Problem Chosen	2025 MCM / ICM Summary Sheet	Team Control Number
B		2503720

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Summary

Here is the abstract of our paper. Here is a test.

Contents

1 Introduction

2 Assumptions and Notations

2.1 Assumptions

The following reasonable assumptions are made to reasonably simplify the model:

- Government policies (such as taxes, subsidies, regulations, etc.) remain unchanged during the period of the model.
- No major event compromising or promoting the tourism industry will occur during the period of our model.
- Consumer behavior, consumer preferences, or market demand are assumed to remain unchanged.
- Consumption per visitor per day remains stable.

2.2 Notations

The primary notations used in this paper are listed in Table 1.

Table 1: Notations

Symbol	Definition
A	the first one
b	the second one
α	the last one

3 Preliminary Analyses

We first analyse the potential factors that may affect the tourism industry in Juneau, thus enabling a smoother transition to the model building process.

3.1 Number of Tourists

We found no existing data on the number of tourists visiting Juneau each year, but we can infer it by other means.

According to [source] and [source], among all the transportation methods, cruise ships are the most popular way to visit Juneau, accounting for over 90% of the total number of tourists. As the number

of cruise ship passengers is available online, we can use it as a proxy to estimate the total number of tourists.

According to [source], the number of cruise ship passengers visiting Juneau is as follows:

Table 2: Number of Cruise Ship Visitors to Juneau

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Num(in thousands)	961	983	1015	1072	1151	1306	0	117	1167	1670

It can be easily noted that numbers plummeted in 2020 and 2021 due to the COVID-19 pandemic. In this section, we use the *SARIMAX* model including the pandemiuc factor to predict the number of tourists in the next few years.

3.1.1 SARIMAX Model

The *SARIMAX* model, which stands for *Seasonal AutoRegressive Integrated Moving Average with eXogenous regressors*, is an extension of the *ARIMA (AutoRegressive Integrated Moving Average)* model that incorporates seasonal effects and external variables. Since we need to consider the impact factors during the pandemic, *SARIMAX* is used instead of *ARIMA*.

3.1.2 Parameters Setting

- **Pandemic Impact Factor**: Given the severity of the COVID-19 pandemic, different factors are set. In 2020, 2021 when the pandemic was at its peak, factors are set to 1, in 2021 set to 0.3, and in other years set to 0.
- **Order (p, d, q)**: The order of the ARIMA part of the model is set to (2, 1, 1) after conducting the ACF and PACF analysis(see Figure 1).
- **Enforce Stationarity**: The enforce_stationarity parameter is set to True to ensure the model is stationary.
- **Enforce Invertibility**: The enforce_invertibility parameter is set to True to ensure the model is invertible.

3.1.3 Model Results

The *SARIMAX* model is trained on the data from 2014 to 2023 and used to predict the number of tourists in the next few years. The prediction result is lited as follows. The residuals, ACF and PACF plots are also shown in Figure 1.

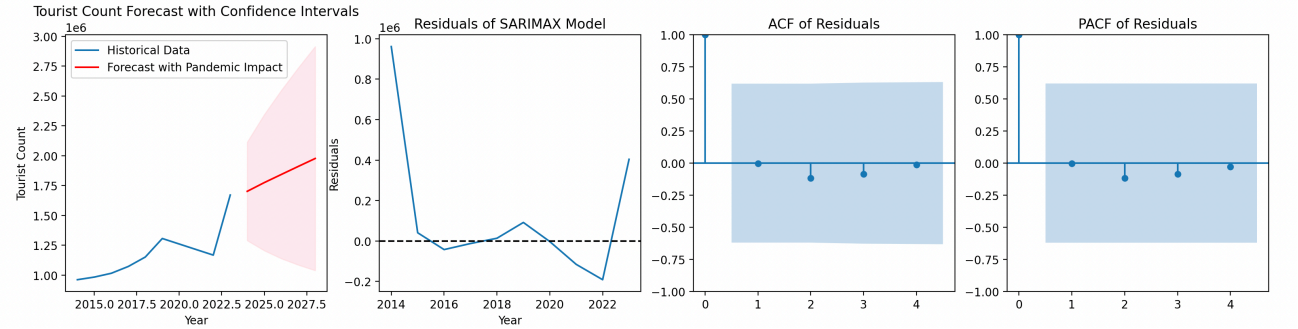


Figure 1: Tourist Prediction

It can be seen that the model correctly handles the plummet during the pandemic and captures the trend of the revival of tourism. The exact number of tourists in the next few years is shown below, which will be utilized in the following sections.

Table 3: Number of Tourists Prediction

Year	2024	2025	2026	2027	2028
Num(in thousands)	1701	1774	1842	1909	1976

3.2 Number of Local Residents

3.2.1 Population of Juneau

According to *World Population Review*, the population of Juneau in the last decade is as follows:

Table 4: Population of Juneau

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Num (in thousands)	31.4	32.2	32.4	32.6	32.5	32.6	32.5	32.1	32.0	32.0	32.2	32.0	31.7	31.6	31.3

3.2.2 Population Prediction

We still use the *SARIMAX* model proposed in the last section to predict the population of Juneau in the next few years. Parameters are the same as the last section. The first four pictures are still the original data and predicted data, the residual, ACF and PACF plots. In addition, official prediction data can also be found in *World Population Review*, therefore two additional pictures are added to compare the prediction results.

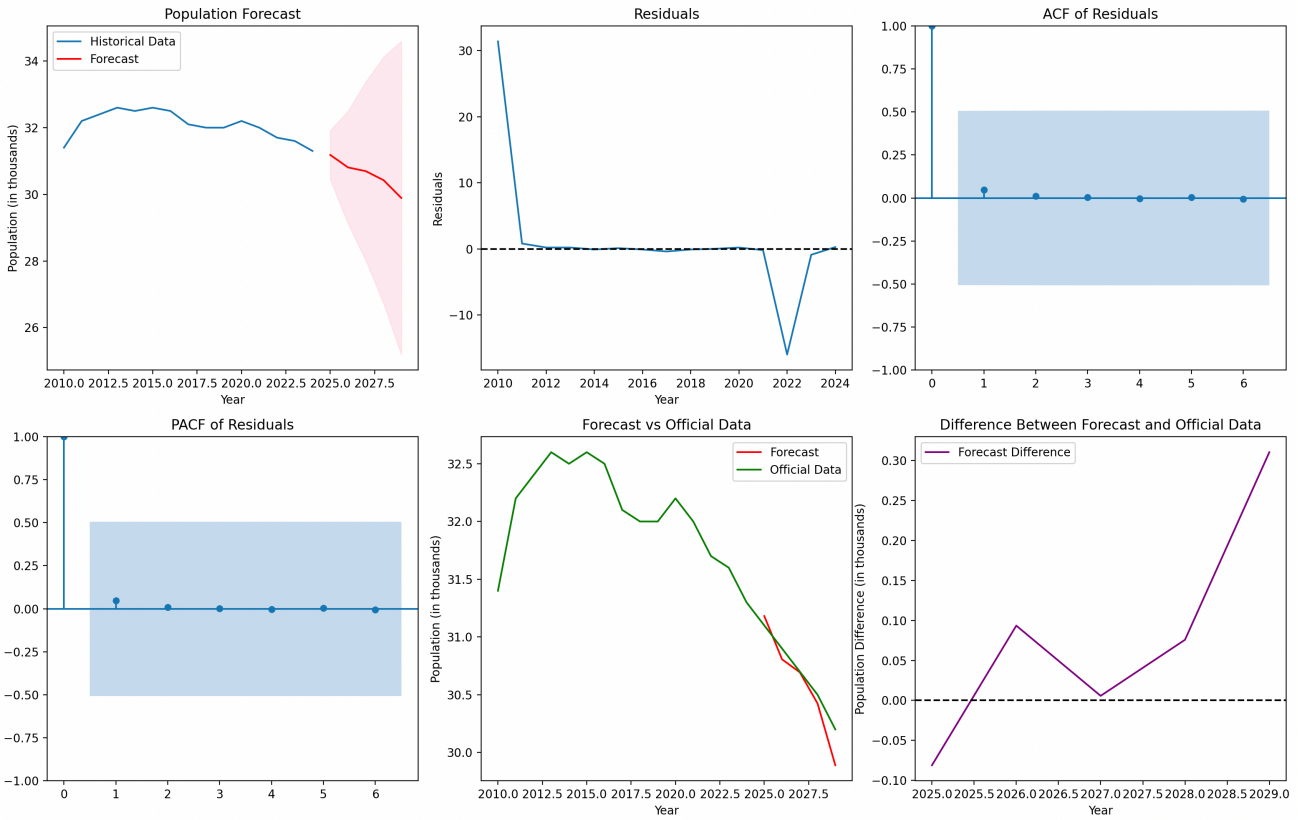


Figure 2: Tourist Prediction

It can be concluded from subfigure 5 and 6 that the model fits the data well and the prediction is reliable. The exact number of local residents in the next few years is shown below.

Table 5: Population Prediction

Year	2025	2026	2027	2028	2029
Num(in thousands)	31.2	30.8	30.7	30.4	30.0

4 Task 1: Model for Tourism Industry in Juneau

4.1 Introduction

In this section we need to select factors to quantify and track the tourism industry in Juneau. It is impossible and unnecessary to consider all the factors that may affect the tourism industry, only those that are relevant to the problem need to be considered. Drawing on the idea of the divide-and-conquer algorithm, we first divide the factors into three categories: economy, society and environment. The untimate goal is listed below:

$$\mathcal{F} = (\alpha \cdot \text{ Economy } - \beta \cdot \text{ Environment }) \cdot \text{ Society} \tag{1}$$

where α and β are the weights of the economy and environment, denoting the importance we attach to each category. Economy means the income generated by the tourism industry, environment means the environmental cost of the tourism industry, and society is an indicator that quantifies the satisfaction of the local residents towards the tourism industry.

Our goal is to maximize the economy income, minimize the social cost and environmental impact, where parameters α, β and γ denote how much importance we attach to each category. Intuitively, the goal aforementioned is equivalent to maximizing the output.

Each category is further divided into several minor factors such as local population, number of tourists to extrapolate a mathematical model fitting the circumstances in Juneau, which will be discussed in the following sections.

4.2 Economy

In this section we consider the actions that will contribute to the income of the tourism industry in Juneau, which are tourists' consumption, tax income and fines.

4.2.1 Tourists' Consumption

We first calculate the average consumption of tourists in Juneau per day. Since there is no existing official data available, we can infer it by other means. According to [source], avearge tax income from tourists in Juneau is 27.7 million dollars in 2018 with a tax rate of 12%. We can use this information to estimate the average consumption of tourists in Juneau per day according to the following equation.

$$\text{Average Consumption} = \frac{\text{Tax Income}}{\text{Tax Rate} \times \text{Number of Tourists}} \tag{2}$$

The number of tourists can be found in Table 2. The average consumption of tourists in Juneau per day is calculated as follows:

$$\text{Average Consumption} = \frac{27.7 \times 10^6}{0.12 \times 1151 \times 10^3} \approx 200.55 \tag{3}$$

Therefore the function of tourists' consumption regarding the number of tourists is:

$$\text{Tourists' Consumption} = 200.55N \tag{4}$$

Given that an average of 3 days are spent by each visitor to Juneau, the total consumption of tourists should multiply by another 3.

4.2.2 Tax Income

According to the official website of Juneau, the tax rate of the tourism industry is 12%. The tax income can be calculated as follows:

$$\text{Tax Income} = 0.12 \times \text{Tourists' Consumption} \approx 24N \tag{5}$$

4.2.3 Fines

As there is no official data available, we assume that the fine rate is negatively correlated with the amount of fines and follows an exponential distribution $f(x) = \lambda \cdot e^{-\lambda x}$. We also assume that fined rate falls to 5% when the amount of fines climbs to 15 dollars, that is:

$$\int_0^{15} \lambda \cdot e^{-\lambda x} dx = 1 - 95\% \Rightarrow \lambda \approx 0.2 \tag{6}$$

Therefore the total amount of fines can be calculated as follows:

$$\text{Fines } = NQ \cdot \left(1 - \int_0^{Q} 0.2 \cdot e^{-0.2x} dx\right) = NQ \cdot e^{-0.2Q} \tag{7}$$

4.3 Society

Societal factors such as infrastructure, price of housing products, and the mental loss due to the overcrowding and rowdy tourists all account for the social cost of the tourism industry.

The result yields:

$$\text{Score} = 5.75 \times 10^{-8} N - 0.002 \times N_{Local} + 61.484 \tag{8}$$

4.4 Environment

In this section we propose a new model $KAYA_{tourism}$ derived from the KAYA model to quantify the environmental impact of the tourism industry in Juneau.

4.4.1 KAYA Model

The original KAYA model is a mathematical model that describes the relationship between the total amount of CO2 emissions and the four factors that affect it: population, GDP per capita, energy intensity and carbon intensity. The KAYA model is expressed as follows:

$$\text{CO2 Emissions } = P \times GDP \times EI \times CI \tag{9}$$

where P denotes the population, GDP denotes the GDP per capita, EI denotes the energy intensity and CI denotes the carbon intensity. This model falls short when only considering the environmental impact of the tourism industry. Based on the data we collect and the goal of our project, we propose a new model $KAYA_{tourism}$.

4.4.2 $KAYA_{tourism}$ Model

The $KAYA_{tourism}$ model is expressed as follows:

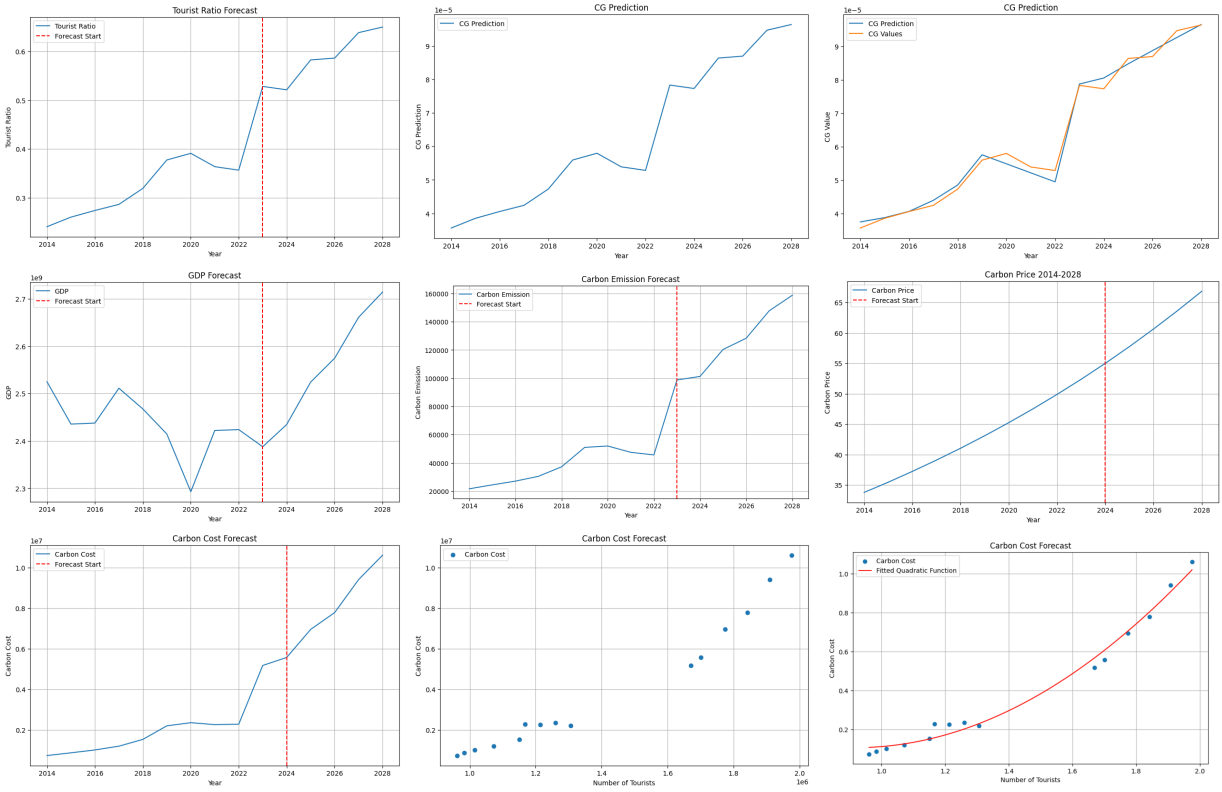
$$CO_{2\_Tourism} = G \times CG_{Tourism} \tag{10}$$

where G denotes the gross income of the tourism industry and $CG = EI \times CI$. To calculate the emission of CO_2 in the tourism industry, we first looked up the data of the Juneau's carbon emission and GDP across the country and calculated the CG_{All} across the country. $CG_{Tourism}$ can be calculated as $CG_{Tourism} = CG_{All} \times Ratio$ where $Ratio$ is the ratio tourism accounts for across all industries. The income of the tourism industry in Juneau has been calculatd in the previous section, and the $CO_{2\_Tourism}$ can thus be estimated. It should be noted that G and $CG_{Tourism}$ are both linear functions of the number of tourists N, therefore when fitting and regressing $CO_{2\_Tourism}$ quadratic regression should be used.

Alongside the historical data, future predictions are also conducted using the *SARIMAX* model. The results are listed below.

From subplot 9 we can see that a quadratic regression fits the data well with an R^2 value of over 0.99. The fitting function yields the following results:

$$CO_{2\_Tourism} = 0.815 \times \frac{N^2}{10^5} - 14.95N + 7924000 \tag{11}$$



4.5 Summary

Summing up all the three categories, we can get the final output of the model:

$$\mathcal{F} = (\alpha \cdot (632N + NQ \cdot e^{-0.2Q}) - \beta \cdot (0.815 \times \frac{N^2}{10^5} - 14.95N + 7924000)) \cdot (5.75 \times 10^{-8} N - 0.002 \times N_{Local} + 61.484) \tag{12}$$

where N is independent variable, α, β and Q are parameters that can be adjusted accordingly, N_{Local} is the local population of Juneau assumed fixed. Our goal is to find the optimal value of N that maximizes the output $\mathcal{F}$.

5 Task 2: Model Adaptation and Migration

In the previous section, we have established a model to quantify the tourism industry in Juneau. Based on this model we…

6 Task 3: Memo

Recommendations for Sustainable Tourism in Juneau, Alaska

Dear Tourist Council,

It is our great honour to present to you our recommendations for sustainable tourism in Juneau, Alaska. We have conducted a thorough analysis of the current situation in Juneau and have identified several key areas that need to be addressed in order to ensure the long-term sustainability of the tourism industry in the region. Our recommendations are based on the principles of sustainable tourism, which aim to balance the economic, social, and environmental impacts of tourism in order to ensure that it can continue to benefit both the local community and the environment for generations to come. Our approaches, findings and suggestions are as follows.

Firstly we summarized a general equation aiming to balance the economic, social, and environmental impacts of tourism. Then we looked into these aspects and devised a model accordingly for each. *SARIMAX, Linear-Regression* models were used to ensure the accuracy and reliability of our findings and suggestions.

Here are some findings based on our predictions.

- **Economic Impact:**
- **Social Impact:**
- **Environmental Impact:**

Basded on these findings, we put forward the following recommendations and measures.

- **Economy**
- **Society**
- **Environment**

I hope you find our recommendations useful and that they will help to guide the development of sustainable tourism in Juneau. We believe that by working together, we can create a more sustainable future for the tourism industry in the region. Thank you for your attention and consideration. Feel free to contact us for any further information.

Sincerely,

Team # 2503720 Members

Appendix A Further on LaTeX

Appendix B Program Codes

```cpp
#include <iostream>
using namespace std;
int main() {
    cout << "Hello, World!" << endl;
    return 0;
}
```

References

[1] Einstein, A., Podolsky, B., & Rosen, N. (1935). Can quantum-mechanical description of physical reality be considered complete?. *Physical review*, 47(10), 777.

[2] *A simple, easy LaTeX template for MCM/ICM: EasyMCM*. (2018). Retrieved December 1, 2019