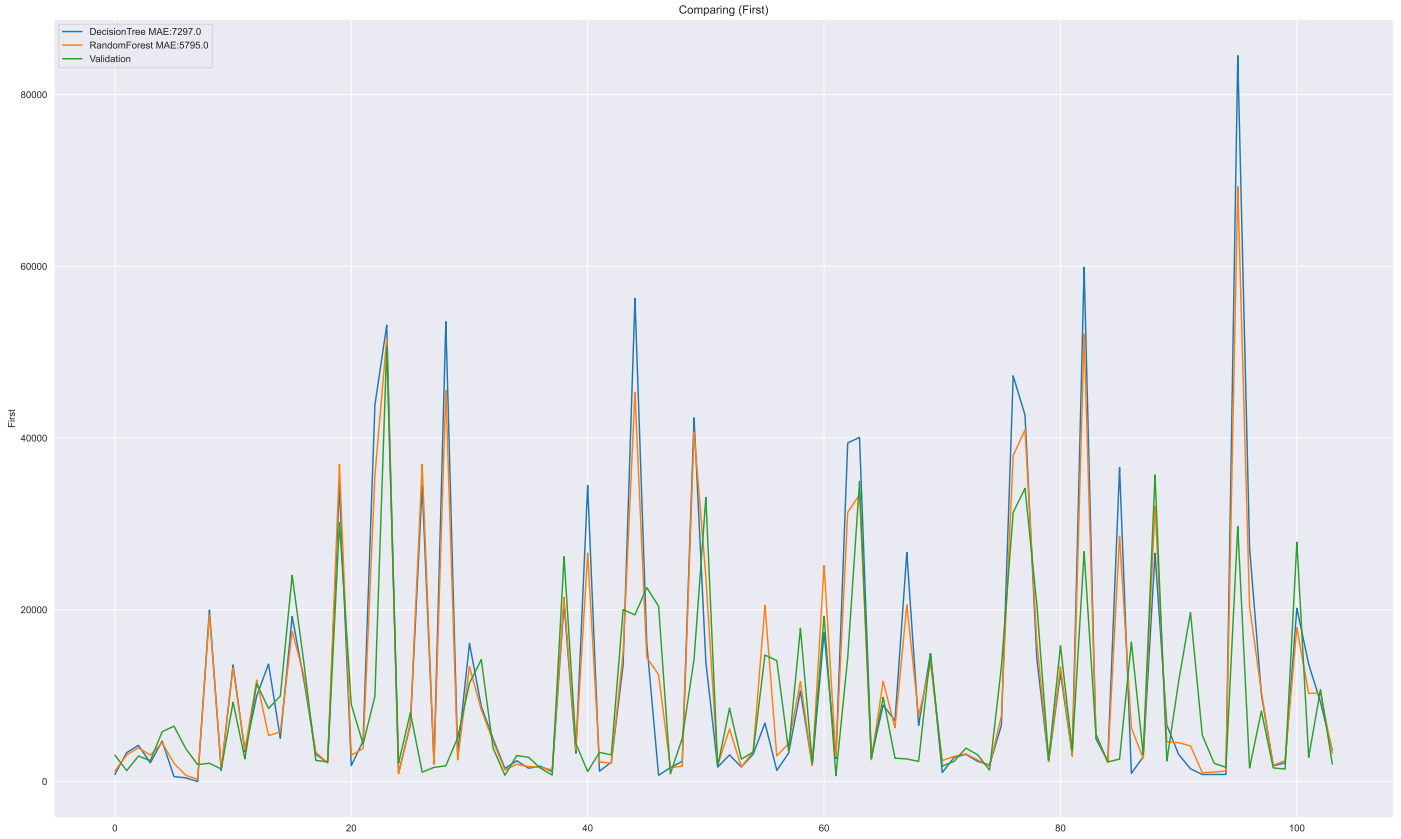


The result is better a little, but extreme values are disappointing.

Also, I suggest checking the model with columns that we discussed during the correlations search.

```
## DecisionTree:  0.338881322155111
```

```
## RandomForest:  0.47495276411406473
```

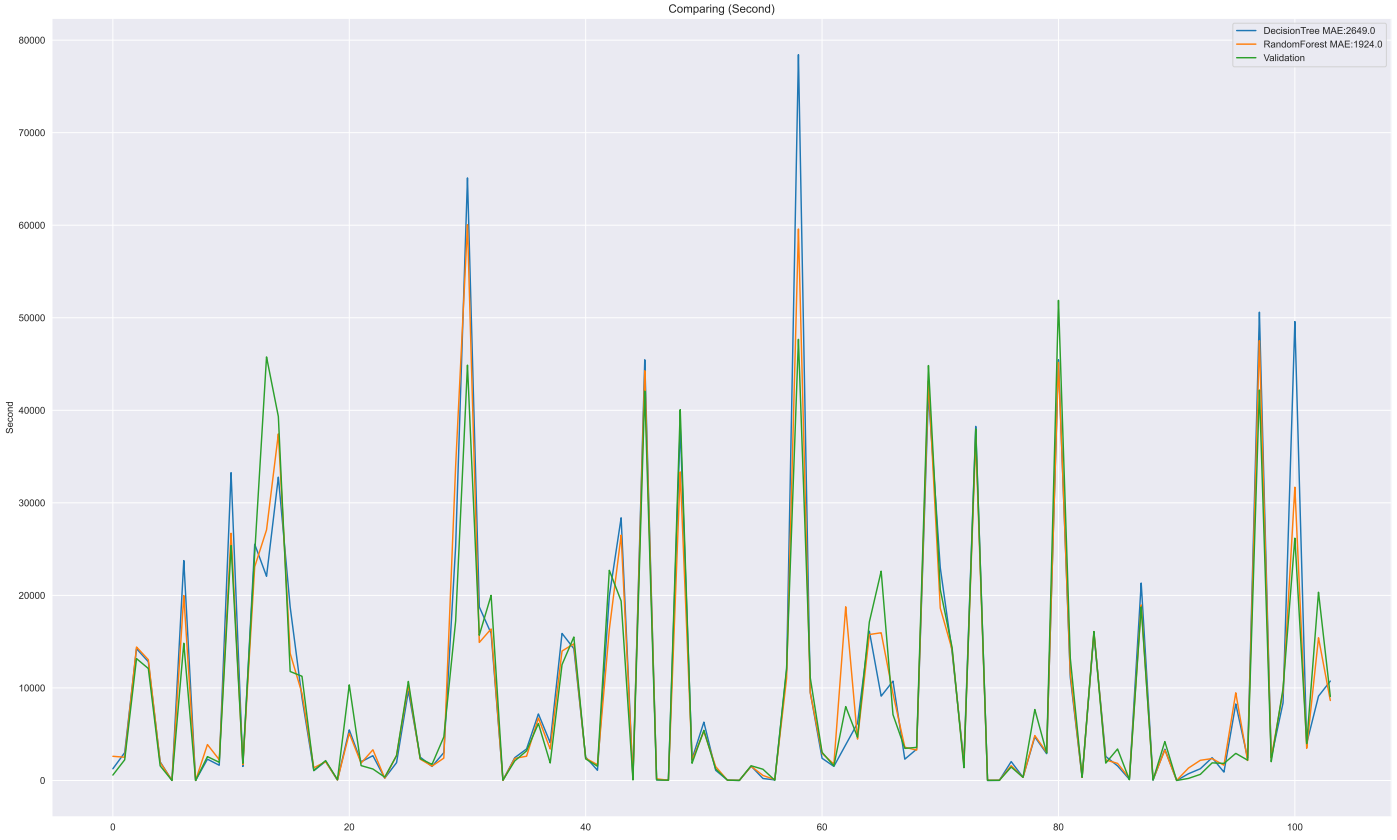


Not so good.

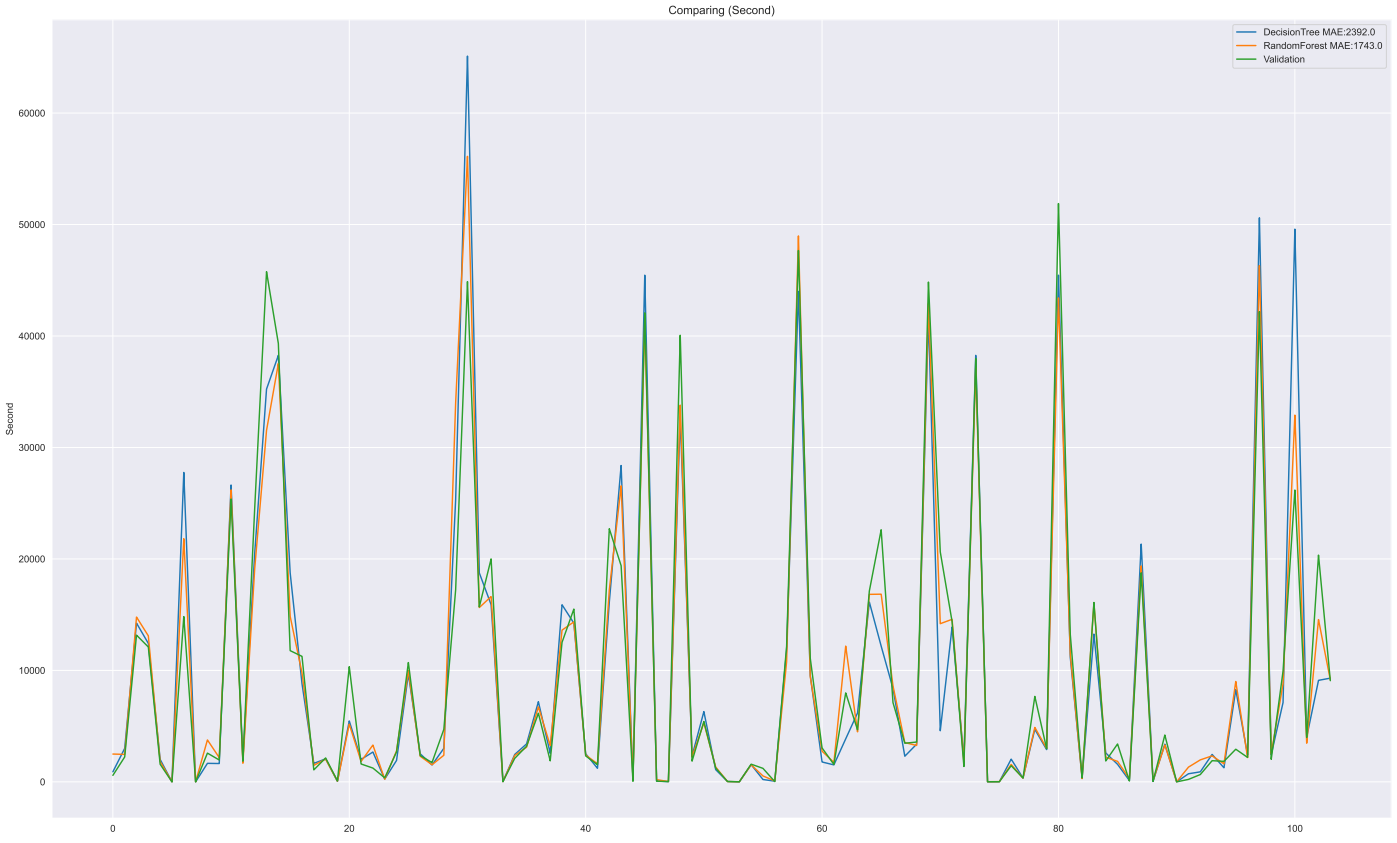
Repeat for the Second

```
## DecisionTree:  0.7445280765098062
```

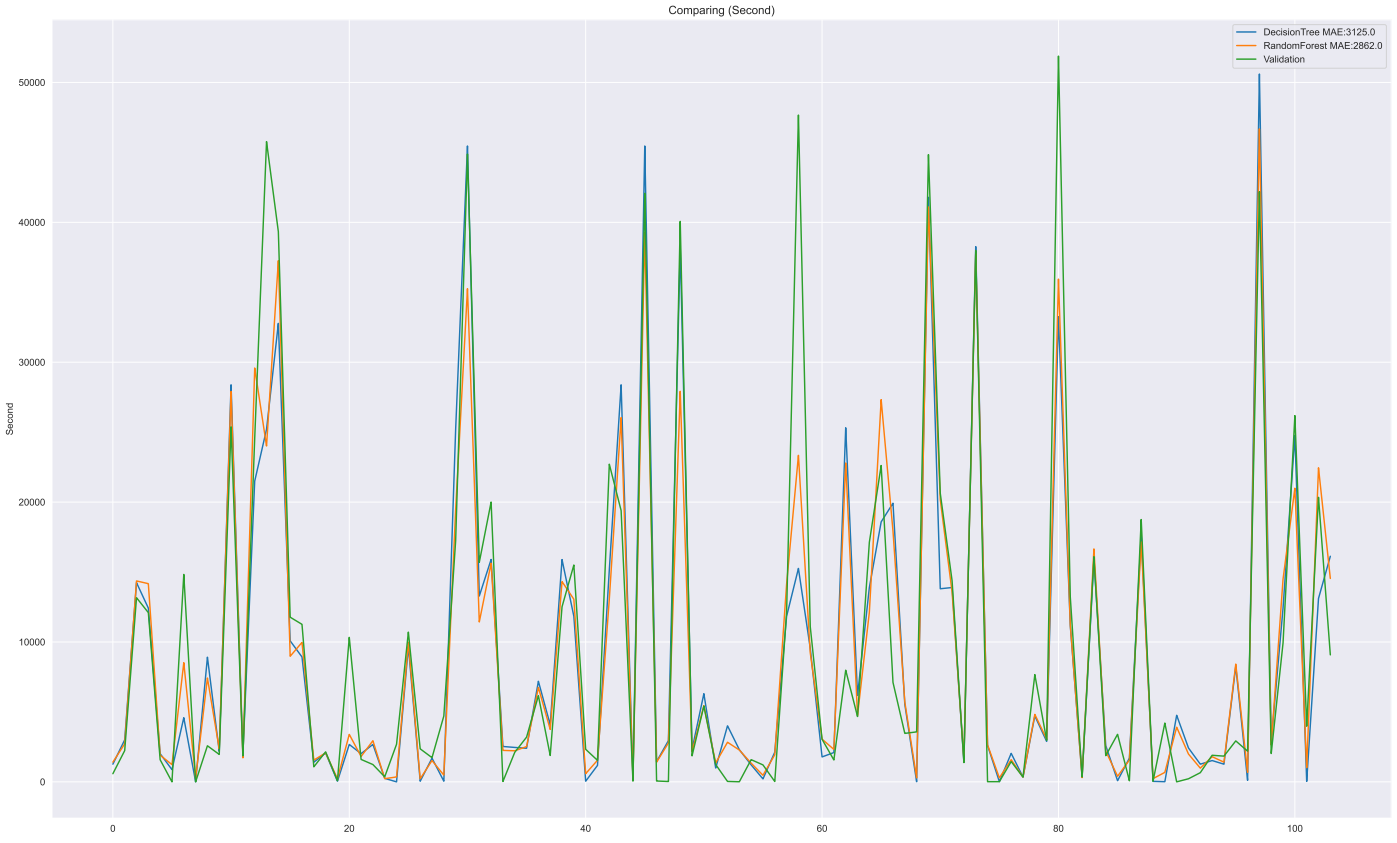
```
## RandomForest:  0.8144473412230163
```


Comparing (Second)
DecisionTree MAE:2649.0
RandomForest MAE:1924.0
Validation
Second
80000
70000
60000
50000
40000
30000
20000
10000
0
0
20
40
60
80
100

```
## DecisionTree:  0.7692636418171874

## RandomForest:  0.8318561653086721
```

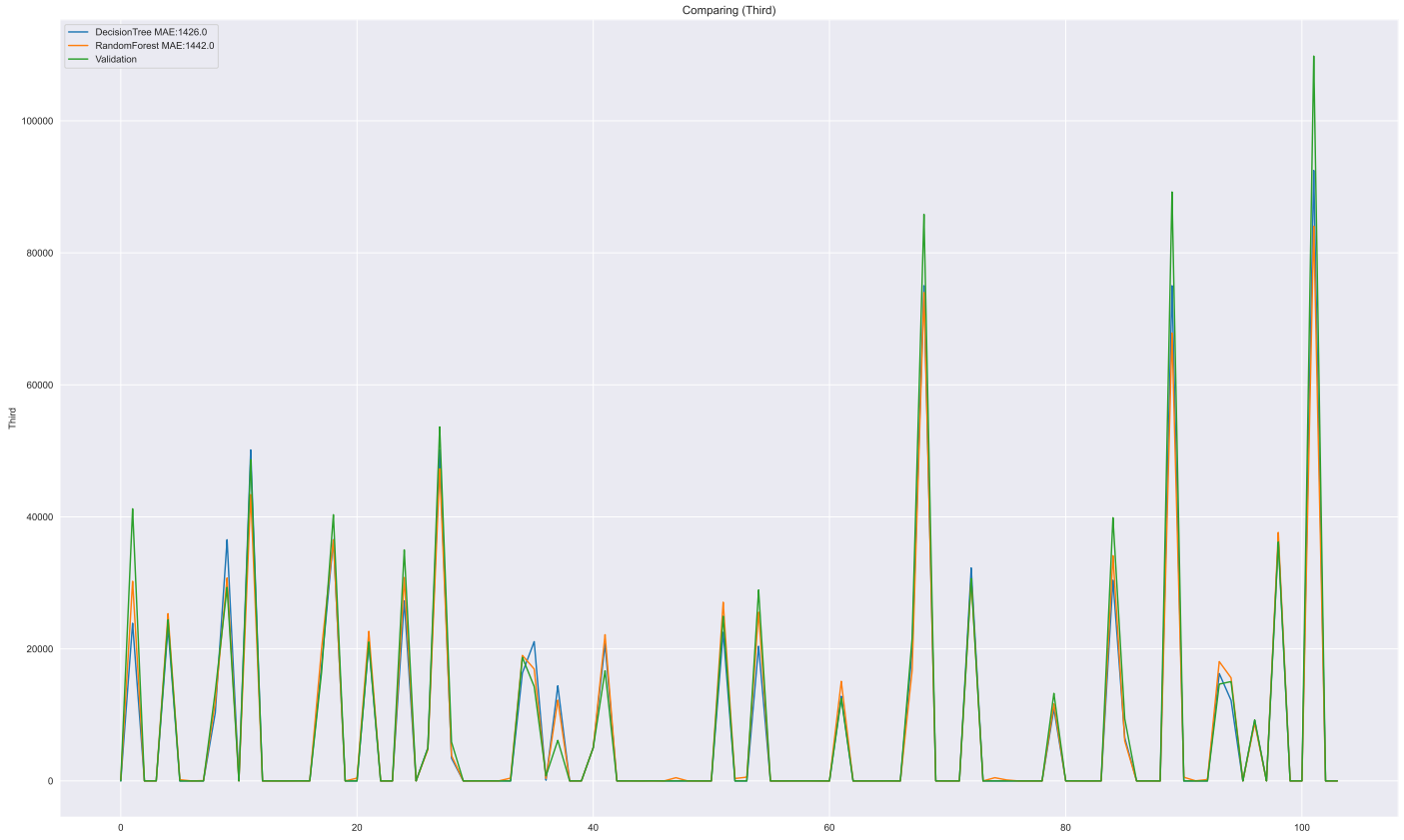


```
## DecisionTree:  0.6985989452917025

## RandomForest:  0.7239113203537064
```

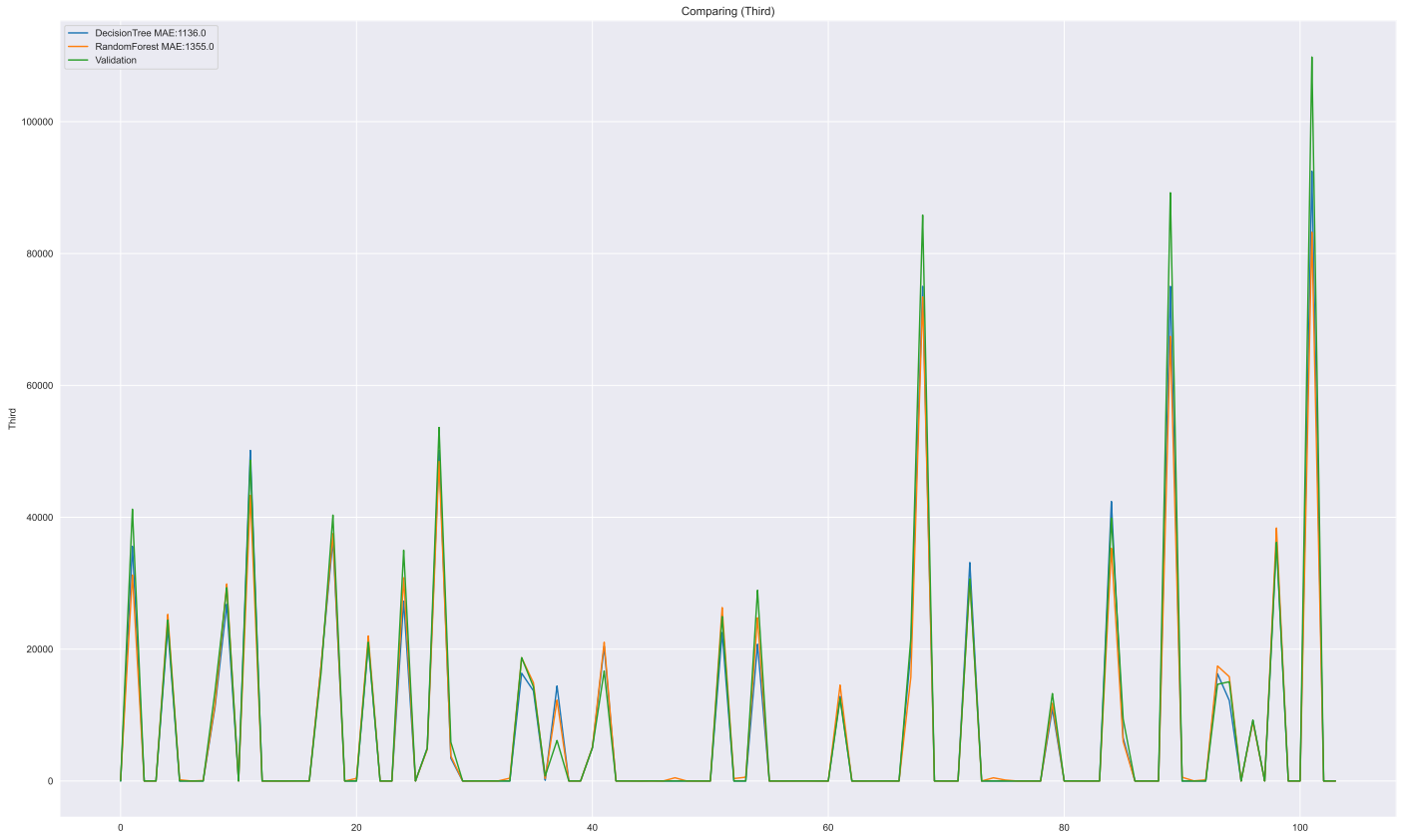


Repeat for Third

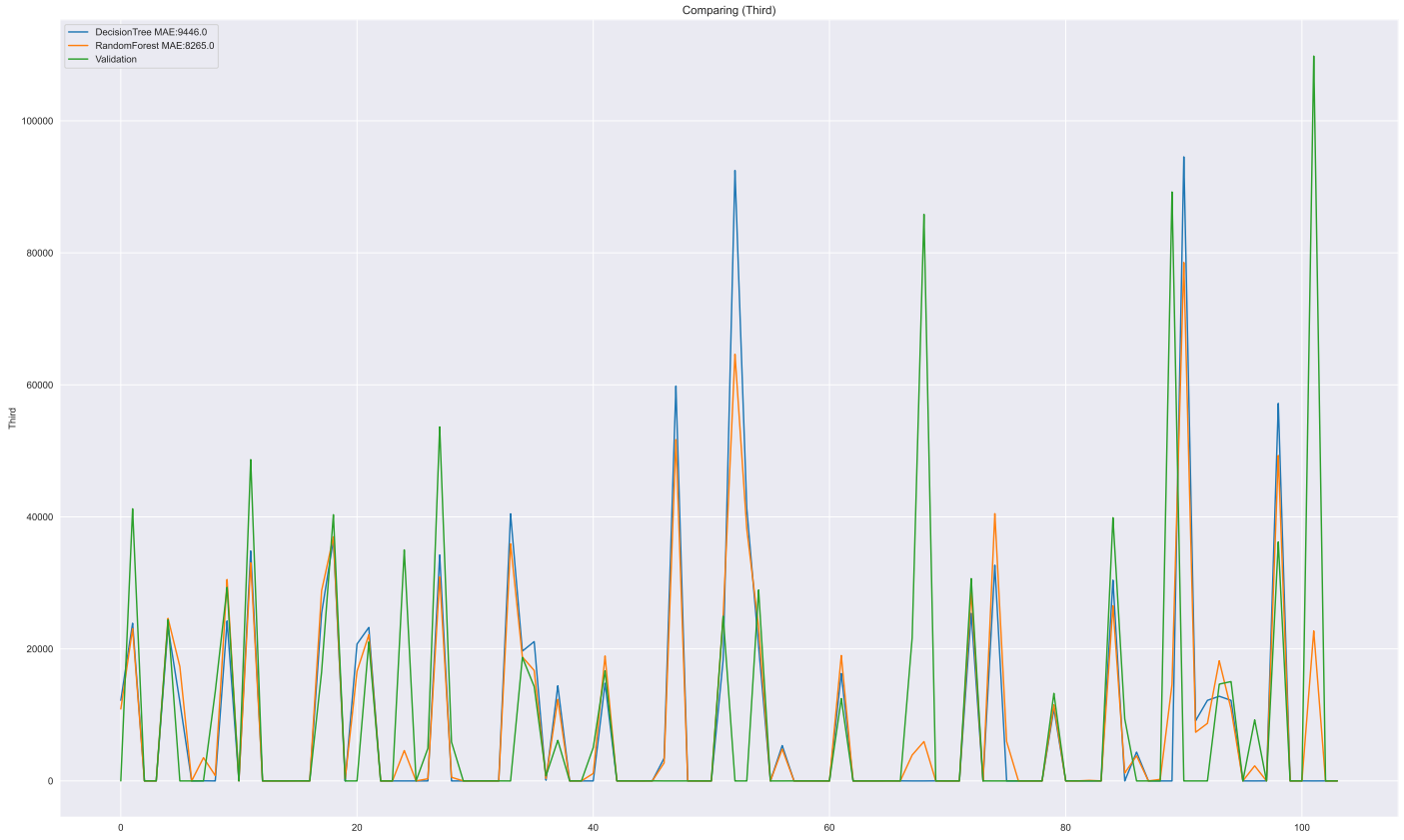
```
## DecisionTree:  0.8323340834065006

## RandomForest:  0.8304365732995669
```



```
## DecisionTree:  0.8664423499345815

## RandomForest:  0.840745098066024
```



```
## DecisionTree:  -0.11041243558502623

## RandomForest:  0.028430358547872348
```



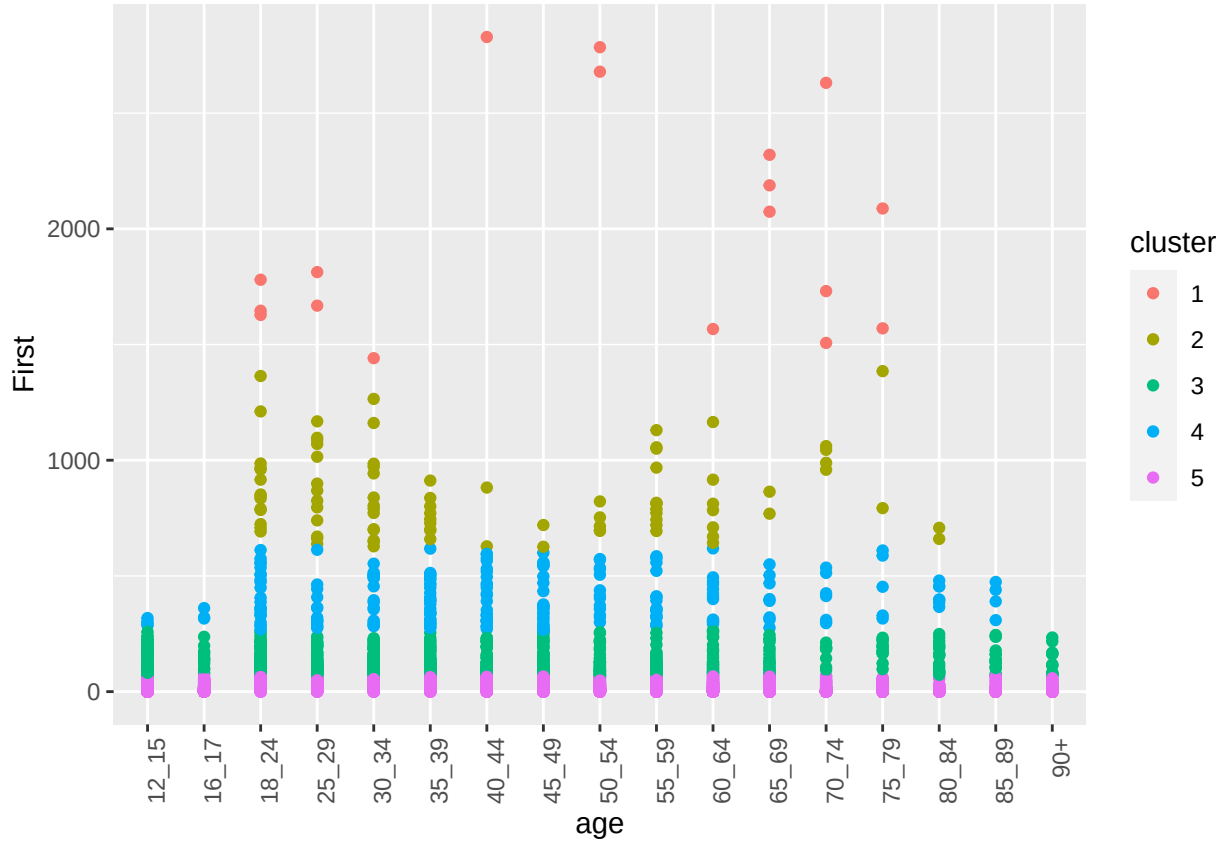
A combination of the following features give us the best result: Weekday, Year, DayOfYear.

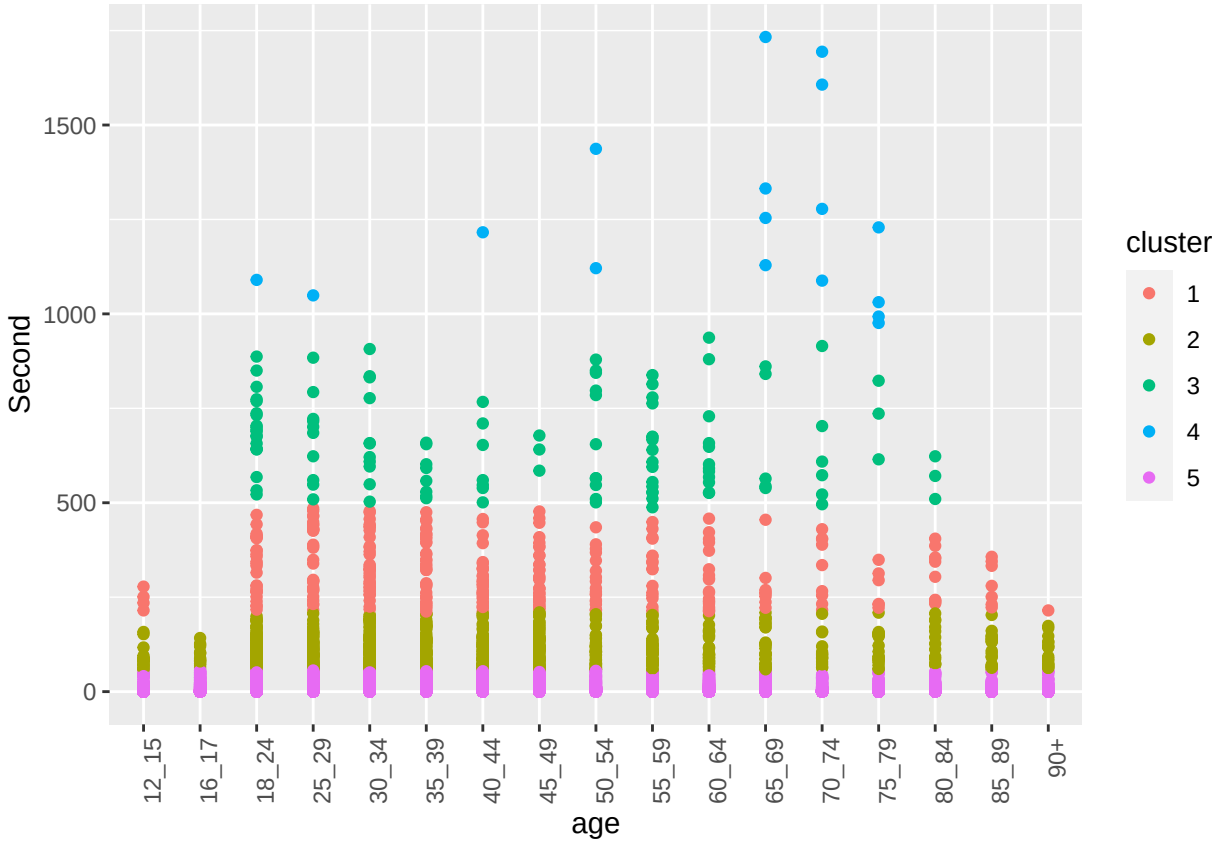
4.2 Bristol

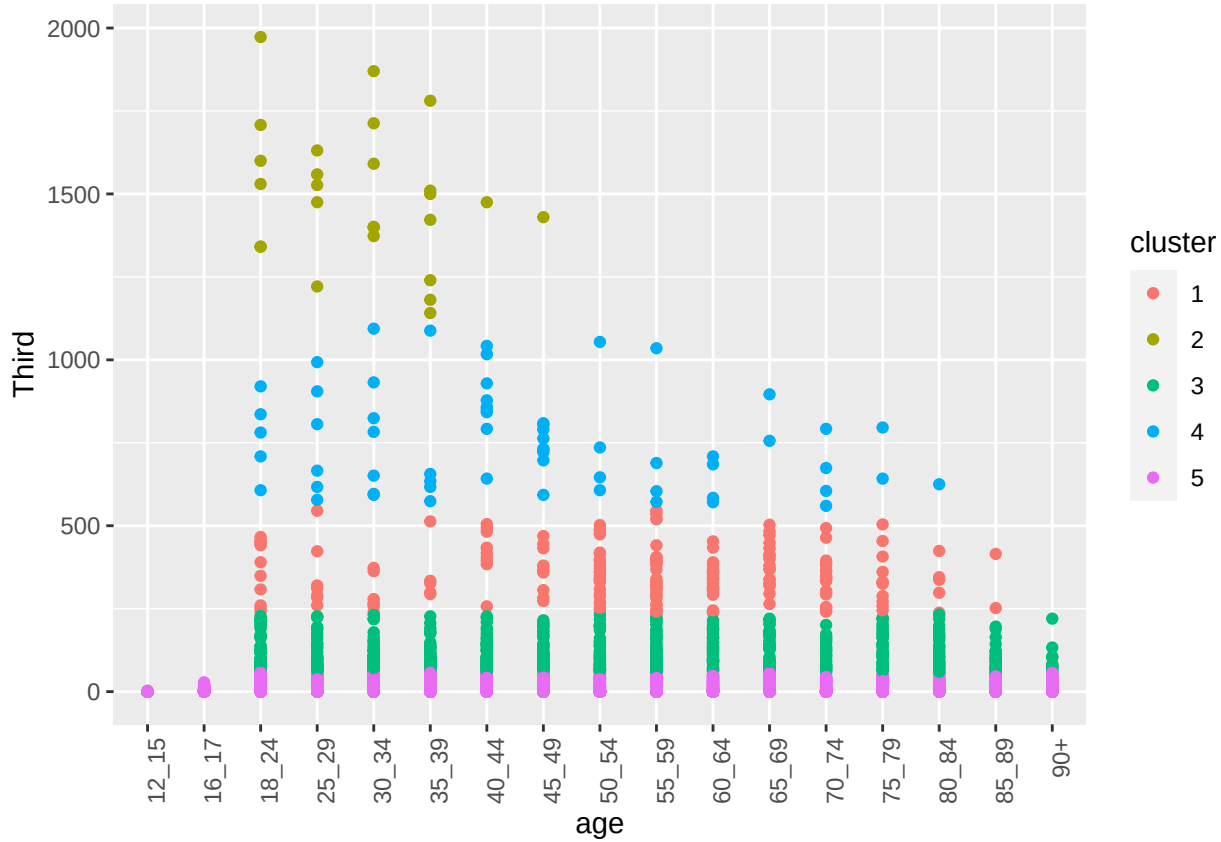
Look at the dataset.

age	date	First	Second	Third	Age
12_15	2022-02-09	28	45	0	1
16_17	2022-02-09	4	8	6	2
18_24	2022-02-09	25	18	83	3
25_29	2022-02-09	11	8	48	4
30_34	2022-02-09	4	10	37	5
35_39	2022-02-09	3	8	26	6

Using the k-means clustering model, we find out that sometimes a lot of people in the same age group got their jabs together. And the group 18-24 is not an exception.


First
2000
1000
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
age
cluster
1
2
3
4
5

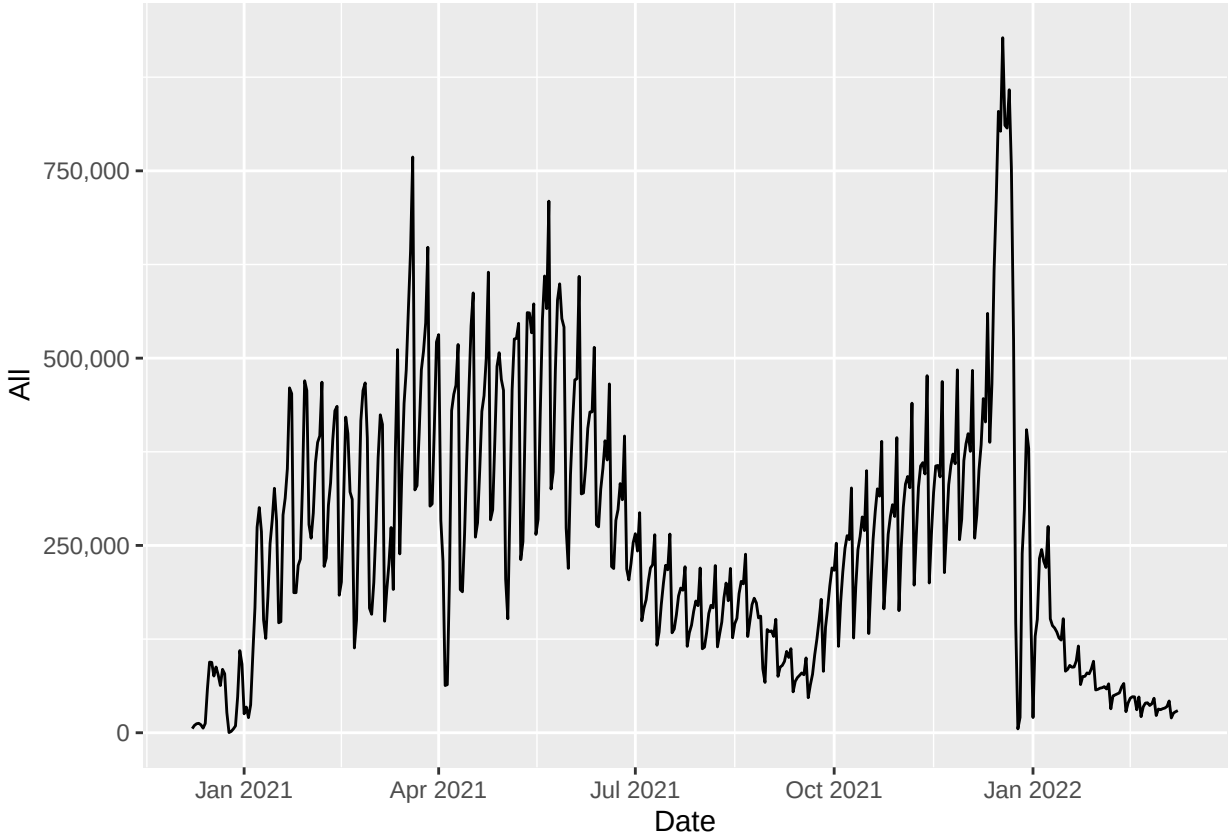

Second
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
age
cluster
1
2
3
4
5


Third
2000
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
age
cluster
1
2
3
4
5

4.3 England

Look at the dataset.

	Date	First	Second	Third	All
457	2020-12-08	5370	146	0	5516
456	2020-12-09	9648	137	2	9787
455	2020-12-10	11888	119	1	12008
454	2020-12-11	12516	82	1	12599
453	2020-12-12	10565	23	3	10591
452	2020-12-13	6134	30	0	6164



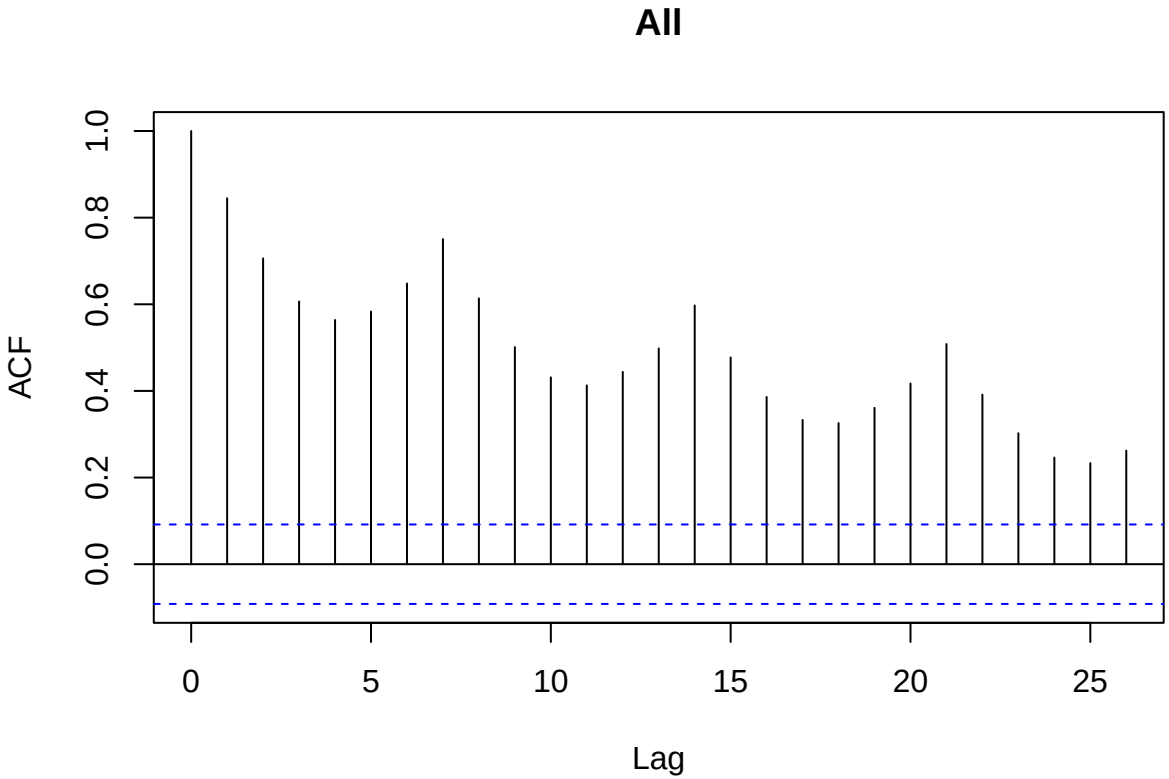
What can we say?

There is a not stationary time series, as the series wanders up and down for long periods.

```
## Series: englandFit
## ARIMA(5,1,3)
##
## Coefficients:
##          ar1      ar2      ar3      ar4      ar5      ma1     ma2      ma3
##       0.1526  -0.7394  -0.2071  -0.2515  -0.5082  -0.4651  0.8182  -0.1551
## s.e.  0.0620   0.0443   0.0633   0.0403   0.0473   0.0666  0.0406   0.0548
##
## sigma^2 = 5.152e+09:  log likelihood = -5743.43
## AIC=11504.87   AICc=11505.27   BIC=11541.97
##
## Training set error measures:
##                     ME     RMSE      MAE      MPE     MAPE      MASE        ACF1
## Training set 102.9716 71064.39 48013.76 -45.9576 63.67967 0.7933718 -0.03107453
```

ARIMA(5, 1, 3) ARIMA(p,d,q)

- p – is the order of Auto-regressive or linear model
- q – is the order of Moving Average/ number of lagged values
- d – difference value to make the time series stationary from non-stationary. If the data is stationary, then d=0. So, I was right earlier.

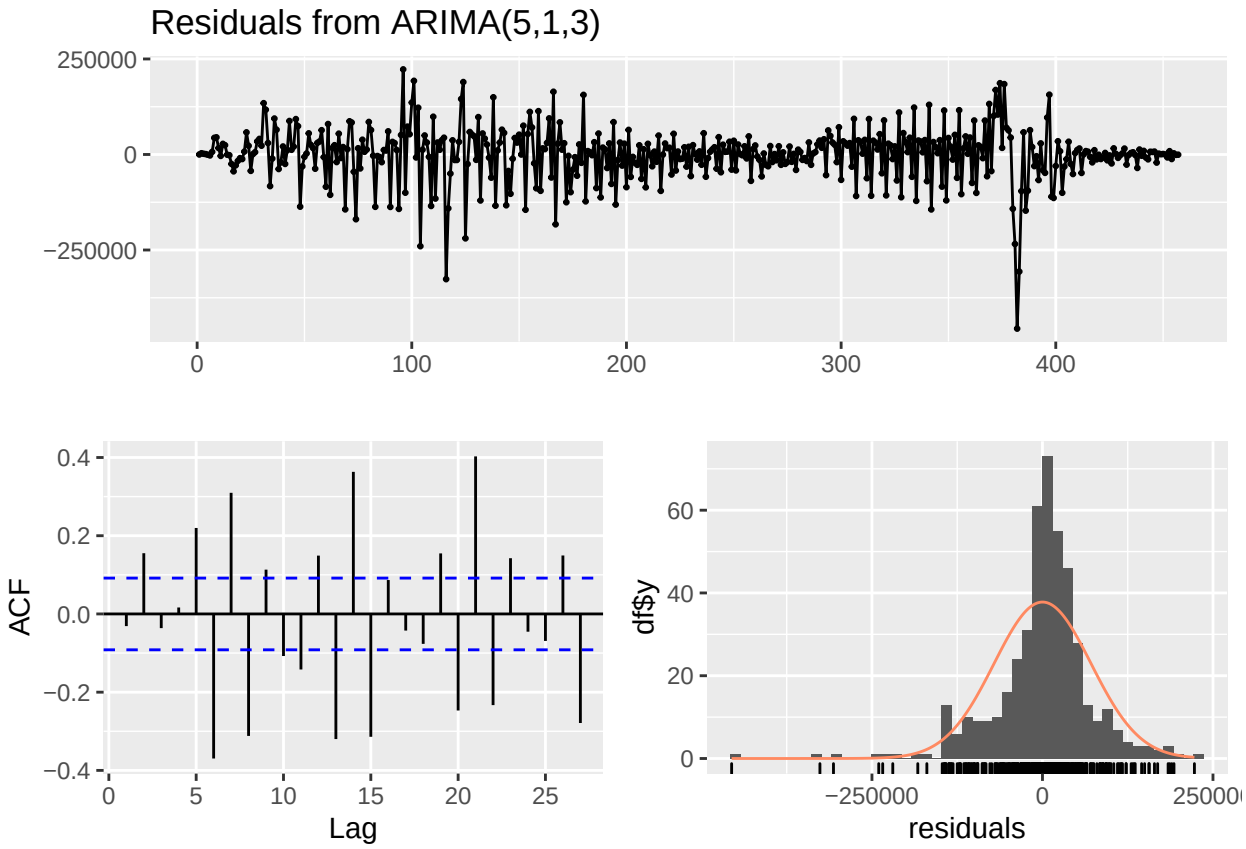


As we know, the autocorrelation function (ACF) assesses the correlation between observations in a time series for a set of lags. In an ACF plot, each bar represents the size and direction of the correlation. Bars that extend across the blue line are statistically significant.

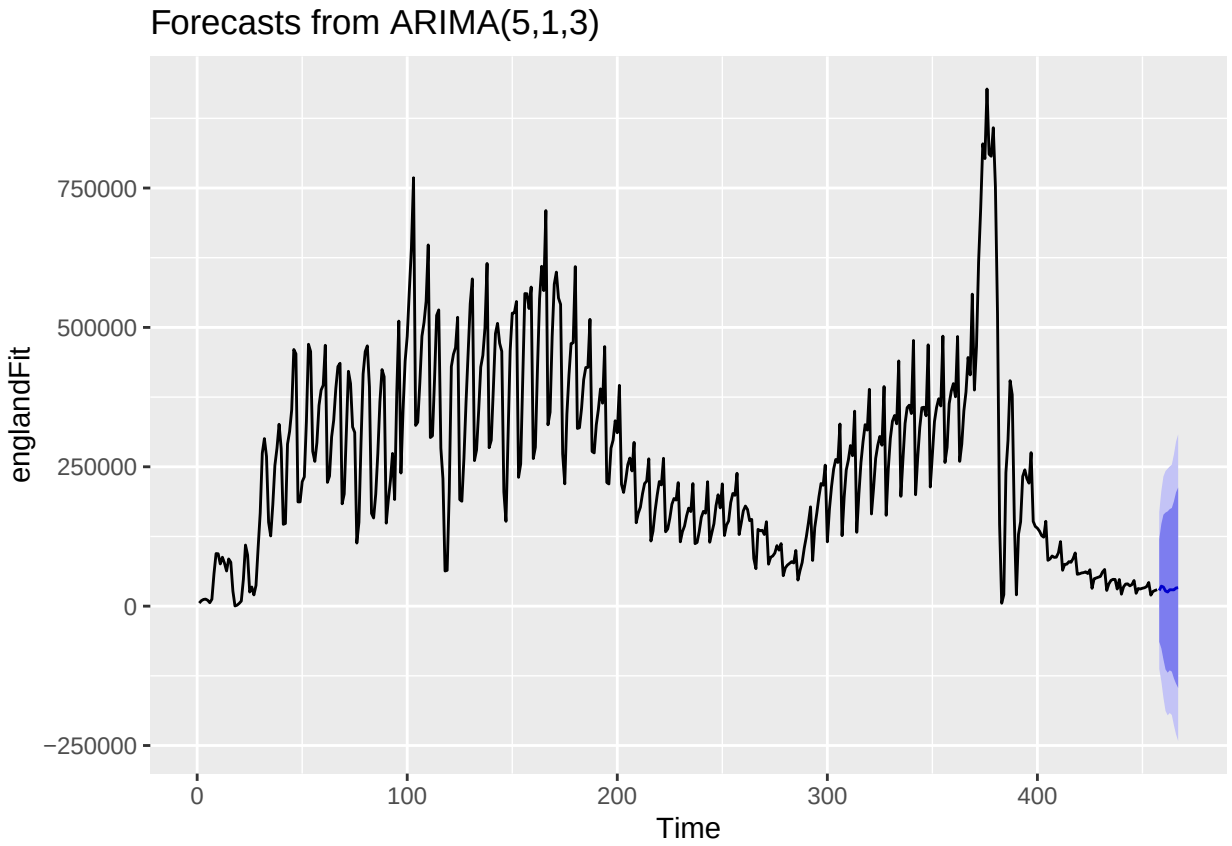
So,

- this ACF plot indicates that these time series data are not random.
- the autocorrelations decline slowly.
- When a time series has both a trend and seasonality, the ACF plot displays a mixture of both effects. Notice how you can see the wavy correlations for the seasonal pattern and the slowly diminishing lags of a trend.

The residuals in ARIMA models tell a story about the performance of your model and should be taken into consideration when evaluating them. The functions checkresiduals, ACF and PACF make it easy to keep track of the information left behind in the residuals by your model. (link)




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(5,1,3)
## Q* = 209.31, df = 3, p-value < 2.2e-16
##
## Model df: 8.   Total lags used: 11
```




```
## Time Series:
## Start = 458
## End = 467
## Frequency = 1
##            80%       95%
## 458  -63973.15 -112666.0
## 459  -75720.72 -134812.5
## 460  -95482.73 -164157.8
## 461 -113509.24 -187992.6
## 462 -119251.50 -195804.7
## 463 -115172.45 -191728.9
## 464 -117516.09 -195230.3
```

```
## 465 -129662.81 -213781.9
## 466 -139135.40 -230020.4
## 467 -146736.26 -241897.0
```

```
##      80%      95%
## 119992.7 168685.5
```