National College of Ireland

# Comparative Preparedness Analysis: Assessing Ireland's Response to Pandemics in Global Context

MSc Research Project
MSc Data Analytics


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**Project Submission Sheet**
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# Comparative Preparedness Analysis: Assessing Ireland's Response to Pandemics in Global Context

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**Abstract**

This study uses predictive modeling and machine learning to investigate how different international COVID-19 strategies may affect the outcome of the Irish outbreak. By comparing actual Irish COVID-19 figures with simulated scenarios based on methods from countries such as Australia, Sweden, Israel and China, the study measures the potential impact of each of these countries strategies in relation to Ireland. Using Regression models such as Linear Regression, Decision Trees and Random Forests we will show how these techniques could have changed the cases and mortality rates in Ireland. The findings provide insights that can be used by policymakers to shape Irish society health responses to increase preparedness for future pandemics. This study highlights the importance of studying global trends to improve crisis management and protect public health.

Keywords – Preparedness, Predictive Analysis, Regression, Crisis Management, Machine Learning

## 1 Introduction

In an era of great technological progress and improved health care, global problems such as pandemics remain a major concern. The COVID-19 pandemic which predominantly took place between 2020 and 2023 had a devastating impact on the world and put a spotlight on different countries ability to deal with it. Aswell as public health issues, these global threats can effect social and economic recovery and also national security. Ireland face these global threats on a daily basis.

This study examines how Ireland strategy to combating COVID-19 fared compared to different countries with notable strategies, particularly Australia, Sweden and Israel. There have been multiple studies analysing Irelands response to COVID-19, focusing in on particular areas like the switch from face to face to online learning Lindbla et all.(2021) but there is a gap in comprehensive predictive analysis research to evaluate how different strategies to combat COVID would work in Ireland.

In this study the strategies of Sweden, Israel and Australia will be transferred to Ireland and see if this would have improved or negatively affected Ireland's COVID cases and deaths. With the use of historical data and predictive models such as linear regression, decision trees and random forests valuable insights will be provided so that policymakers or government actions can be informed to make better decisions in the future to handle the next global threat with increased preparedness. This study aims to highlight the weaknesses and strengths of Ireland's COVID-19 strategy and by utilising other countries strengths Ireland will know what they need to improve on to become more prepared.

In Chen et al. (2020) it was discussed how timely interventions could have impacted the spread of COVID and that's what this study aims to accomplish for the next global threat.
This study wants to answer these questions, What impact would Australia, Sweden and Israels strategies have on the outcome of the COVID pandemic in Ireland? What is the best predictive analysis model to simulate these scenarios and provide valuable data? Can improving some aspects of Irelands strategy lead to noticeable improvements? By answering these questions, Ireland will be given the tools to improve their preparedness and improve their crisis management.
As highlighted by Ardabili et al. (2020) machine learning can be used to forecast outbreaks of pandemics, this showed that machine learning can be used as a good prediction tool and good for predicting the impact of different countries strategies on Ireland.

This research could be used to determine future policies and how Ireland will deal with future crises. Th aim of this study is to contribute to the improvement of Ireland's crisis management.

This paper is organised as follows.

**Introduction:** Explain the reseach problem and identify the questions to be answered.

**Related work:** Identifying existing work related to this research question and find knowledge gaps to contribute to.

**Research Methodology:** Describe the research methodology, including research design and data sources used.

**Design Specification:** Describe the design of the predictive model and the tools used.

**Implementation:** Show how the data was generated and how the models were developed and evaluated.

**Evaluation:** Summarise the evaluation metrics and discuss the results.

**Conclusion and future work:** Summarise key insights and suggest avenues for

# 2 Related Work

Since the beginning of COVID-19 there has been multiple studies published on analysing how countries deal with the pandemic and how it affected them. This study wants to add to the current knowledge base and use the existing knowledge along with predictive models to see how other countries strategies would have worked in Ireland. This study focuses on comparing COVID-19 strategies and the use of predictive models.

**Comparative Pandemic Response Analysis**
There has been many studies comparing countries testing strategies, vaccine roll outs, lockdown approaches and contact tracing, like Chenyang et al.(2021) looked at 13 dif-

ferent countries and scored them based on there governments responses, showing what responses worked and what didn't. Similary Lindblad et al. (2021) looked at the responses to the COVID pandemic in European countries in the early phases and what part education had in it, they showed the advantages of school closures and how this contributed to social distancing.

**Predictive Modeling in Epidemiology**
Predictive modeling plays a key role to understand and forecast how COVID-19 spreads. Researchers use different models then what is used in this study but in Kucharski et al.(2020) they built a model to show how different actions may have changed the outcome of the epidemic in the UK.

**Machine Learning Applications in Public Health**
There are multiple different machine learning methods to make predictions, in this study we will used 3 different ones with varying complexity.Ardabili et al. (2020) Used different machine learning methods to predict how COVID-19 spreads, they found random forests gave the best predictions when dealing with this subject rather that using manual research prediction methods.

# 3 Methodology

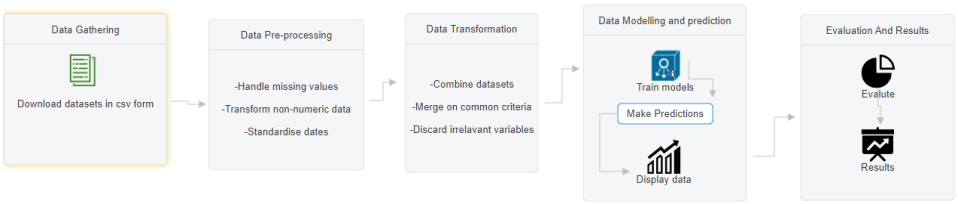


Figure 1: Research Methodology

This study aims to compare different COVID-19 strategies from three countries to see what impact it would have on Irelands pandemic outcomes. The three countries are Australia, Sweden and Israel. We will also be examining how increasing testing and vaccines would impact pandemic outcomes in Ireland aswell.

## 3.1 Data Collection and Preprocessing Data Sources:

Our World in Data COVID-19 dataset: This is a complete COVID-19 dataset with daily figures for data such as Vaccinations, Tests and positivity,Hospital and ICU, Confirmed cases, Confirmed deaths and Other variables of interest

## 3.2 Data cleaning:

New cases were only calculated at the end of every week so the data was cleaned to remove any rows that had no new COVID cases. Then this cleaned version was saved.Next any irrelevant columns were removed like tests units as this was not numeric data. Next a csv file of the country of choice was created from the COVID data to only include that countries COVID data. This was done for Ireland, Australia, Israel and Sweden.

## 3.3 Data Modification:

Any predictors we wanted to use from the other countries were renamed and merged into the Irelands data set. Any columns which were NAN were set to zero.

## 3.4 Data modeling and prediction

To predict how other countries strategies would perform in Ireland we used three regression models.

Linear regression: This is the simplest of all the models, this is used to understand the relationships independent and dependent variables.

Decision Tree Regression: A nonlinear model that divides the data into subgroups based on feature values, considering more intimate relationships. An impromptu retreat into the woods: A clustering approach using multiple decision trees to improve forecasting performance and efficiency.

A decision tree is a machine-learning algorithm. It has the structure of a tree. A decision tree is a series of sequential decisions made to reach a specific result Vidhya(2024) This type of regression divides the data into subgroups based on feature values, considering more intimate relationships.

Random Forest Regression: This type of predictive analysis combines multiple decision trees to become a Forrest. Each of one these are built randomly from the training data and features.The random forest combines the output of all the decision trees to generate the final output.Vidhya (2024)

Models were trained with historical data from Ireland including variables new cases, new deaths, stringency, testing, vaccine rollout and much more. Each model was executed separately to identify new cases and new deaths. Prediction. Following the training, the model was used to predict the outcome of Ireland's COVID-19 results if the strategies of Australia, Sweden or Israel were used and also if the vaccines and tests were increased by 50%. Government policies and economic factors were also taken into account.

### 3.5 Evaluation and results:

The models were evaluated using two comprehensive metrics:
Mean Squared Error (MSE): Penalises larger errors more than smaller ones, providing a measure of prediction accuracy. This looks at larger errors rather than smaller ones. This measures the average squared difference between the predicted values and the actual values Singh(2024)The lower the MSE, the better the model predictive accuracy, and, the better the regression model is.
R-squared:This model can be explained as ratio of the sum of squares regression and the sum of squares total Singh(2024) Or the different in the dependent variable that is predictable from the independent variables.
By utilising these evaluation techniques it can be determined which model is the best fit and give the most accurate predictions.

## 4 Design Specification

The design specification outlines the architecture, components, and workflow of the research methodology to evaluate the impact of various COVID-19 strategies on Ireland's pandemic outcomes. The following sections describe the detailed design of the system used to perform the analysis.

### 4.1 Functional Requirements:

This system must be able to compare different strategies from multiple different countries to calculate the potential impacts on Ireland pandemic outcomes.

This system must be able to take in great amounts of data and separate it by country.

The predictive models should be able to produce accurate and comprehensive outcomes based on different countries strategies

### 4.2 Performance Requirements:

The system must be able to handle large datasets to be able to effectively and efficiently provide the predicted outcomes.

The prediction models should have high accuracy when producing outputs using metrics like Mean Squared Error (MSE) and R-squared used to evaluate their effectiveness.

The system should be salable to accommodate new data sources and evolving COVID-19 metrics.

This system should be scalable and be transferable to be used in future situations, like a new pandemic or global threat. New data should also be easily interpreted in this system.

### 4.3 Technical Specifications:

Data Sources: Our World in Data
Data Preprocessing: Standardised methods for cleaning and transforming data, including handling missing values and normalizing dates.
Data Modeling: The creation and the implementation of three models, linear regression, decision trees and random forrests.

Programming Languages and Tools: Use of Python for data processing and model building, along with libraries like pandas, scikit-learn, Numpy and matplotlib.

### 4.4 Constraints:

Time: The project must be completed within a six-month timeframe.
Regulatory Requirements: Complying with data privacy laws and ethical guidelines for handling public health data.

### 4.5 User Interface:

This should be easily usable and clear to effectively produce graphs for each of the models to view the outcomes of the different strategies had on Irelands outcomes.
Visualisation tools to present data trends, model predictions, and performance metrics.
Interactive features for comparing multiple strategies and scenarios.

### 4.6 Compliance and Standards:

Complying with GDPR laws for data privacy and protection.

## 5 Implementation

The implementation of this study revolved around using machine learning methods(linear regression, decision trees and random forests) to analyse how using different COVID-19 strategies would impact on Irelands outcomes. Data was collected and transformed, models were developed, predictions and visulisations were produced and these were then evaluated.

### 5.1 Data Sources:

Our World in Data was the only dataset as this had comprehensive daily COVID data for every data point that was needed including data on new cases, new deaths, testing, vaccines, ICU and hospitals.

### 5.2 Data Collection:

The data was downloaded and stored locally on a csv file from a GitHub repository that combine all of Our world in data collected data.

### 5.3 Data Transformation:

New cases were only calculated at the end of every week in the data set so the data was cleaned to remove any rows that had no new COVID cases. Then this cleaned version was saved. Any irrelevant columns were removed like tests_units as this was not numeric data. A csv file of the country of choice was created from the COVID data to only include that countries COVID data. This was done for Ireland, Australia, Israel and Sweden. Any predictors we wanted to use from the other countries were renamed and merged into the Irelands data set. Any columns which were NAN were set to zero.

### 5.4 Developed Models:

Models were trained then predicted outcomes using different countries COVID strategies on existing irelands data these models included Linear Regression, Decision Tree Regression, and Random Forest Regression.

### 5.5 Predictions and Visualisations:

Predicted new cases and deaths in Ireland using different COVID-19 strategies. These strategies were: Australia: Elimination Strategy, Sweden: Herd Immunity and Israel: Rapid Vaccination Campaign. These visuals compared predicted vs. actual new cases and new deaths. These visualisations provided clear insights into the effectiveness of different strategies.

### 5.6 Evaluation Metrics:

The predictions were evaluated using metrics such as Mean Squared Error (MSE) and R-squared (R2)scores.
Using these evaluation methods each models performance was evaluated and the best model was chosen to show the predicts for irelands outcomes using different countries COVID strategies.

## 6 Evaluation

This section presents a comprehensive analysis of the results from this study, it focuses on the case studies of Australia, Sweden and Israel. The performance of each model is evaluated and the implications of the findings are shared. Each model is evaluated with the mean squared error an R-squared. The models used are linear regression, Decision Tree, and Random Forest. These are used to predict the new cases and new deaths of Ireland using these three countries COVID-19 strategies. Aswell as this the increase of testing and vaccines in Ireland will also be analysed and evaluated to see what impact that had on the outcomes of COVID.

### 6.1 Case Study 1: Australia Strategy:

To assess the performance of linear regression, decision tree and random forest model in predicting daily COVID- 19 new cases and deaths in Ireland using Australian methods.The Australian data used is total_vaccinations_per_hundred and stringency_index as Austrlias COVID strategy was the elimination strategy with included strict lockdowns.

## Results

Table 1: Regression and Decision Tree Metrics

| Metric | New Cases | New Deaths |
|---|---|---|
| **Linear Regression** | | |
| R-square ($R^2$) | 0.33 | -0.15 |
| Mean squared error (MSE) | 236107273.68 | 5687.61 |
| **Decision Tree** | | |
| R-square ($R^2$) | 0.97 | 0.72 |
| Mean squared error (MSE) | 8990566.48 | 1374.63 |
| **Random Forest** | | |
| R-square ($R^2$) | 0.94 | 0.70 |
| Mean squared error (MSE) | 21196449.02 | 1483.28 |

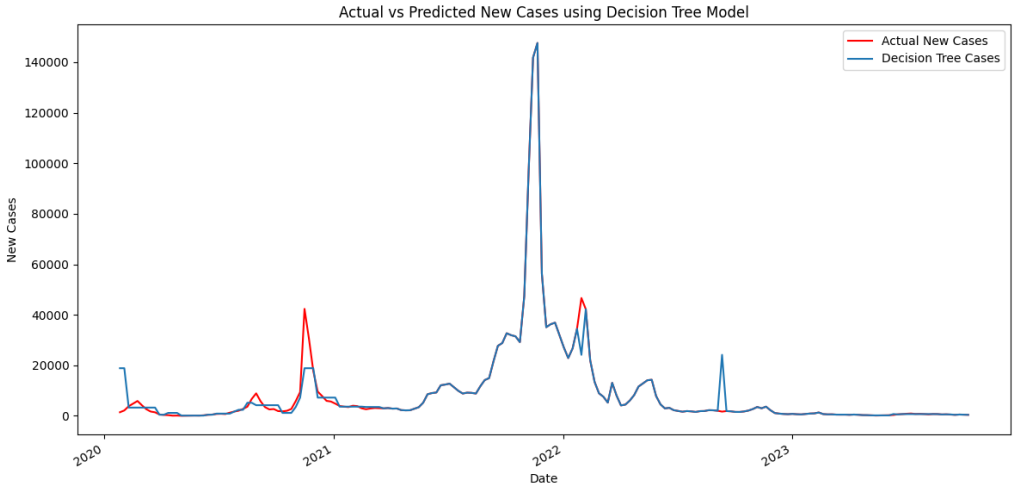


Figure 2: Decision tree cases

Analysis: Model Performance: The decision trees model shows the highest performance with the highest R-squared values and lowest mean squared error values. Random forests performed slightly worse and linear regression was the poorest performing. Linear regression isn't able to capture complex patterns in the COVID-19 data.

Implications: The Decision tree model provides the best predictions in this scenario , Policy makers and healthcare planners could use these models for superior accuracy and reliability were forecasting COVID-19 outcomes.

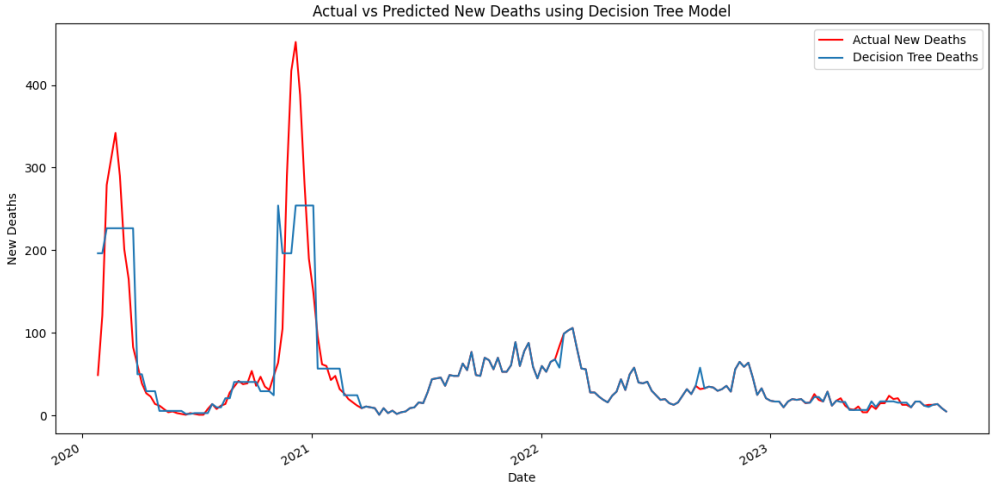


Figure 3: Decision tree Deaths

## 6.2 Case Study 2: Sweden Strategy

To assess the performance of linear regression, decision tree and random forest model in predicting daily COVID- 19 new cases and deaths in Ireland using Swedens methods.The Sweden data used is stringency_index, new_tests_per_thousand, positive_rate and new_cases_per_millionas. Sweden COVID strategy was the Herd Immunity.

## Results

| Metric | New Cases | New Deaths |
|---|---|---|
| **Linear Regression** | | |
| R-square ($R^2$) | -0.38 | 0.01 |
| Mean squared error (MSE) | 482,343,177.34 | 4,882.74 |
| **Decision Tree** | | |
| R-square ($R^2$) | 1.00 | 1.00 |
| Mean squared error (MSE) | 1,329.22 | 13.57 |
| **Random Forest** | | |
| R-square ($R^2$) | 0.98 | 0.94 |
| Mean squared error (MSE) | 8,599,876.71 | 316.75 |

Table 2: Regression, Decision Tree, and Random Forest Metrics

Analysis: Model Performance: The decision trees model shows the highest performance with near perfect accuracy in predicting the new cases and new deaths with the highest R-squared values and lowest mean squared error values. Random forests performed slightly worse and linear regression was the poorest performing by far, linear regression wouldn't be able to provide accurate results.

Implications: The Decision Tree and Random Forest models would be highly effective in this scenario with such complex data in Sweden's approach. linear regression can serve as a quick and simple predictor but it is not suitable for precise predictions in this context.

## 6.3 Case Study 3: Israel Strategy

To assess the performance of linear regression, decision tree and random forest model in predicting daily COVID- 19 new cases and deaths in Ireland using Israel methods.The Sweden data used is stringency_index, new_tests_per_thousand, positive_rate, new_cases_per_millions and people_vaccinated_per_hundred. Israels COVID strategy was Rapid Vaccination Campaign.

## Results

| **Metric** | **New Cases** | **New Deaths** |
|---|---|---|
| **Linear Regression** | | |
| R-square ($R^2$) | -0.13 | -0.19 |
| Mean squared error (MSE) | 396,234,349.80 | 5,867.68 |
| **Decision Tree** | | |
| R-square ($R^2$) | 0.99 | 0.95 |
| Mean squared error (MSE) | 3,836,178.82 | 244.37 |
| **Random Forest** | | |
| R-square ($R^2$) | 0.95 | 0.83 |
| Mean squared error (MSE) | 17,281,069.37 | 844.96 |

Table 3: Regression, Decision Tree, and Random Forest Metrics

Analysis: Once again the decision tree model performed the best out of all the models. This model performed excellently in predicting death rates. The random forest model also performed well but less than decision trees. Again linear regression proved to be the least accurate because of its inability to handle complex data.

Implications: The decision tree model had extremely high values for R-squared similarly to random Forests, this showed how suitable these are for making these predictions, policy makers can yous think with a high level of confidence that it would be able to produce accurate predicted outcomes in future crises. This model could be used to prepare for the future.

## 6.4 Case Study 4: Increase vaccinations in Ireland

In this section, the *total_vaccinations_per_hundred* data point will be increased by 50% to evaluate whether this adjustment will have a positive or negative effect on the results.

## Results

Table 4: Prediction Metrics for New Cases and New Deaths

| Metric | MSE | $R^2$ |
|---|---|---|
| **New Cases Predictions** | | |
| **Linear Regression** | 248,985,465.47 | 0.28 |
| **Decision Tree** | 260,534,107.49 | 0.25 |
| **Random Forest** | 111,163,219.72 | 0.68 |
| **New Deaths Predictions** | | |
| **Linear Regression** | 4,207.45 | 0.14 |
| **Decision Tree** | 468.23 | 0.90 |
| **Random Forest** | 406.22 | 0.92 |

Analysis: In this occasion the random forest model provided the most accurate results with a high R-squared value of 0.92 for new deaths. By reducing the vaccination rate by 50% this showed a reduction in both new deaths and new cases. The decision tree model also performed well with linear regression being the least effective

Implications: This showed that when you increase the vaccination rate it can have a significant improvement in reducing the number of new cases and new deaths. This can provide information to policy makers and government officials that vaccination rollout is extremely important and that increasing the spending in this area would show significant improvements.

## 6.5 Case Study 5: Increase the number of tests in Ireland

In this section, the *total_test_per_thousand* data point will be increased by 50% to evaluate whether this adjustment will have a positive or negative effect on the results.

## Results

Table 5: Prediction Metrics for New Cases and New Deaths

| Metric | MSE | $R^2$ |
|---|---|---|
| **New Cases Predictions** | | |
| **Linear Regression** | 258,920,046.87 | 0.25 |
| **Decision Tree** | 139,113,351.85 | 0.60 |
| **Random Forest** | 218,992,527.12 | 0.37 |
| **New Deaths Predictions** | | |
| **Linear Regression** | 3,659.48 | 0.25 |
| **Decision Tree** | 1,921.22 | 0.61 |
| **Random Forest** | 1,499.58 | 0.69 |

Analysis: In this occasion the decision tree model provided the most accurate results for new cases with a decent R-squared value but then the random forest model performed better in predicting new deaths. Increasing the number of tests showed a reduction in

the number of deaths but not much in new cases.

Implications: By increasing the number of tests the death rate decreased but the new cases didn't change, this shows that testing can prevent deaths by catching the cases early. This shows the importance of testing and how it could be a life saver.

# 7 Conclusion and Future Work

Conclusion: This study compared different covid-19 strategies to ireland and used those strategies along with predictive analysis models to show what inmpact these strategies would have on irelands outcomes. The models used were linear regression, Decision Trees, and Random Forests. The countries were Australia, Sweden and Israel and also increaing vacinations and testing by 50% was also looked at.

It was concluded that looking at Austrlias strategy of severe lockdowns and trying to eliminate cases could have reduced both cases and deaths in Ireland. Then also applying Israel's rapid vaccination campaign also showed an improvement. Sweden's herd immunity program didn't show any noticeable improvements, some little increased spikes in cases but nothing major. Then increasing the vaccinations and testing rates showed a noticeable improvement in decreasing deaths and cases. This shows how important testing and vaccines are.

Throughout the analysis, Decision Tree and Random Forest models consistently provided more accurate predictions compared to linear regression, making them valuable tools for policymakers in simulating and evaluating different strategies.

## 7.1 Comparative Analysis:

1.Australias strategy of elimination included strict lockdowns which were more extreme than Ireland and a more extensive testing and quarantine measures,if Ireland took all these improvements of board they could have significantly reduced deaths and cases but these may have also lead to more economic and social issues. Decision trees showed the highest performance for this strategy.
2. Swedens approach of herd immunity and minimal restrictions would have lead to an increase in cases but the prediction analysis showed a slight improvement in new deaths. Both decision tree and random forest models showed an improvement in deaths so this strategy could be looked at as a way of managing deaths but its not as significant as other strategies.

3.Israel had a rapid vacination capaign with strict lockdowns, both of these together would have significantly decreased irelands new cases and new deaths. The decision tree model show significant improvements in both of these metrics.

4. Both increasing vaccinations and tests in Ireland showed a significant decrease of both cases and deaths. If Ireland increase preparedness in both of these areas they should be ready for another pandemic.

## 7.2 Implications of Findings:

Implications of Findings: This study shows that adopting different strategies from different countries have upsides and downsides. The recommendations based on these strategies are as follows Australia's early and strict measures led to a decrease in deaths and cases, Ireland could apply this in the future at the start of a crisis, Israel's aggressive vaccination campaign showed a significant improvement in decreasing deaths, Ireland could improve their vaccination roll out basing it of Israels campaign. Sweden herd immunity would not be recommended as even though it reduced deaths it significantly increased cases. Increasing both vaccines and testing would be recommended as together these would dramatically decrease deaths and cases
Overall, the Decision Tree and Random Forest models consistently provided more accurate predictions compared to linear regression, making them valuable tools for policymakers in simulating and evaluating different strategies.

## 7.3 Future Work:

1.More stategies: Looking at more countries COVID-19 strategies could provide useful insights like in the strategies in this study, future work could focus on more strategies such as Singapores Targeted Lockdowns and Extensive Testing.
2.Incorporating Real-Time Data: Looking at real time data could show if the predicted results are accurate to the data being produced on a daily basis, this would provide another evaluation technique and improve the results being predicted.
3.Using different models: Different predictive models could be incorporated such as neural networks.
These future directions aim to enhance Irelands preparedness for future pandemics and contribute to more effective global crisis management strategies.

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