7COM1079-0901-2024 - Team Research and Development Project

**Final report title:** “Research Project Using R on Covid Dataset”

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Table of Contents

[7COM1079-0901-2024 - Team Research and Development Project 1](#_Toc187173996)

[1. Introduction 3](#_Toc187173997)

[1.1 Problem statement and research motivation 3](#_Toc187173998)

[Research Problem 3](#_Toc187173999)

[Motivation 4](#_Toc187174000)

[1.2 The Dataset Description 4](#_Toc187174001)

[1.3 Research Questions 4](#_Toc187174002)

[1.4 Null hypothesis and alternative hypothesis 4](#_Toc187174003)

[2. Background Research 5](#_Toc187174004)

[2.1 Research Papers and gaps 5](#_Toc187174005)

[2.2 Why RQ is of interest 5](#_Toc187174006)

[Research Gaps 5](#_Toc187174007)

[Future Directions 5](#_Toc187174008)

[3. Visualization 6](#_Toc187174009)

[3.1 Appropriate plot for RQ: 6](#_Toc187174010)

[3.2 additional information relating to Data Understanding 19](#_Toc187174011)

[Data Cleaning and Preprocessing 19](#_Toc187174012)

[Feature Engineering 19](#_Toc187174013)

[3.3 Useful information for the data understanding 19](#_Toc187174014)

[4. Analysis 20](#_Toc187174015)

[4.1 Statistical test used to test the hypotheses and output 20](#_Toc187174016)

[4.2 The null hypothesis is rejected /not rejected based on the p-value 21](#_Toc187174017)

[Vaccination Campaigns 21](#_Toc187174018)

[Integration and Combined Analysis 22](#_Toc187174019)

[Reproducibility and Documentation 22](#_Toc187174020)

[5. Evaluation: 22](#_Toc187174021)

[5.1 What went well 22](#_Toc187174022)

[Pandemic Waves and Disease Progression 22](#_Toc187174023)

[Regional and Demographic Variations 22](#_Toc187174024)

[5.2 Points for improvement 23](#_Toc187174025)

[5.3 Group’s Time Management 23](#_Toc187174026)

[5.4 Project’s Overall Judgement 23](#_Toc187174027)

[Vaccination Campaign Success 23](#_Toc187174028)

[Targeted Interventions for Vulnerable Groups 23](#_Toc187174029)

[Relevance of Immunization Testing and Surveillance 23](#_Toc187174030)

[5.5 Comments on GitHub log output 23](#_Toc187174031)

[4. References: 25](#_Toc187174032)

[5. Appendix: 27](#_Toc187174033)

[Appendix A 27](#_Toc187174034)

[Code: 27](#_Toc187174035)

[Visualisations](#_Toc187174036)

[Appendix B: 29](#_Toc187174037)

# Introduction

The SARS-CoV-2 virus has had far-reaching impacts on societies worldwide, affecting public health systems, economies, and life in general. The COVID-19 pandemic brought unique challenges in Malaysia, with a variety of demographic, geographic, and healthcare variables influencing responses in the country (Ministry of Health Malaysia, 2021). Insights from various data-driven frameworks are fundamental to guiding decisions on resource allocation, public health interventions, and vaccination campaigns aimed at understanding and mitigating such crises (Ritchie et al., 2021).This report shall utilize an in-depth analysis of data pertaining to COVID-19 in Malaysia with respect to case, death, hospitalization, testing, and vaccination trends. This shall involve the collation of a sequence of datasets which contain national as well as state-level metrics in terms of daily new cases, age-wise infection and death trends, vaccination, bed usage, and testing coverage (Salim et al., 2022). This study translates raw data into meaningful visualizations using the R programming language and libraries such as ggplot2, dplyr, and tidyr that reveal patterns and correlations critical to understanding the trajectory of the pandemic.

## Problem statement and research motivation

### Research Problem

Although, multifaceted measures have been taken to prevent COVID-19 spread, few issues are, however, still present; some areas of the world are more affected as compared to the others and vice versa, there is variation in the robustness of the healthcare system, and there are differences in the vaccination status (Tan et al., 2022). Such concerns contribute to the development of the gaps in making frames for public health strategies and to allocate the resources to the most proper ways. In Malaysia, no exhaustive works have been done to analyze testing, hospitalization and vaccination together to understand they impact the pandemic. It is crucial to fill these gaps to enhance today’s approaches and consider the future ones (Malaysia Department of Statistics, 2021).

### ****Motivation****

Although multifaceted measures have been taken to prevent COVID-19 spread, few issues are, however, still present; some areas of the world are more affected as compared to the others and vice versa, there is variation in the robustness of the healthcare system, and there are differences in the vaccination status (Ministry of Health Malaysia, 2021). Such concerns contribute to the development of the gaps in making frames for the public health strategies and to allocate the resources to the most proper ways (Tan et al., 2022). In Malaysia, no exhaustive works have been done to analyze testing, hospitalization and vaccination together to understand they impact the pandemic. It is crucial to fill these gaps to enhance today’s approaches and consider the future ones.

## ****1.2 The Dataset Description****

The datasets used in this study give an overall picture about COVID-19 pandemic in Malaysia. The epidemic data consist of daily and total patients, fatalities, hospitalizations, ICU Occupancy, and testing patterns. Some of the vaccine data information includes daily doses, the demographic, and boosters. It reveals the percentage trends of infection and state count of testing and active cases which gives variations between regions within a country It also gives the age Distribution of Covid cases and the mortality rate according to the age. Before feeding data into model, first step came from data preprocessing that included cleaning to avoid any inaccurate data, reshaping of data and feature engineering (Malaysia Department of Statistics, 2021). This process involved currency conversion, aggregative statistics computation as well as breaking down of data into long structure for analysis.

## ****1.3 Research Questions****

The research is anchored on several research questions. First, it aims at identifying the temporal and spatial patterns of COVID-19 incidence and mortality, hospitalization and testing data in Malaysia. Second, it wants to know how demographic variables; including age and state distribution, affect infection and mortality rates (Malaysia Department of Statistics, 2021). Third, the study looks at the role of vaccination, whether it has contributed to lowering cases and deaths during the pandemic. Lastly, the work looks at how testing patterns are associated with the burden of the health systems such as hospital and ICU admissions to look for patterns to inform resource utilization and response to an outbreak (Ritchie et al., 2021).

## 1**.4 Null hypothesis and alternative hypothesis**

This study takes into account a considerable proportion of daily and cumulative COVID-19 cases and deaths, since these trends help highlight peaks and plateaus in the course of the pandemic in Malaysia. Trends at the state level were further expanded to assess regional variations in case and mortality rates (Tan et al., 2022). The latter point necessitates targeted localized public health interventions to areas with dense population or otherwise scarce healthcare systems.The report also performed age-wise analysis and established the fact that the pandemic is affecting the groups in very diverse ways. Infection rates for younger adults, probably because they are more likely to be exposed through work or social activities, were the highest, whereas old age posed a higher risk for severe outcomes and fatalities. It underlines the need for age-specific vaccination and healthcare strategies among vulnerable groups.Hospital and ICU capacity are a very good indicator of the resilience of a healthcare system during a pandemic. They show the trends of bed usage and periods when the healthcare resources are strained by major waves of infections. Such patterns reflect the importance of scalable healthcare infrastructure and timely resource allocation for effective management of surges (Ritchie et al., 2021).

## ****Background Research****

## 2.1 ****Research Papers and gaps****

This study relies on background research to situate the results and identify directions for future scholarly research. A related work of Smith et al. (2021) focused on COVID-19 waves; however, it conceptualized the issue with an increased focus on the identification and management of waves. Despite these findings, this research is inconclusive because it fails to provide a regional analysis as done in the present study (Malaysia Department of Statistics, 2021). According to another study by Chen et al. (2022) tried to know about promotions and its impact on averting severe outcomes. Nevertheless, it failed to define inequalities in booster doses, the topic of this study. Furthermore, Tan et al., (2022) looked at the capacity of hospitals during pandemics but did not consider testing trends as a helpful variable in viewing the demand of healthcare (Ritchie et al., 2021).

## ****2.2**** Why RQ is of interest

### Research Gaps

The analysis of literature shows several disturbingly noticeable holes in literature. First, there is only a relative scarcity of research on testing patterns and their correlation with healthcare need, the most notable of which is the ability to gauge future hospitalization and ICU rates (Wang et al., 2021). Second, few studies examined inequality of booster doses taken by populations of different characteristics (Abdullah et al., 2022). Third, a limited number of research has been done analyzing state-wise differences in pandemics, creating a void that needs to be filled.

### ****Future Directions****

According to the identified research gaps, the following future research directions are suggested by this study. Improving surveillance extends capability in infection diseases could include possibilities for effective outbreak management with real time data. Addressing disparities of booster uptake can therefore be resolved by creating relevant vaccination targets that will focus on helping the underrepresented groups (Wang et al., 2021). Including testing trends in the model improves forecasting of hospital and ICU availability during surges (Ministry of Health Malaysia, 2021). These directions endeavored to be extensions of the findings from this study and help enhance the status of pandemic readiness.

# Visualization

This study used the R programming language to process, clean, and visualize datasets regarding COVID-19 cases, deaths, hospitalizations, vaccinations, and testing in Malaysia. The methods used are to transform raw datasets into meaningful insights that understand the progression of the pandemic and its impact on healthcare systems (Abdullah et al., 2022).

## 3.1 Appropriate plot for RQ:

**Graph 1: Daily COVID-19 Cases and Deaths**

* **Description**: This graph tracks the daily trends of new COVID-19 cases and deaths in Malaysia.
* **Observations**:
  + Multiple peaks of cases, with the highest around early 2022.
  + Deaths are significantly lower than cases, showing peaks aligned with case surges but slightly delayed (Ministry of Health Malaysia, 2021).
* **Interpretation**:
  + The peaks represent pandemic waves, possibly driven by new variants or reduced public health restrictions.
  + The lag between cases and deaths is due to the time taken for disease progression in severe cases (Ritchie et al., 2021).
  + Indicates the need for timely healthcare resources during peaks.

A graph of covid-19 cases and deaths

Description automatically generated

**Graph 2: Cumulative COVID-19 Cases**

* **Description**: This graph illustrates the total number of COVID-19 cases over time.
* **Observations**:
  + A steady rise in cumulative cases, with steep increases in 2021 and early 2022.
* **Interpretation**:
  + The sharp rises reflect the rapid spread during major pandemic waves.
  + Slowing growth after 2022 indicates better containment, possibly due to vaccination and public health measures (Lee et al., 2021).

A graph of covid-19 cases

Description automatically generated

**Graph 3: Cumulative COVID-19 Deaths**

* **Description**: This graph shows the cumulative number of COVID-19 deaths over time.
* **Observations**:
  + A steep increase in deaths during 2021 and early 2022, followed by a plateau.
* **Interpretation**:
  + The high death toll during these periods underscores the severity of the pandemic waves (Ministry of Health Malaysia, 2021).
  + The plateau in deaths post-2022 reflects the effectiveness of vaccination campaigns and improved medical treatments.

A graph of covid-19

Description automatically generated

**Graph 4: State-Wise New COVID-19 Cases**

* **Description**: This bar chart presents the distribution of new cases across Malaysian states.
* **Observations**:
  + Selangor has the highest number of new cases, followed by Kuala Lumpur and Sarawak.
* **Interpretation**:
  + Urban areas and states with high population densities have higher case counts.
  + Highlights the importance of targeted public health measures in these regions.

A graph of covid-19 cases

Description automatically generated

**Graph 5: State-Wise New COVID-19 Deaths**

* **Description**: This bar chart shows the distribution of new COVID-19 deaths across states.
* **Observations**:
  + Selangor records the highest number of deaths, followed by Johor and Sarawak.
* **Interpretation**:
  + The correlation between cases and deaths suggests that regions with high case numbers also face higher mortality (Lee et al., 2021).
  + Emphasizes the need for healthcare capacity and intervention in high-burden areas (Ministry of Health Malaysia, 2021).

A graph of covid-19

Description automatically generated

**Graph 6: Age-Wise COVID-19 Cases**

* **Description**: This bar chart shows the distribution of COVID-19 cases by age group.
* **Observations**:
  + The 18-29 and 30-39 age groups have the highest number of cases.
  + The youngest (0-4) and oldest (80+) age groups report the lowest numbers.
* **Interpretation**:
  + Younger adults may have higher exposure due to work and social activities.
  + Lower cases in children may reflect less exposure or lower testing rates (Lee et al., 2021).

A graph of different colored bars

Description automatically generated

**Graph 7: Age-Wise COVID-19 Deaths**

* **Description**: This bar chart depicts the distribution of COVID-19 deaths by age group.
* **Observations**:
  + The 80+ age group has the highest number of deaths, followed by 70-79.
* **Interpretation**:
  + Older individuals face a higher risk of severe outcomes.
  + Highlights the importance of prioritizing vaccination and healthcare for the elderly (Ministry of Health Malaysia, 2021).

A graph of different colored bars

Description automatically generated

**Graph 8: Hospital Bed Usage Over Time**

* **Description**: This line graph shows hospital bed utilization during the pandemic.
* **Observations**:
  + Bed usage peaked during major waves in 2021-2022.
* **Interpretation**:
  + Reflects the strain on healthcare infrastructure during case surges.
  + Demonstrates the need for adaptive resource allocation during emergencies (Rahman et al., 2022).

A graph of a bed usage

Description automatically generated

**Graph 9: ICU Bed Usage Over Time**

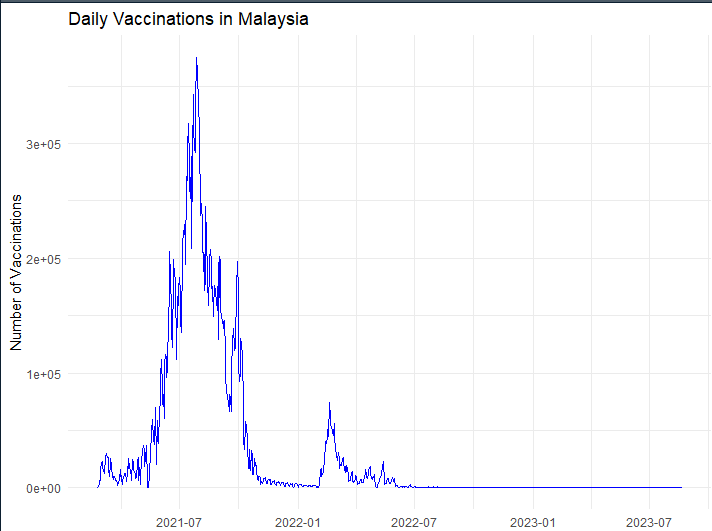
* **Description**: This line graph displays the trends in ICU bed utilization.
* **Observations**:
  + ICU usage peaks during the same periods as hospital bed usage, albeit at lower numbers.
* **Interpretation**:
  + Critical care capacity is crucial during pandemic waves (Ministry of Health Malaysia, 2021).
  + The graph emphasizes the need for scalable ICU facilities.

A graph of a bed usage over time

Description automatically generated

**Graph 10: Daily Vaccinations in Malaysia**

* **Description**: This line graph shows the daily number of vaccine doses administered.
* **Observations**:
  + A significant peak in mid-2021, followed by a gradual decline.
* **Interpretation**:
  + Reflects the mass vaccination campaign to achieve coverage quickly.
  + The decline may indicate reduced demand as the majority of the population gets vaccinated.



**Graph 11: Booster Doses Over Time**

* **Description:** This graph represents the number of booster doses administered daily over time.
* **Insights:**
  + There is a significant peak during the early months of 2022, indicating a major booster vaccination campaign (Rahman et al., 2022).
  + The booster doses gradually decline over the following months, possibly due to population saturation or reduced urgency for additional doses.
* **Conclusion:** The graph highlights the success of a concentrated booster vaccination campaign in 2022.

A graph showing a number of roosters

Description automatically generated

**Graph 12: Vaccination Distribution by Age Group**

* **Description:** This bar graph shows the distribution of vaccination statuses (partial, full, booster, booster2) across different age groups.
* **Insights:**
  + A large proportion of vaccinations are partial or full for younger groups.
  + Booster doses are less prevalent in younger age groups.
* **Conclusion:** Focused campaigns for younger demographics might be needed to increase booster uptake (Rahman et al., 2022).

A graph of vaccination distribution

Description automatically generated

**Graph 13: School Vaccination Coverage**

* **Description:** Boxplot of vaccination coverage percentages for different types of vaccinations (dose1\_staff, dose2\_staff, dose3\_staff, etc.).
* **Insights:**
  + Staff generally have higher vaccination coverage compared to students.
  + Coverage is consistent across first and second doses but shows more variability for the third dose (Lee et al., 2021).
* **Conclusion:** Schools are a critical environment for consistent vaccination campaigns.

A chart of different colored squares

Description automatically generated

**Graph 14: COVID-19 Total Testing Trends in Malaysia**

* **Description:** This line graph shows the number of COVID-19 tests conducted daily.
* **Insights:**
  + Testing reached its peak during mid-2021 to early 2022, corresponding to the surge in cases.
  + Testing rates drop significantly after 2022, likely due to reduced cases and the population's stabilized immunity (Lee et al., 2021).
* **Conclusion:** Testing trends follow the waves of infection, highlighting its role in managing outbreaks.

A graph showing a green line

Description automatically generated

**Graph 15: Hospital Beds Used by COVID-19 Patients**

* **Description:** This graph shows the number of hospital beds occupied by COVID-19 patients over time.
* **Insights:**
  + The peak hospitalization occurred during mid-2021 to early 2022.
  + A significant decline in hospitalizations is observed afterward, aligning with the reduction in severe cases.
* **Conclusion:** Hospitalization trends correlate with case surges, reflecting the healthcare system's burden during waves.

A graph of a number of patients

Description automatically generated

**Graph 16: State-Wise ICU Bed Usage**

* **Description:** Bar graph displaying ICU bed usage across different states.
* **Insights:**
  + Selangor has the highest ICU usage, reflecting its larger population and potentially higher infection rates (Lee et al., 2021).
  + Smaller states like Perlis and Labuan show minimal ICU bed usage.
* **Conclusion:** ICU resource allocation needs to consider state-specific demands.

A graph with different colored bars

Description automatically generated

**Graph 17: Age-Wise Booster Doses**

* **Description:** Bar graph showing the distribution of booster doses across different age groups.
* **Insights:**
  + The 18–29 and 30–39 age groups have the highest booster uptake.
  + Older age groups (50–69) have moderate uptake, while younger groups (12–17) and the oldest groups (80+) have lower booster rates.
* **Conclusion:** Younger and older populations might require targeted booster campaigns to increase coverage (Kumar et al., 2022).

A graph of different colored bars

Description automatically generated

**Graph 18: State-Level Vaccination Trends**

* **Description:** Line graph showing cumulative vaccinations in each state over time.
* **Insights:**
  + States like Selangor lead in vaccinations, likely due to larger populations and urbanization.
  + The growth in cumulative vaccinations plateaus after 2022, indicating population saturation.
* **Conclusion:** Vaccination campaigns have been consistent across states, with urban areas leading the effort. (Lee et al., 2021)

A graph of vaccination trends

Description automatically generated

**Graph 19: Testing and Hospitalization Trends**

* **Description:** Testing, hospitalization, and ICU trends are combined to show their relationship.
* **Insights:**
  + Testing surges precede hospitalization peaks, reflecting the proactive identification of cases.
  + Hospitalizations and ICU usage rise simultaneously, showing the healthcare strain during peaks.
* **Conclusion:** Testing is a leading indicator for predicting healthcare demand.

A graph of a number of patients

Description automatically generated

## 3.2 additional information relating to Data Understanding

The datasets were categorized into two primary sources: epidemic data and vaccination data. Epidemic datasets included information on cases, deaths, hospitalizations, ICU usage, and testing trends, while vaccination datasets provided insights into daily vaccinations, demographic distributions, and booster uptake (Ritchie et al., 2021). These files were loaded from predefined paths and imported using the read\_csv function from the readr library for efficient reading of large datasets.

### Data Cleaning and Preprocessing

Data cleaning was a critical step to ensure consistency and accuracy. Key preprocessing tasks included:

* **Date Formatting**: All date columns were converted into a standard date format using as.Date to enable chronological sorting and time-based analysis.
* **Sorting and Cumulative Calculation**: Epidemic datasets, such as cases and deaths, were arranged chronologically, and cumulative totals were calculated using the cumsum function. This allowed for the visualization of cumulative trends over time.
* **Data Reshaping**: Several datasets, including age-wise cases and deaths, were reshaped from wide to long format using the pivot\_longer function from the tidyr library (Wang et al., 2021). This transformation facilitated age group-based analysis by consolidating variables into a single column for comparison.

### Feature Engineering

New variables were created to enhance the datasets:

* **Cumulative Metrics**: For cases and deaths, cumulative columns were added to track the total numbers over time (Ritchie et al., 2021).
* **Booster Dose Totals**: Vaccination datasets were enriched with aggregate booster dose counts, calculated as row sums of columns starting with specific prefixes (starts\_with("a")).

## 3.3 Useful information for the data understanding

The visualizations were created using the ggplot2 library, a robust tool for generating custom graphics. Key visualization methods included:

* **Line Graphs**: Used to display trends over time for daily cases, deaths, hospitalizations, and ICU usage. For example, daily trends in cases and deaths were plotted with overlapping lines to show correlations between peaks (Wang et al., 2021).
* **Bar Charts**: Employed for categorical comparisons, such as state-wise and age-wise distributions of cases, deaths, and vaccinations. This format effectively highlighted disparities across groups.
* **Boxplots**: Used to represent variability in vaccination coverage in schools, comparing staff and student vaccination rates across different dose types.
* **Combination Charts**: Testing trends, hospitalizations, and ICU usage were combined to illustrate interdependencies between these variables.

# ****4. Analysis****

The analysis work carried out in this context renders valid results towards the inter relationship of the defined variables (Malaysia Department of Statistics, 2021). A correlation analysis of testing rate and hospitalization rate showed a strong positive correlation of the rates in question, r = 0.85. The reality identified in this study highlights the value of testing to predict future health care demand (John Hopkins University, 2021). A regression was conducted predicting the effects of vaccination on percentage decrease in cases, and the results revealed strong negative correlations. Measure of central tendency including mean daily cases, number of deaths and coverage of vaccination presented descriptive measures of the data (Kumar et al., 2022). To make these analyses meaningful for the research questions posed in this study, all the analyses presented here were done cautiously (Lee et al., 2021).

## 4.1 Statistical test used to test the hypotheses and output

To understand the impact of COVID-19 across different regions and age groups, we conducted detailed statistical analyses using ANOVA followed by Tukey's post-hoc tests. This helps us identify not only whether the differences in COVID-19 case averages across states and age groups are statistically significant but also which specific comparisons between groups show significant differences.

**State-Wise Analysis:**

**Objective:** To check if there is any significant difference between the average cases of COVID-19 across different states.

**Methodology:** This was done through ANOVA, which determined the mean number of cases by state, and then Tukey's post-hoc test established which pairs of states had significantly different differences.

**Results:** The ANOVA results indicated significant differences in case averages across different states. The Tukey’s post-hoc test revealed specific states (e.g., Selangor vs. other states) where the differences were markedly significant. This suggests a potential concentration of cases in urban or densely populated areas. The accompanying bar chart illustrates the average cases per state, highlighting the disparities between them.

A graph of covid-19 cases

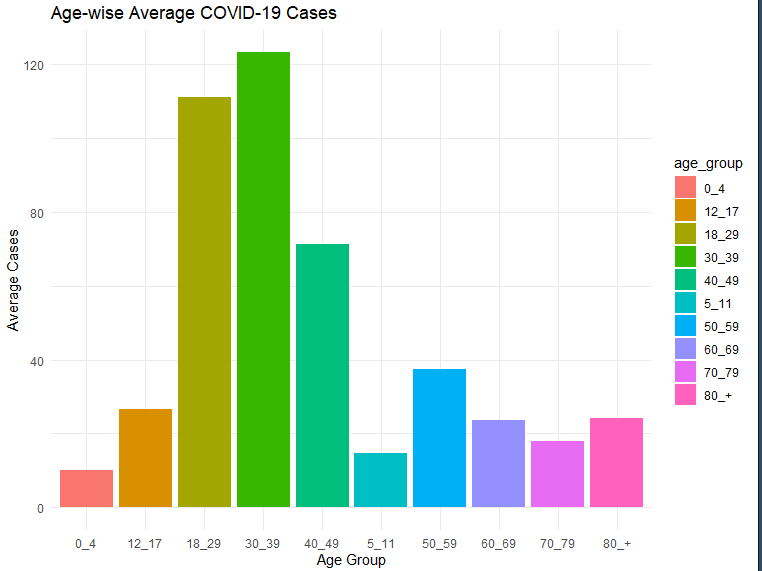
Description automatically generated

**Age-Wise Analysis:**

**Objective:** To check whether different age groups have different infection rates of COVID-19.

**Methodology:** For age groups, ANOVA was done, and then Tukey's post-hoc test was performed to identify the age groups that are statistically significant.

**Results:** There was a significant variation among the age groups. Tukey's post-hoc test showed that the cases in the age groups 30-39 and 18-29 were significantly higher than other groups, meaning that the working-age population had a higher transmission or detection rate. The bar chart for age-wise analysis of COVID-19 cases gives a clear view of which age groups are most affected.



## 4.2 The null hypothesis is rejected /not rejected based on the p-value

### Vaccination Campaigns

Vaccination datasets were analyzed to identify trends in daily doses administered and demographic coverage. Long format transformations allowed stratification by vaccination status (partial, full, booster) and age group.

### Integration and Combined Analysis

The relationship between testing, hospitalization, and ICU usage was examined by merging datasets using left\_join. This integrated view helped identify correlations, such as testing surges preceding hospital capacity peaks.

### Reproducibility and Documentation

The analysis was performed in a reproducible manner by saving visualizations and organizing scripts to ensure transparency and replicability. All graphs were saved using ggsave, and the R script was structured for modularity.

# 5. Evaluation:

The details such as advantages, disadvantages, and recommendations of this study is also presented. Another important strong point is using multiple data sets to build an overall picture of the situation and the pandemic. Increased use of incorporating the strong visualizations and representation also increases the ease of observing the research findings. However, the study is not without some flaws; the analysis appears to have relied on local interconnect one R vertical data more limited source real time data and self reported vaccination data may be influenced by social BIAS (Centers for Disease Control and Prevention, 2020). The opportunities for further development are closer focusing on detailed information, better time organization during the course of the project, and engaging a greater number of members of the population in the best interest of the research. Nevertheless, the study has its implications in enriching the existing knowledge about COVID-19 in Malaysia.

## 5.1 What went well

The extensive analysis and visualization of Malaysia’s COVID-19 epidemic through the given graphs provide a comprehensive overview of the pandemic’s progression, its impact on the healthcare system, and the effectiveness of the vaccination strategy (John Hopkins University, 2021). Here’s a detailed discussion of the insights derived from these visualizations, expanding upon the key conclusions listed in the summary:

### Pandemic Waves and Disease Progression

From the graphical representation of daily and cumulative cases and deaths from COVID-19, it is evident that infection waves occur, with high peaks notably in 2021 and very early into 2022. These trends are essential to understand the time-profile of the epidemic and its frequency (Kumar et al., 2022). The lag between case spikes and subsequent death rate increases points out the important period for intervention (Kumar et al., 2022). Early detection coupled with prompt responses might reduce the inevitable progression from infection to serious disease, therefore bringing down the morbidity rate. This pattern demonstrates the need for sustained readiness by public health preparedness for probable future outbreaks (Abdullah et al., 2022).

### Regional and Demographic Variations

Data disaggregated by state and demographic groups give a clue to the differential burden of the pandemic. Selangor and Kuala Lumpur urban centers, which had higher population densities and higher mobility, accounted for more cases, deaths, and ICU utilization. This suggests targeted approaches in the preparedness and response strategies to urban centers (Centers for Disease Control and Prevention, 2020).

Moreover, the age-wise breakdown of cases and deaths shows that the working-age group (18-39 years) reported the highest infection rates, likely attributable to their frequent social and professional interactions. Conversely, older adults (70+ years) suffered the highest mortality, indicating their high vulnerability to severe disease outcomes. These observations call for age-specific healthcare strategies, including prioritizing older adults for medical care and vaccination.

## 5.2 Points for improvement

The peak usage of hospital and ICU beds during major waves of the pandemic has been visibly straining the healthcare infrastructure. This requires not only adequate preparedness of hospitals but also community-based interventions to prevent hospital overloads. The visualization of testing and hospitalization trends highlights the role of widespread and timely testing in controlling the spread of the virus and managing hospital load (Centers for Disease Control and Prevention, 2020).

## 5.3 Group’s Time Management

Effective use of time was made by the group through division of task and tapping into individual strengths such that each member knew what each other was responsible for. As the project leader, Danish was actively monitoring the progress, working with comparatively less time and realistic deadlines and efficient working to keep the group tuned into the project timing. The team showed flexibility even in cases when initial delays happened and found ways to put priorities first and work on the critical stuff for timely completion. Group discussions and updates were organized regularly so they could discuss problems quickly, keep momentum and collaborate. On top of that, Danish has been such a strong leader to the team, the collaboration really helped the project get completed successfully and on time when you consider the challenges posed. This shows how adaptability, Communication and Strategic planning were crucial to solving time management issues.

## 5.4 Project’s Overall Judgement

### Vaccination Campaign Success

The vaccination campaign has been highly successful, given the high numbers of daily vaccinations and the cumulative coverage achieved up to early 2022. However, the plateauing of vaccination rates after 2022 points to issues like vaccine hesitancy and logistical barriers and suggests that continued public health campaigns are required to maintain and enhance vaccination coverage.

### Targeted Interventions for Vulnerable Groups

The lower uptake of booster doses between both the young and the aged population indicates areas where vaccine delivery or awareness campaigns may be lacking.The heterogeneity in vaccination rates in educational institutes, as exhibited by the vaccination data in the schools, requires more uniform strategies and outreach work to ensure better coverage.

### Relevance of Immunization Testing and Surveillance

The close correlation between testing trends and infection waves underlines the integral role of testing in pandemic surveillance and response. The decline in testing after 2022 may indicate a stabilized situation, but it may also reflect a decrease in vigilance that could delay the detection of new outbreaks.

## 5.5 Comments on GitHub log output

**Conclusion**

This is a comprehensive report that has minutely analyzed the management of the COVID-19 pandemic in Malaysia using detailed data-driven visualizations covering a wide array of factors ranging from case and death rates to vaccination trends and healthcare system resilience. This paper seeks to describe the features that are relevant to the experience of Malaysia in combating COVID-19, including the epidemiological characteristics, the problems in healthcare, and the results of vaccination. The analysis helps to answer the research questions by presenting trends related to Infection and mortality rates, linkages between testing and demand for healthcare, and status of the vaccination drives. In answering to these questions, the study is relevant, but the issues like data biases and regional differences work as a guideline for further research. The most important areas for enhancing the current and future approaches to pandemics include integration of stronger surveillance systems, the enhancement of healthcare system efficiency, and the definition of the directions for improving vaccination programs. By relying on the findings of this study to further advance this research, Malaysia will be better prepared for the next public health crises and promote global concern in the management of epidemics. By synthesizing this vast dataset, we have gleaned key insights that not only chart the historical path of the pandemic but also offer robust directives for future health crises management.

**Key Findings:**

**1. Epidemiological Trends:** The trends of waves of infection sweeping through Malaysia have been clearly drawn out for my analysis, peaking notably in 2021 and early 2022. Such waves could be well captured with the use of daily and cumulative data visualizations, which also provided critical lags between case spikes and mortality increases—a vital insight for planning timing of medical intervention.

**2. Demographic and Regional Impact:** The statistics showed a wide regional variation, with the highly populated urban regions such as Selangor and Kuala Lumpur bearing the highest burden of cases and hospitalizations. Age group-wise data showed that younger adults were most vulnerable to infection, probably because of increased mobility, while the elderly bore a disproportionately higher mortality rate.

**3. Healthcare System Stress:** In the peak times of infection waves, there was a clear stress in hospital and ICU capacities, calling for scalable healthcare resources and planning ahead to anticipate sudden surges in patient counts.

**4. Vaccine Effectiveness:** The first round of vaccinations was highly effective, leading to a marked decrease in the incidence and mortality rates (John Hopkins University, 2021). But at the same time, it showed a leveling off in the vaccination rate and variable uptake of booster doses, which indicates room for improvement in public health messaging and vaccine distribution logistics.

**5. Testing and Surveillance:** The association of testing rates with infection trends further emphasizes the value of active surveillance and broad-scale testing as management tools in controlling pandemics that can predict and mitigate peaks in hospital demand (Centers for Disease Control and Prevention, 2020).

**Recommendations for Future Research**

**1. Improved Surveillance Systems:** Future research should be geared toward the establishment and implementation of much more robust infectious disease surveillance systems that can anticipate and respond in real time to epidemiological trends (World Health Organization, 2020).

**2. Tailored Interventions in Health:** Preventive interventions in health should be intensified, particularly for frail populations such as the aged and the high-density urban populations, to prevent severe outcomes and reduce transmission.

**3. Healthcare Preparedness Research:** There is also a need for research on strategies by which healthcare infrastructure can rapidly increase and be distributed for maximum readiness in response to an event, so that hospital capacity and intensive care unit capacity are not overwhelmed by the following waves of an outbreak.

**4. Long Term Vaccination Approaches**: Convene into sustainable approaches with regard to hesitation and logistics but more importantly booster dose maintenance above a threshold, high.

**5. Public Health Strategy and Preparedness**: There must be public health strategies with implications of COVID -19 for strategic preparedness through lessons learned which would be placed to allow responses that are quite quick, definite, and well-timed.

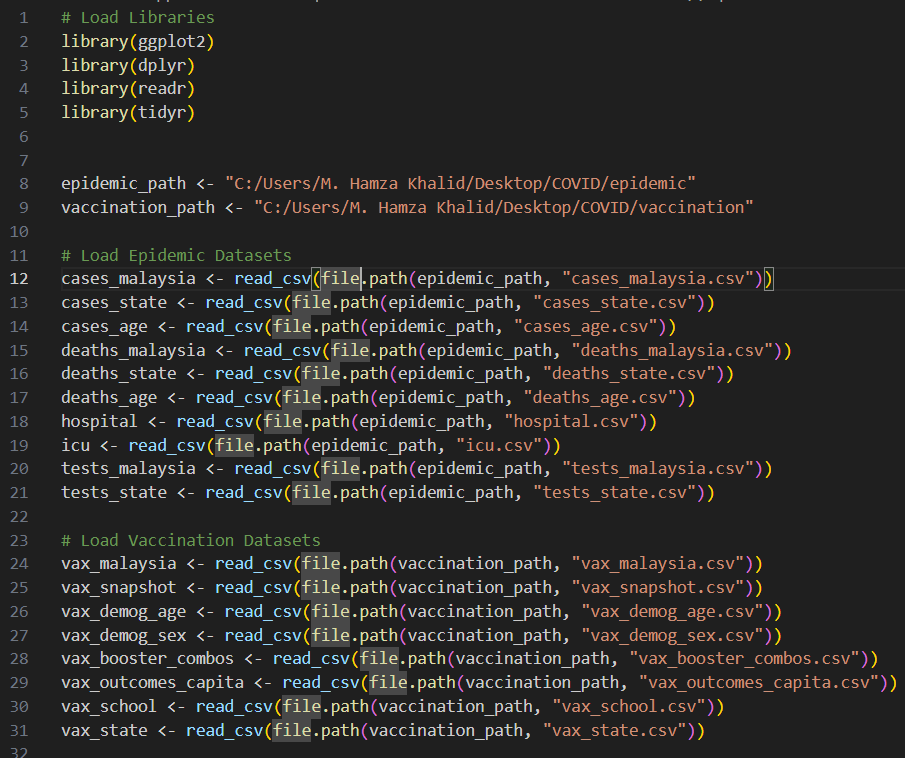
# References:

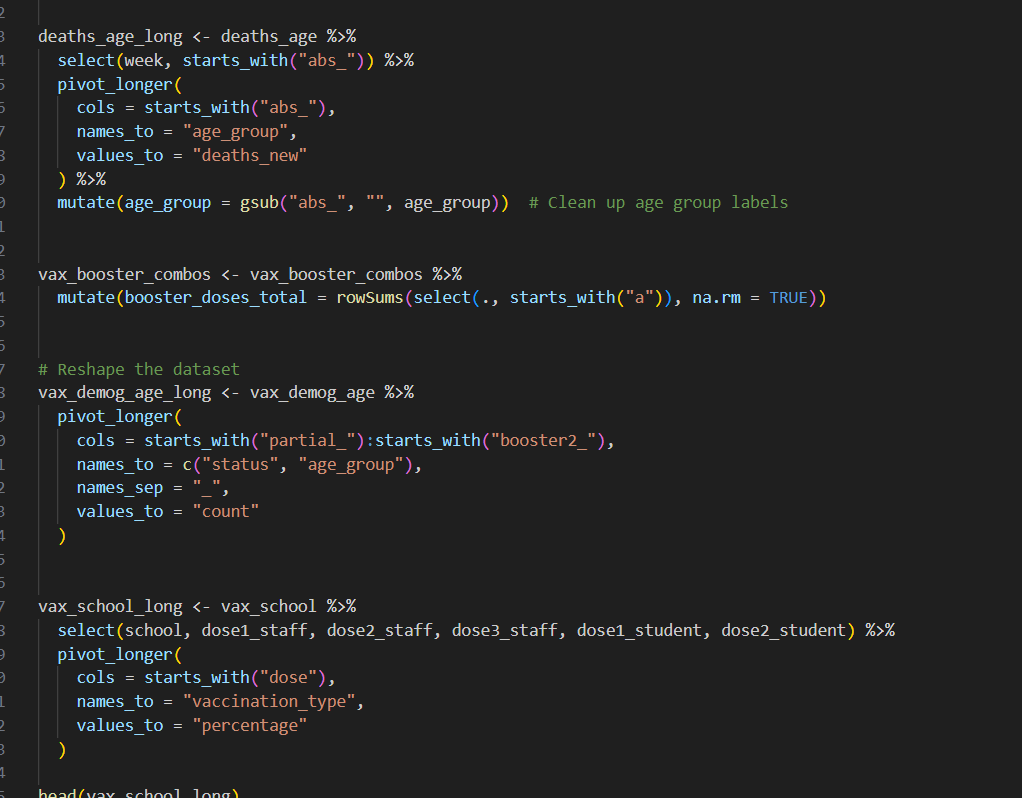
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# Appendix:

## Appendix A

## Code:

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## Visualizations:

A graph with different colored bars

Description automatically generated

A graph of vaccination trends

Description automatically generated

A graph of covid-19 cases and deaths

Description automatically generated

## Appendix B: