Problem Chosen	2025 MCM/ICM Summary Sheet	Team Control Number
B		2510625

Optimization Models for Sustainable Tourism

Summary

For Problem1, to achieve sustainable development, we considered environmental, economic, and social factors and built a sustainable development model. The objective function is to increase economic benefits and social satisfaction while reducing environmental pollution. The main constraints are the maximum carbon emissions, partial infrastructure capacity, and maximum number of tourists. Through data analysis, we derived the seasonal fluctuations in the number of tourists and established a more accurate relationship between infrastructure capacity and the number of tourists, considering the feedback of government redistribution of fiscal revenue on the model. Based on the historical data of Juneau, we conducted a non-linear fit of social satisfaction and the number of tourists. The model results are shown in **Section 3.1.4**, The optimal number of tourists per year is around 1,431,579 people. In the sensitivity analysis, we assessed the local and global sensitivity of the variables and found that the number of tourists is a key variable. Finally, we used the **population iteration algorithm** and **Pareto optimization** to build a multi-objective optimization model, and verified the results of the previous single-objective model to ensure reliability.

For Problem2, to adapt to another scenic spot, we need to modify the key parameters in the sustainable tourism development model based on the actual situation of the spot, such as the number of tourists, per capita consumption, local water resources and waste treatment capacity. In the article, we take Jiuzhaigou Scenic Area in Sichuan Province, China as an example to show the process and results of modifying the model, and find that the results basically conform to the local actual situation.

For Problem3, based on the previous model, we constructed a diversion model, which optimizes and constructs independent sustainable development models for the main scenic spot and the secondary scenic spots used for diversion according to their actual situations. After completing the construction of the sub-models, we built the diversion model with the objective function of maximizing the total benefits of each scenic spot while minimizing the publicity input cost, using the number of people diverted from the scenic spots as the decision variable. We took Mendenhall Glacier as the main scenic spot and whale-watching spot as the diversion spot for actual construction, used **simulated annealing algorithm** for model solving, and finally believed that the Juneau government could maximize the overall benefits when diverting about 329,888 people, with a diversion ratio of about 20

For the Memorandum, based on the previous sustainable development model, we constructed a dynamic model, which takes the final state of one year as the initial state of the next year, simulates the accumulation effect of infrastructure capacity and maximum carbon emissions over time, and analyzes the changes of key variables within ten years. According to the model results, we made predictions for Juneau and assessed the effectiveness of the measures, and proposed optimization suggestions combining the results

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1 Introduction

1.1 Problem Background

Here is the problem background. Three major problems are discussed in this paper, which are:

- **Geographical Location:** Juneau is the capital of Alaska, located in the southeastern part of the state, with a population of approximately 30,000 residents.
- **Current Tourism Situation:** In 2023, Juneau set a record for hosting 1.6 million cruise passengers, with up to 7 large cruise ships and 20,000 passengers received in a single day.[1] These tourists brought considerable economic benefits to the city, amounting to approximately $375 million.[2] However, this rapidly developing tourism industry has also brought a series of problems, especially challenges related to over-tourism.
- **Environmental Impact:** Mendenhall Glacier in Juneau is one of the city's main tourist attractions, but in recent years, due to rising temperatures, the glacier has been retreating rapidly. Since 2007, the glacier has retreated a distance equivalent to eight football fields. This environmental change has not only caused damage to the natural landscape but also raised concerns among local residents about the sustainability of tourism.[3]

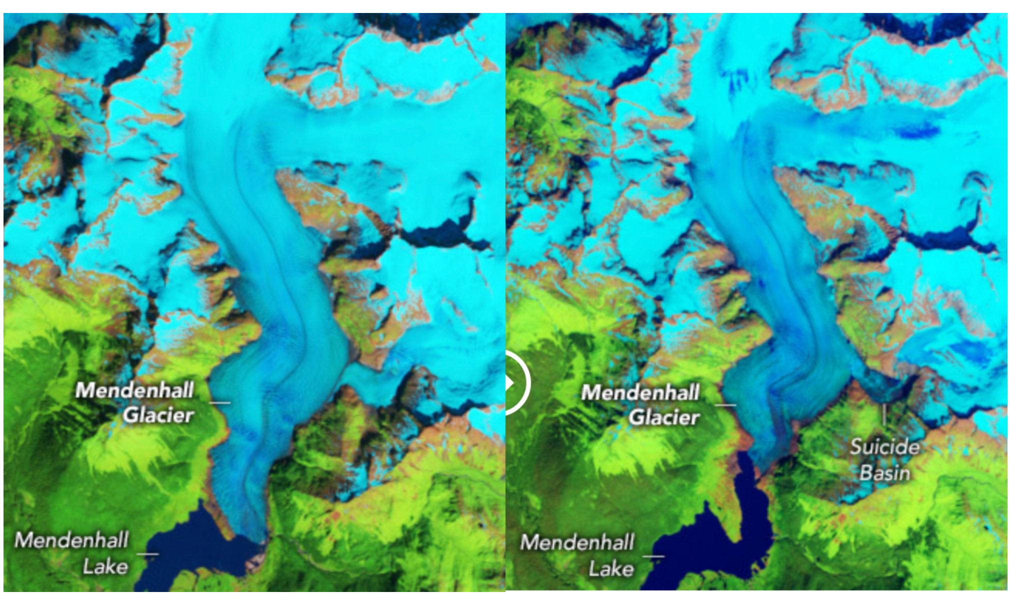


Figure 1: Volume Change of Mendenhall Glacier from August 17, 1984 to July 28, 2023

1.2 Problem Restatement and Analysis

- **Problem1:** Develop a model for a sustainable tourism industry that should meet the maximization of revenue, the maximization of environmental quality, and the maximization of social satisfaction, and conduct a sensitivity analysis on it.
- **Problem2:** Demonstrate how the model can be adapted to another tourist destination affected by overtourism, by obtaining relevant information from another city and analyzing it with the model.
- **Problem3:** Develop a model to address the issue of visitor diversion, which is also a measure to increase revenue and reduce regional pressure.
- **An article:** Write a memo to the Juneau Convention and Visitors Bureau, outlining the forecast of the results, the impact of various measures, and suggestions on how to optimize the results.

1.3 Our work

To avoid complicated description , intuitively reflect our work process, the flow chart is show as the following figure:

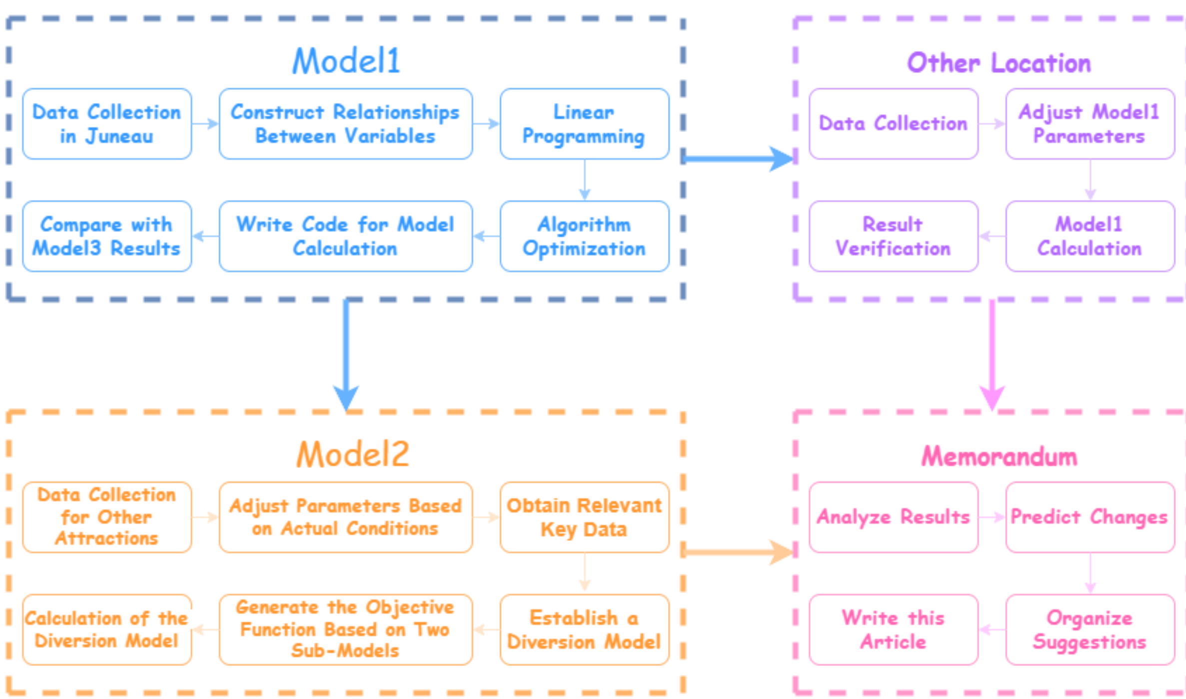


Figure 2: Flowchart of Work

2 Preparation of the Models

2.1 Assumptions

For Problem1:

- Assuming that the positive impact of tourist consumption will drive indirect effects such as job creation, which can be uniformly measured by tourist consumption. To simplify the model, only the most important factor for the economic impact of tourism, namely tourist consumption, is considered, and indirect economic impacts such as job creation brought about by the development of tourism are not taken into account.
- It is assumed that changes in tax rates within a reasonable range will not have a significant impact on tourist consumption and the number of tourists. This is because increasing taxes does not significantly affect the growth in the number of tourists, and at the same time, it takes into account the combined effect of reduced willingness to consume and increased tourist consumption due to tax increases.
- To simplify the model, it is assumed that the per capita consumption of tourists is a constant. Based on the analysis of data from recent years,[4] there has been no significant fluctuation in the per capita consumption of tourists, and it has not had a significant inhibitory effect on the number of tourists. It can be considered a constant when analyzing and optimizing for a shorter period of one year or several years.
- Considering the infrastructure pressure and its associated implicit costs and environmental pollution, based on resident survey reports and actual conditions,[5] the waste treatment system, which residents consider to be under the greatest pressure, and the water supply system, which is prone to stress, are chosen as representatives to measure implicit costs. It is assumed that the pressure conditions and trends of other aspects such as traffic pressure and energy supply are similar to these two, and their carrying capacities are used to measure them, ignoring their specific mathematical relationships in the model.
- It is assumed that expenditures can directly reflect in the carrying capacity and maximum carbon emissions, and enable their linear growth. To simplify the model and evaluation, considering the time-lag effect of investments on infrastructure and

other aspects in the current year, it is simplified into a linear function, and the immediate benefits of expenditures are adjusted by regulating the coefficients in front of them.

For Problem3:

- It is assumed that the cost consumption of publicity and the number of people that can be diverted have a linear relationship to facilitate the quantitative calculation of publicity costs.

2.2 Notations

The primary notations used in this paper are listed in the following Table.

Table 1: Notations

Symbol	Definition
R	Economic Development Index
R_e	Total tourism income
N_t	Number of tourists
N_{tmax}	Maximum number of tourists allowed per year
τ_t	Tax rate
P_t	Average spending per tourist
E	Environmental Pollution Index
CO_{2max}	Maximum allowed annual CO_2 emissions
CO_{2p}	Carbon emissions per person
C_{waste}	The number of annual tourists that the city's waste treatment system can accommodate.
C_{water}	The number of annual tourists that the city's drinking water supply system and water pollution treatment system can accommodate.
$S_{residents}$	Residential satisfaction
S	Social satisfaction
P_{waste}	Cities' investment in waste management
P_{water}	Cities' investment in water management
P_e	Cities' investment in environment management

Continued on next page

Table 1: Notations

Symbol	Definition
Z	Representation of target equation

3 Solution to Problem1

3.1 Establish a Sustainable Tourism Development Model

3.1.1 Identifying Relationships Between State Variables

Considering the needs of sustainable tourism development, we evaluate the comprehensive benefits of Juneau's tourism industry from three perspectives: environment, economy, and society. Environmental pollution index E, economic index R, and social satisfaction index S are set for the evaluation.

Our objective function should be influenced by income, social satisfaction and environmental quality. We aim to maximize economic effects and social satisfaction while minimizing environmental pollution. Therefore, the economic index R and social satisfaction index S have positive effects on the objective function, while the environmental pollution index has a negative inhibitory effect on the objective function. Finally, we obtain:

$$\text{Objective Function} : Z = R + S - E \tag{1}$$

We mainly measure tourism income through the total expenditure of tourists during their travels. Total tourism revenue is mainly affected by per capita consumption and the total number of tourists. To simplify the model, we assume that per capita consumption will not fluctuate significantly in the short term and is a constant value. Therefore, the total tourism revenue should have a simple linear relationship with the number of tourists, so we can easily obtain Function 2.

$$R_e(N_t, P_t) = P_t N_t \tag{2}$$

It should be noted that since most tourism taxes, such as hotel taxes and alcohol taxes, are hidden taxes that are directly reflected in consumption, we consider that the tax revenue obtained by the government from the tourism industry is included in the calculated revenue, which is obtained by converting from the revenue according to the proportion of total tax revenue.

Meanwhile, in order to perform mathematical operations with environmental and social indices in the objective function for benefit evaluation, we normalized the per capita income to eliminate dimensional differences to obtain the objective function.

$$R = R_e / R_{estandard} \tag{3}$$

Where $R_{estandard}$ is the theoretical maximum value set for income. We believe that due to the need for environmental protection and other factors, the economy will not grow too much in the short term. Therefore, we select a constant slightly higher than the highest annual income in the most recent year as the maximum income to perform normalization and obtain the economic index.

In terms of environmental quality, we mainly consider the impact of three factors: carbon dioxide emissions, water consumption, and waste generation, all of which are closely related to the number of tourists. For the carbon emission factor, we mainly consider the glacier melting problem in Juneau caused by excessive tourism. According to NASA data,[6] the Mendenhall Glacier melted approximately 1.6 kilometers between 1984-2023 over 40 years, with an average melting rate of 40 meters per year, and its melting speed needs to be controlled. We can use the **degree-day factor method** to estimate the glacier melting rate:

$$M = \mathrm{DDF} \times \mathrm{DDT} \tag{4}$$

Where **DDF** is the degree-day factor, which varies little and is close to constant, and **DDT** is the positive temperature sum, which is directly affected by temperature. To control the rate of glacier melting, the key is to control temperature rise, and carbon emissions are the main factor affecting temperature rise. According to the *Paris Agreement*, the average annual temperature rise between 1850-2100 should be controlled between 1.5-2.0 degrees, and we use 1.5 degrees as the maximum temperature rise to calculate the maximum carbon emissions.

$$\Delta T = \lambda \times \ln(\mathrm{CO}_2 / \mathrm{CO}_{2pre-industrial}) \tag{5}$$

According to this formula, we calculate the global average increase in carbon dioxide concentration, multiply it by atmospheric mass to obtain the total global carbon dioxide emissions over 250 years, and estimate Juneau's average annual emissions through its population proportion. Tourism is Juneau's largest industry, accounting for 60 percent of total emissions. Meanwhile, we calculate the maximum carbon emissions by adding the forest wetland area and average carbon absorption of Juneau. As for tourists' per capita carbon footprint, we considered that tourists mainly travel by cruise ships, which have relatively high carbon emissions, and estimated per capita carbon emissions by combining the average carbon emissions of cruise travel and tourists' onshore activities. Through Juneau's processing capacity for the latter two factors and the per capita consumption/-generation of tourists and residents, we can calculate the number of tourists that Juneau's water supply system and waste treatment system can accommodate annually, C_{waste} and C_{water}. We normalize the actual number of people compared to the carrying capacity to measure the pressure on the infrastructure system. Finally, combining the importance factors of each factor, we obtained Function 6:

$$E = k_1 \frac{\mathrm{CO}_{2p} N_t}{\mathrm{CO}_{2max}} + k_2 \frac{N_t}{C_{waste}} + k_3 \frac{N_t}{C_{water}} \tag{6}$$

Specifically, we believe that Juneau currently faces a relatively serious glacier melting problem and needs to control carbon emissions. Additionally, its waste treatment system has a smaller capacity compared to its water supply system, and population growth puts greater pressure on it. Therefore, we consider $k_1 > k_2 > k_3$.

Regarding social satisfaction, since tourist satisfaction has shown no significant changes in statistical data over a long time span, with overall satisfaction remaining around 99%, we believe that tourist satisfaction will not change significantly when factors like taxation are reasonable. Therefore, we mainly consider resident satisfaction. We primarily collected social satisfaction survey results from Juneau for five years: 1998, 2002, 2006, 2022, and 2023. After excluding invalid evaluations marked as "no impact" and "don't know," the remaining evaluations were categorized into five levels according to the Likert scale. We converted the data scoring to a 100-point scale. Additionally, we looked up the tourist numbers for these five years and performed data fitting with social satisfaction, obtaining the following results:

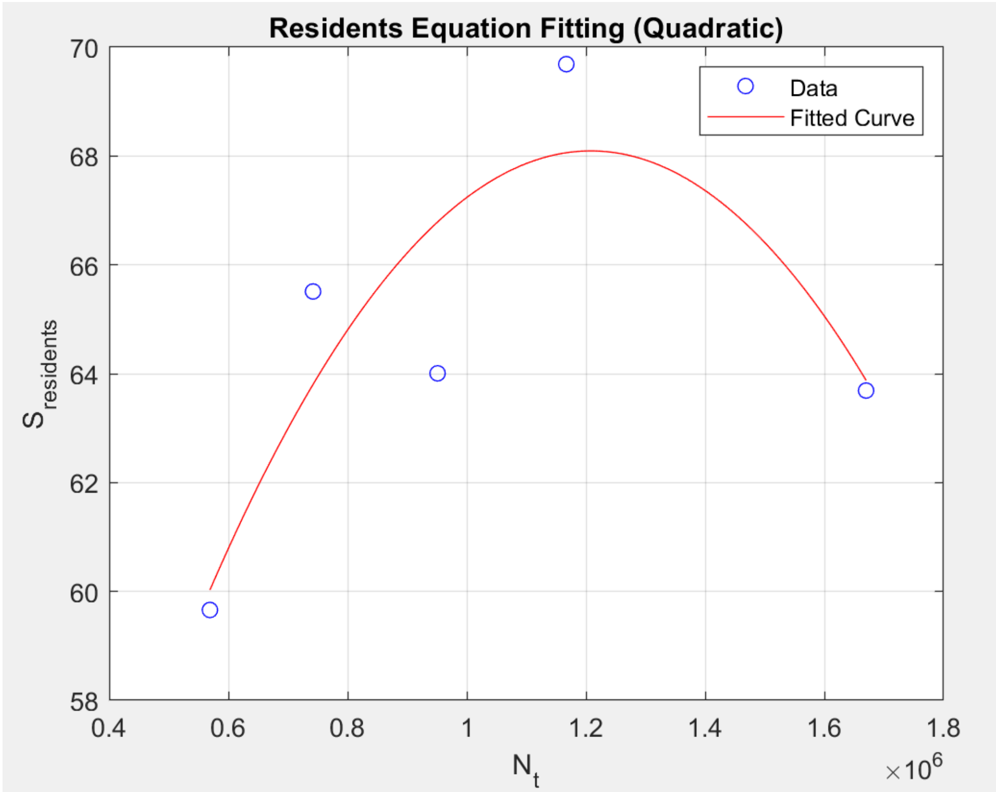


Figure 3: Nonlinear Fitting between N_t and $S_{residents}$

Where $a_1 = -1.9753\text{e}{-11}$, $a_2 = 4.772\text{e}{-5}$, $b = 39.2660$, $R^2 = 0.7423$. Finally, to eliminate the impact of dimensionality, we divided the satisfaction score by the maximum satisfaction value of 100 points. The resulting Function 7 is as follows:

$$\begin{cases} S_{residents} = a_1 N_t^2 + a_2 N_t + b_1 \\ S = S_{residents}/100 \end{cases} \tag{7}$$

In terms of additional investment, we considered the feedback effect of the government's tax allocation plan on the system. The government can invest in water supply systems, waste treatment systems, and environmental protection, such as infrastructure construction or increasing afforestation efforts, to improve the maximum carrying capacity of infrastructure and maximum carbon emissions, thereby obtaining higher returns. We believe that the government can adjust the proportion of investment in actual government allocation to maximize returns. The resulting Function 8 is as follows:

$$\begin{cases} P_{waste} = k_5 \tau_t R_e \\ P_{water} = k_6 \tau_t R_e \\ P_e = k_7 \tau_t R_e \\ k_5 + k_6 + k_7 \leqslant 0.4 \end{cases} \tag{8}$$

To simplify the model, we assume that investment can directly generate returns, and expenditures directly increase infrastructure carrying capacity or maximum carbon emissions at a certain ratio, in order to facilitate model decision-making.

$$\begin{cases} C_{waste} += \alpha_1 P_{waste} \\ C_{water} += \alpha_2 P_{water} \\ CO_{2max} += \alpha_3 P_e \end{cases} \tag{9}$$

3.1.2 Find the constraints

In terms of economics, to limit the tax rate value and ensure the accuracy of assumptions, we set a restriction that the overall tax rate should be less than or equal to 8%. Therefore, we have Formula 10:

$$\text{Financial}: \tau_t \leqslant 8\% \tag{10}$$

Regarding tourist numbers, based on Juneau's policy[7], we derived the daily tourist number limit. Function 11 is as follows:

$$\text{Touristic}: 0 \leqslant N_t \leqslant N_{tmax} \tag{11}$$

Regarding environmental aspects, first, we set a limit on the maximum carbon dioxide emissions. For the maximum carrying capacity of water resources and waste treatment, we considered that seasonal fluctuations in tourist numbers would lead to increased infrastructure pressure during peak seasons. Based on the data, we obtained the ratio of maximum daily tourist numbers during peak season to total annual tourist numbers. Taking into account the elasticity of infrastructure capacity within a year, we set 1.2 times the daily average carrying capacity as an upper limit to restrict the maximum daily number of tourists. Function 12 is as follows:

$$\text{Environmental}: \begin{cases} N_t \cdot CO_{2p} \leqslant CO_{2max} \\ 0.012 N_t \leqslant \frac{1.2}{365} C_{waste} \\ 0.012 N_t \leqslant \frac{1.2}{365} C_{water} \end{cases} \tag{12}$$

Regarding social satisfaction, after appropriate quantification, we set 60 as the passing threshold. Therefore, Function 13 is as follows:

$$\text{Social}: \; S_{residents} \geqslant 60 \tag{13}$$

3.1.3 Multi-start Optimization Algorithm

Since our model has five decision variables, namely N_t, τ_t, k_5, k_6 and k_7, which interact with each other and have varying degree of influence on the objective function. In order to achieve relatively optimal conditions for each decision variable locally and at the same time strive for the global objective to be optimal, such as maximizing tourism revenue, minimizing environmental impact, and maximizing resident satisfaction, etc., we use a multi-start optimization strategy to optimize the various influencing factors of the objective function. The pseudocode is as follows:

Algorithm 1 Multi-start Optimization Algorithm

```
Input: n_starts, Nmax
Output: best_result
/* Initialize variables */
best_result ← null
best_objective ← ∞
/* Generate starting points for each parameter */
Nt_starts ← linspace(100000, 0.8 × Nmax, n_starts)
τ_starts ← linspace(0.02, 0.07, n_starts)
k_starts ← linspace(0.05, 0.15, n_starts)
Define optimization bounds
/* Perform optimization from multiple starting points */
for i ← 0 to n_starts − 1 do
    /* Construct initial point */
    x0 ← [Nt_starts[i], τ_starts[i], k_starts[i], k_starts[i]]
    /* Minimize objective function */
    result ← minimize_function
    /* Update best result if better solution found */
    if result.success and result.objective < best_objective then
        best_objective ← result.objective
        best_result ← deepcopy(result)
    end if
end for
return best_result
```

The solution and output of the model: The model maximizes economic, environmental, and social benefits through multi-start optimization of five decision variables. In the initialization phase, the algorithm first sets up an empty optimal solution container and an infinite initial optimal objective value as the benchmark. Then, the algorithm generates multiple sets of different starting points within reasonable value ranges to ensure that the algorithm can explore a larger solution space. During the optimization loop phase, the algorithm performs a complete optimization attempt for each set of starting points. Each attempt uses the **Sequential Least Squares Quadratic Programming** (SLSQP) method to find the solution that optimizes the objective function, considering all constraints, such as visitor number limits, tax rate range, investment ratio restrictions, etc.). If an optimization attempt is successful and the resulting objective function value is better than the currently recorded optimal value, the optimal solution and objective value are updated. This process repeats until all starting points have been tested, and the globally optimal result is retained.

3.1.4 Calculation Results

Regarding total tourism revenue, based on historical data, we assign the value x to the average tourist expenditure. Through our calculations, we can determine that the annual number of tourists should be 1,431,579 people, with P_e being $4272,000,000,000. Looking at historical data, this figure appears relatively reasonable.

Regarding resident satisfaction, after inputting the number of tourists into the fitting equation, we obtain a resident satisfaction score of 67.18, which falls within our expected range.

Regarding environmental quality, through calculations, we obtained $k_5 = 0.179$, $k_6 = 0.113$, $k_7 = 0.108$. After substituting the number of tourists, CO_{2max}, C_{waste}, C_{water}, and N_t into the equation, we got a result of 0.4876, which falls within our expected range.

3.2 Sensitivity Analysis

Since we have used a multi-start optimization strategy, we use **Sobol Analysis** to simultaneously analyze the local sensitivity and global sensitivity of the input variables N_t, τ_t, k_5, k_6 and k_7. The pseudocode is as follows:

Algorithm 2 Sensitivity Analysis

1: **Input:** *n_samples*
2: **Output:** *Si* (result of Sobol Analysis)

/* Define problem structure */
Initialize problem dictionary:
    number of variables, variable names, variable bounds
/* Generate samples */
$param\_values = saltelli.sample(problem,\ n\_samples)$
/* Evaluate model for all samples */
Initialize empty array Y
for each parameter set X in $param\_values$ **do**
    Calculate objective function value for X
    Add result to array Y
end for
/* Normalize results */
$Y = (Y - minimum\ of\ Y)/(maximum\ of\ Y - minimum\ of\ Y)$
/* Perform Sobol Analysis */
$Si = sobol.analyze(problem,\ Y)$
Print results
Visualize results
return Si

The results are shown in the figure below:

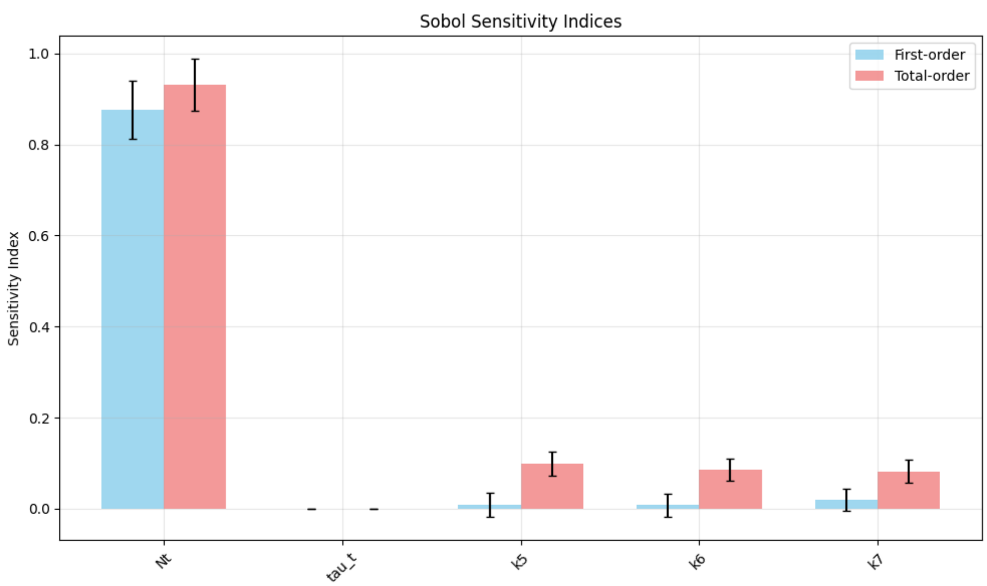
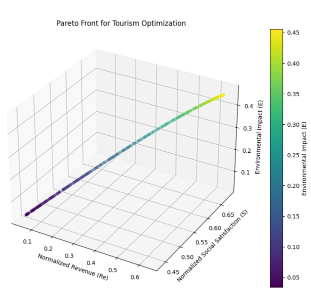


Figure 4: Sensitivity Analysis

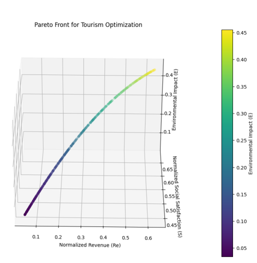
From the figure, it is clear that the number of tourists is the most critical variable, with its local and global sensitivities reaching 0.877 and 0.932, respectively, far greater than the other input variables. This also aligns with the objective fact that, as a tourist city, Juneau's income is heavily influenced by the number of tourists.

3.3 Model Validation

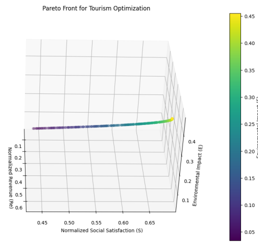
In Section 3.1, we used a multi-starting point hybrid optimization strategy to calculate our established sustainable tourism development model, and conducted sensitivity analysis in Section 3.2. Although our calculation results were relatively consistent with reality, we still raised some doubts about their accuracy. Therefore, we employed a multi-objective optimization strategy to recalculate the optimal conditions for the above model to verify the correctness of the multi-starting point hybrid optimization strategy in Section 3.1. Our optimization objectives remained maximizing income, minimizing environmental impact, and maximizing social satisfaction. In the new multi-objective optimization strategy, we used the **DEAP (Distributed Evolutionary Algorithms in Python)** framework to implement **NSGA-II (Non-dominated Sorting Genetic Algorithm II)**. We then used Pareto optimization to obtain a series of optimal conditions under this model, and based on requirements and actual situations, selected the final result range between 1,300,000 and 1,450,000. This result both met our expectations and corroborated the results from the multi-starting point hybrid optimization strategy in Section 3.1. Additionally, we also performed **Sobol sensitivity analysis** on the multi-objective optimization strategy algorithm, obtaining results that were very similar to those in Section 3.2, which further proved the correctness of both the multi-objective optimization strategy algorithm in Section 3.3 and the multi-starting point hybrid optimization strategy algorithm in Section 3.1. The figure shows the execution results of the multi-objective optimization strategy algorithm.



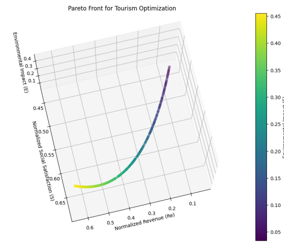
(a) Pareto Front 1



(b) Pareto Front 2



(a) Pareto Front 3



(b) Pareto Front 4

4 Solution to Problem2

To demonstrate how the model adapts to another destination affected by overtourism, after searching and collecting data, we decided to analyze the Jiuzhaigou Scenic Area in Sichuan Province, China.

4.1 Data Collection

Since each location has significantly different infrastructure pressures, per capita consumption, and other factors, we need to conduct data research and modify the corresponding parameters before we can use the current model for predictions.

Based on data collected from official websites[10], we can determine the relationship between Jiuzhaigou County's annual income and the Jiuzhaigou Scenic Area. However, due to the lack of satisfaction survey data and other related information on official websites, we made simple estimates of these values based on general public evaluations. By modifying relevant constraints such as per capita water consumption, per capita waste generation, carrying capacity for water resources and waste treatment, and average tourist spending levels, we can adapt the model to Jiuzhaigou's specific circumstances.

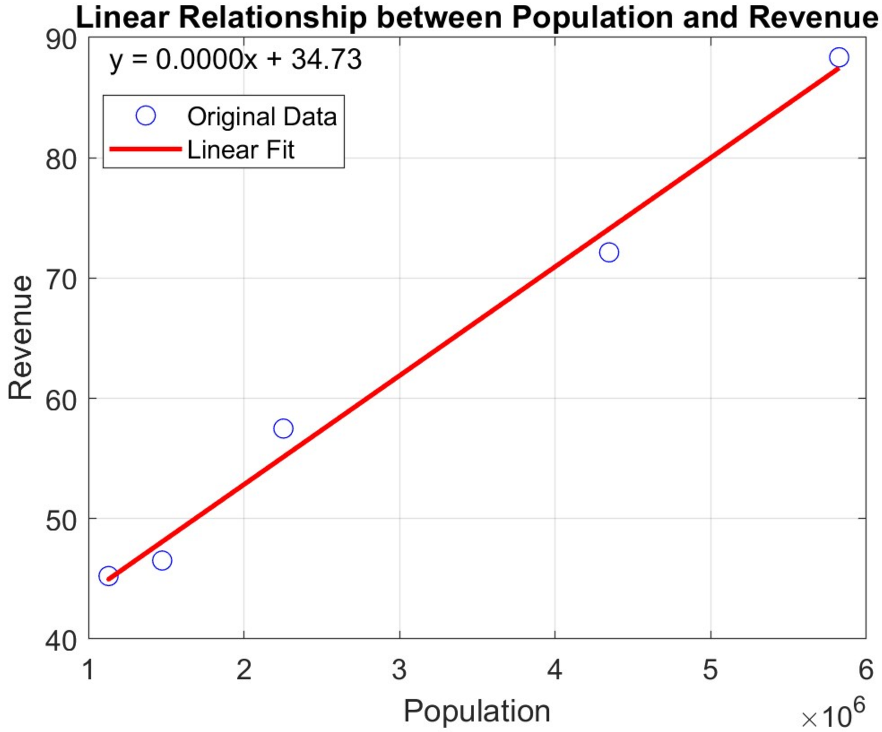


Figure 7: The Relationship between Tourism Revenue and Number of Visitors in Jiuzhaigou Scenic Area

4.2 Results

According to the optimal results from our model, N_t is 3,747,368, P_e is 2,248,421,052.70 yuan, $S_{residents}$ is 65.10, k_5 is 0.169, k_6 is 0.123, and k_7 is 0.108. These results are relatively reasonable when compared with data from previous years.

5 Solution to Problem3

5.1 Sustainable Development Models for Different Tourist Attractions

To manage visitor flow between different attractions, we need to obtain sustainable development models for each attraction to determine development strategies and calculate comprehensive benefits at specific tourist volumes. Therefore, we need to gather relevant data for each specific attraction. Because different attractions have varying environmental conditions, per capita consumption, infrastructure capacity, and other factors, the infrastructure pressure and social satisfaction caused by tourist numbers also vary greatly.

Thus, we need to modify the parameters of Model One to adapt to the actual situations of different attractions.

We mainly focus on analyzing two popular attractions in Juneau: the Mendenhall Glacier and the whale watching rainforest. Building upon Model One, we collected relevant data for whale watching activities, including annual visitor numbers and average tourist spending,[11] and adjusted the related parameters accordingly. Since tourists participating in whale watching activities mainly stay around Juneau, we consider the maximum carrying capacity of the whale watching site to be similar to that of Mendenhall Glacier. Additionally, as the whale watching program does not face severe environmental issues, we increased the maximum carbon emissions limit and the environmental investment return coefficient to better simulate actual conditions. We performed separate optimization calculations for both models to determine the optimal number of visitors, optimal tax revenue, and optimal expenditure allocation strategies. Then, we constructed a diversion model to optimize the actual distribution of visitors.

5.2 Establish a Flow-Distribution Model

Suppose there are n sub-models in the model, representing n specific attractions. The actual number of visitors for each model is N_{ti}, and the optimal number is N_{ei}. For attractions n_i where the actual number exceeds the optimal number, we want to divert the excess visitors to attractions n_j with fewer actual visitors, where $C_{i-j} = C_{pi-j} \times \Delta N_{i-j}$, representing that the total cost of this diversion equals the promotional cost of diverting one person from n_i to n_j multiplied by the number of people diverted. The total promotional cost is $C = \sum_{i,j} C_{i-j}$, Therefore, the decision variables are:

$$\Delta N_{i,j}(1 \leq i, j \leq n) \tag{14}$$

Objective function is:

$$Z = \sum_{i=1}^{n} Z_i(N_{ti}) - \frac{C}{C_{std}} \tag{15}$$

Where C_{std} is the estimated maximum promotional cost, used for normalization to remove the dimension of promotional expenditure.

5.3 Calculation Result

Taking Juneau's two attractions - Mendenhall Glacier and whale watching site - as an example to specifically demonstrate the results of the flow distribution model. We aim to divert tourists from Mendenhall Glacier to the whale watching site to reduce environmental pressure on the glacier. We first optimized the two sub-models separately, calculating the optimal number of visitors, tax rates, and expenditure allocation ratios, and used these as inputs to adjust the flow distribution model. Then we estimated the approximate promotional cost per person diverted and input this into the flow distribution model to complete its construction. Specifically, we used the **simulated annealing algorithm** to solve the model. By setting an initial temperature and controlling step size to simulate the cooling process of a solid, we sought to find the global optimal solution for the model. Through calculations, we determined that the optimal number of people to divert is around 329,888, with a diversion ratio of about twenty percent. Based on our model's results, the Juneau government could consider adopting better promotional strategies to achieve better overall benefits.

6 Strengths and weaknesses

6.1 Strengths

- The model takes into account the impacts from environmental, economic, and social aspects, and also considers the feedback effect of fiscal revenue redistribution on the model, achieving a more comprehensive modeling optimization.
- The multi-objective model has verified the optimization results of the single-objective model, ensuring the correctness and rationality of the objective function construction of the single-objective model, and ensuring the feasibility of the model.
- The model evaluates various indicators through commonly used and universal decision variables, demonstrating strong applicability. When changing locations, only a few key parameters need to be modified to adapt to the actual conditions of most areas and carry out optimization. For instance, it quantifies the environmental impact using carbon emissions instead of directly using the rate of glacier melting.
- The branching model has strong scalability, which allows for independent modeling of multiple adjacent scenic spots and subsequent optimization, not limited to a small number of scenic spots, and can optimize more reasonable results among multiple scenic spots.

6.2 weaknesses

- Some data have many defects and have not quantified the variables that have a great and complex impact, such as taxes and fees.
- The estimation of the return on fiscal investment is relatively simple, and it has not fully quantified the specific impacts caused by the time lag effect, etc.

Memorandum

To: City Government of City and Borough of Juneau
From: Team 2510625
Date: January 27th, 2025
Subject: Some Recommendations for the Government Regarding Tourism

As the tourism market continues to develop, Juneau, as the capital of Alaska, with its rich natural landscapes and unique cultural charm, has attracted a large number of tourists. To better understand tourism market development trends, evaluate the impact of various measures on the tourism market, and propose optimization recommendations, we have conducted in-depth market research and data analysis.

First, regarding tourism market predictions, based on our market research and data analysis, Juneau's tourism market is expected to show the following trends in the coming years: **Tourist Growth:** With the global economic recovery and improving living standards, the number of tourists visiting Juneau is expected to show steady growth in the coming years. In particular, there will be a significant increase in the number of tourists from Asia and Europe. **Tourism Season Changes:** Although summer remains Juneau's peak tourism season, the winter tourism market will gradually heat up as winter tourism activities continue to diversify, including activities such as dog sledding and ice fishing.

Second, regarding the impact of various measures, we analyzed a series of initiatives to promote Juneau's tourism market development, which have had the following effects: **Moderate Tax Rate Increase:** A moderate increase in tax rates will not significantly impact tourist numbers in the short term, while higher tax rates can increase tourism-generated revenue. The additional income can then be invested in infrastructure to improve water resource and waste treatment capacity. **Daily Tourist Number Restrictions:** Limiting daily visitor numbers helps alleviate infrastructure pressure and improve resident satisfaction. Additionally, if the restricted numbers are maintained at an optimal level, it can ensure daily revenue remains at a relatively high level.

Finally, here are some optimization recommendations: **Strengthen Tourism Infrastructure:** Continue to increase investment in tourism infrastructure, further improving conditions in accommodation, dining, and transportation. Particularly, increase infrastructure development in remote areas to improve tourism accessibility and convenience. This will help tourists visit more attractions and distribute pressure from popular individual sites. **Improve Tourism Service Quality:** Strengthen training for tourism industry employees to improve service quality and standards. Particularly focus on training tour guides, hotel staff, and other service personnel to enhance their professional qualities and service awareness. This can improve Juneau's tourism reputation and increase visitors' willingness to come. **Enhance Marketing and Promotion:** Continue marketing and promotional efforts in major domestic and international tourism markets to increase Juneau's visibility and reputation. This can be done through organizing tourism promotion events and participating in tourism exhibitions to promote Juneau's tourism resources and products to attract more tourists and stimulate tourist spending, thereby increasing average tourist expenditure levels.

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Appendix A: Report on Use of AI

1. **OpenAI *ChatGPT* (ChatGPT-4o)**
   Usage: For the purpose of gathering some ideas, assisting with formula generation, and helping with LaTeX generation.

2. **Anthropic *Claude* (Claude-3.5-sonnet)**
   Usage: Code and LaTeX code generation assistance.

3. **DeepSeek *deepseek* (deepseek R1)**
   Usage: Data and information collection.