

An MCM Paper Made by Team 2510625

Summary

Here is the abstract of our paper.

For Problem1, 通过数据分析, 我们发现游客人数、税率和基建投入占比对收入有影响。为此, 我们构建了一个综合收入、社会满意度和环境质量的目标函数, 并采用多起点优化算法寻找最优解。基于朱诺市的历史数据, 我们对社会满意度和游客人数进行了非线性拟合, 拟合可靠度为 0.7423。通过去量纲处理, 我们量化了社会满意度和环境质量对目标函数的影响。模型结果显示, 当游客人数为 1,431,579 人, 游客税率为 8%, 废物管理投入占比为 0.179, 水资源管理投入占比为 0.113, 环境保护投入占比为 0.108 时, 总收入达到 272 亿美元, CO₂ 排放量为 1,331,368.42 吨, 居民满意度为 67.18 (满分 100), 环境指数为 0.4876 (满分 1, 越小越好)。在敏感性分析中, 我们评估了变量的局部和全局敏感性, 发现游客人数是关键变量。最后, 我们使用种群迭代算法和帕累托优化对模型进行了验证。

For Problem2, 为了去适应另一个景点, 我们需要结合该景点的实际情况, 如游客人数, 游客人均消费, 当地的水资源和废物处理承载能力等因素来修改可持续旅游发展模型中的关键参数。在我们的文章中, 我们以位于中国四川省的九寨沟景区为例展示了修改模型的过程以及得到的相应结果并发现结果基本符合当地的客观情况。

For Problem3,

For the Memorandum, 基于上述的模型的结果的分析, 我们预测了之后游客数量可能会发生的变化并考虑了季节性因素, 分析了政府措施带来的影响, 并在最后提出了三点优化的建议。

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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]

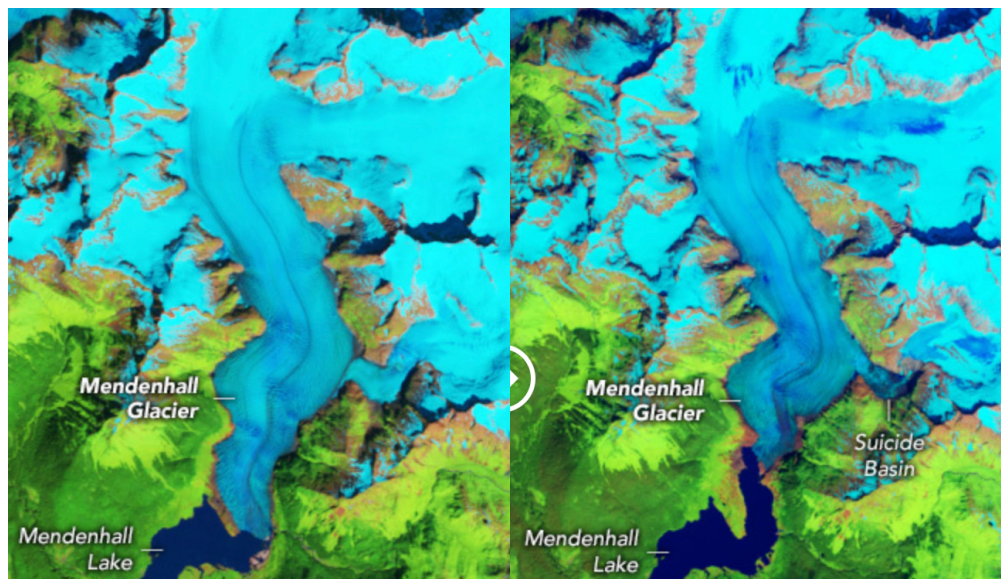


Figure 1: Volume Change of Mendenhall Glacier from August 17, 1984 to July 28, 2023

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:

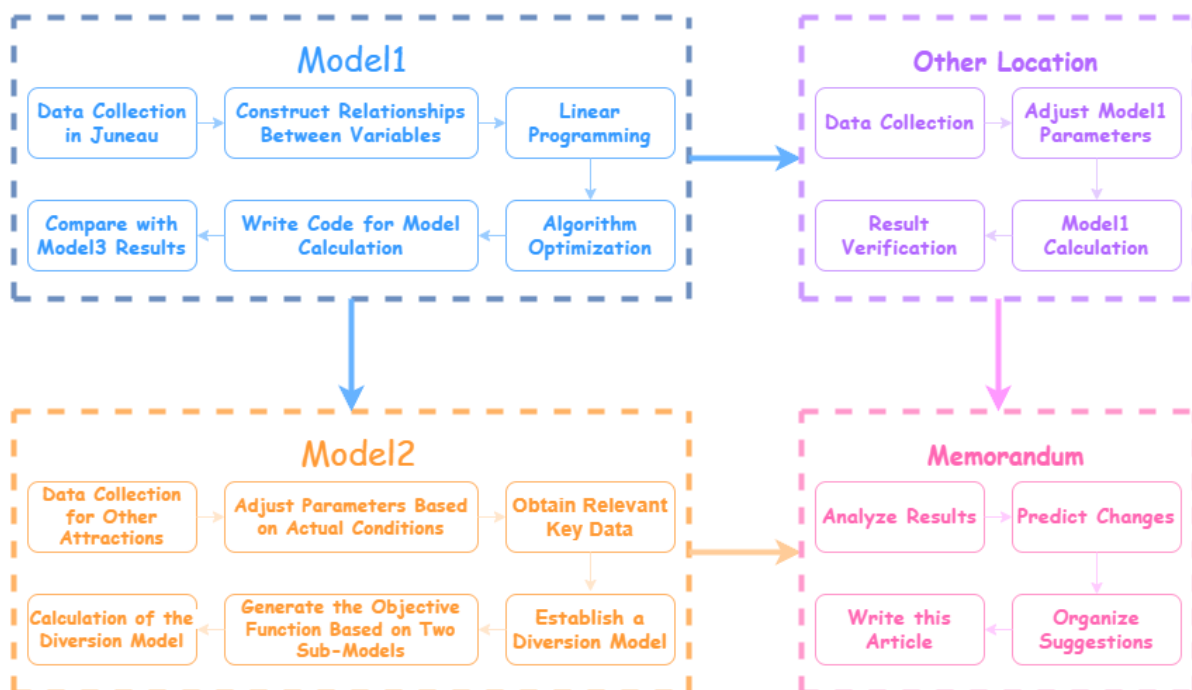


Figure 2: Flowchart of Work

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, 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, 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:

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

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.

$$R_e(N_t, P_t) = P_t N_t \quad (2)$$

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.

$$R = R_e / R_{\text{standard}} \quad (3)$$

Where R_{standard} 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, 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:

$$M = DDF \times DDT \quad (4)$$

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.

$$\Delta T = \lambda \times \ln(CO_2 / CO_{2\text{pre-industrial}}) \quad (5)$$

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 3:

$$E = k_1 \frac{CO_{2p} N_t}{CO_{2max}} + k_2 \frac{N_t}{C_{waste}} + k_3 \frac{N_t}{C_{water}} \quad (6)$$

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[4]. 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:

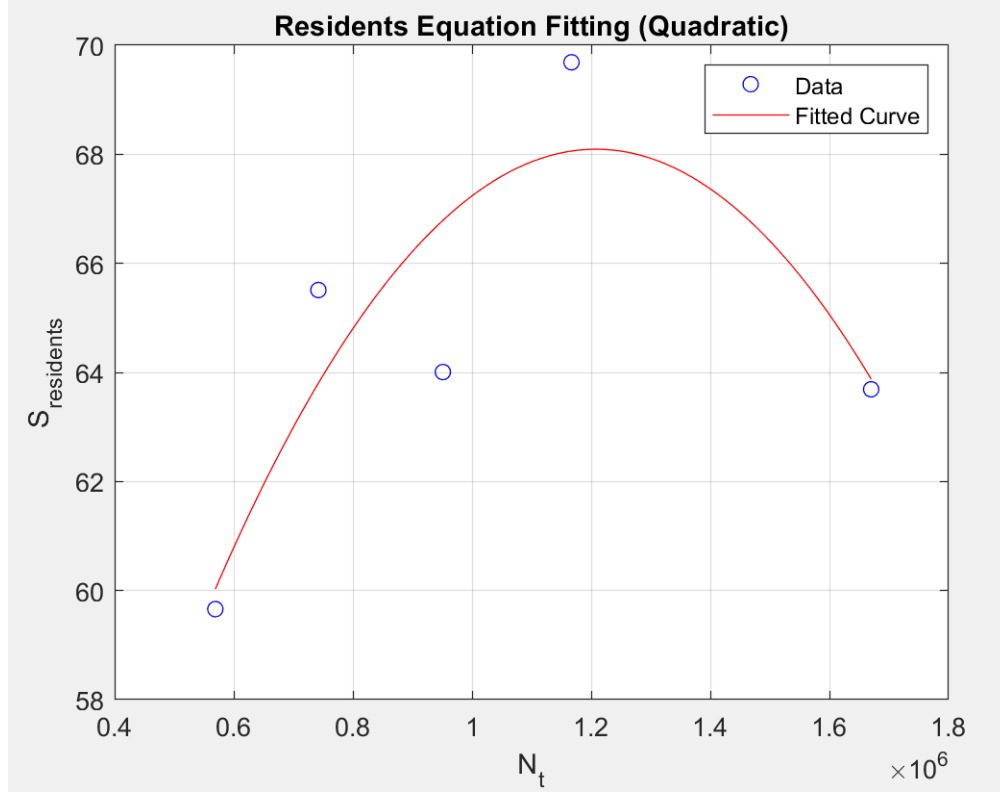


Figure 3: Nonlinear Fitting between N_t and $S_{residents}$

Where $a_1 = -1.9753e-11$, $a_2 = 4.772e-5$, $b = 39.2660$, $R^2 = 0.7423$. Finally, to eliminate the impact of dimensionality, we divided the satisfaction score by the maximum satisfaction value of 100 points. The resulting Function 4 is as follows:

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

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 5 is as follows:

$$\begin{cases} P_{waste} = k_5 \tau_t R_e \\ P_{water} = k_6 \tau_t R_e \\ P_e = k_7 \tau_t R_e \\ k_5 + k_6 + k_7 \leq 0.4 \end{cases} \quad (8)$$

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.

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

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 7:

$$\text{Financial} : \tau_t \leq 8\% \quad (10)$$

Regarding tourist numbers, based on Juneau's policy[?], we derived the daily tourist number limit. Function 8 is as follows:

$$\text{Touristic} : 0 \leq N_t \leq N_{tmax} \quad (11)$$

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 9 is as follows:

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

Regarding social satisfaction, after appropriate quantification, we set 60 as the passing threshold. Therefore, Function 10 is as follows:

$$\text{Social} : S_{residents} \geq 60 \quad (13)$$

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

```

1: Input:  $n\_starts$ ,  $Nmax$ 
2: Output:  $best\_result$ 

3: /* Initialize variables */
4:  $best\_result \leftarrow null$ 
5:  $best\_objective \leftarrow \infty$ 
6: /* Generate starting points for each parameter */
7:  $Nt\_starts \leftarrow linspace(100000, 0.8 \times Nmax, n\_starts)$ 
8:  $\tau\_starts \leftarrow linspace(0.02, 0.07, n\_starts)$ 
9:  $k\_starts \leftarrow linspace(0.05, 0.15, n\_starts)$ 

10: Define optimization bounds

11: /* Perform optimization from multiple starting points */
12: for  $i \leftarrow 0$  to  $n\_starts - 1$  do
13:   /* Construct initial point */
14:    $x0 \leftarrow [Nt\_starts[i], \tau\_starts[i], k\_starts[i], k\_starts[i]]$ 
15:   /* Minimize objective function */
16:    $result \leftarrow minimize\_function$ 
17:   /* Update best result if better solution found */
18:   if  $result.success$  and  $result.objective < best\_objective$  then
19:      $best\_objective \leftarrow result.objective$ 
20:      $best\_result \leftarrow deepcopy(result)$ 
21:   end if
22: end for

23: return  $best\_result$ 

```

The solution and output of the model: The model maximizes economic, environ-

mental, 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:** S_i (result of Sobol Analysis)

```

3: /* Define problem structure */
4: Initialize problem dictionary:
5:   number of variables, variable names, variable bounds
6: /* Generate samples */
7: param_values = saltelli.sample(problem, n_samples)
8: /* Evaluate model for all samples */
9: Initialize empty array Y
10: for each parameter set X in param_values do
11:   Calculate objective function value for X
12:   Add result to array Y
13: end for
14: /* Normalize results */
15:  $Y = (Y - \text{minimum of } Y) / (\text{maximum of } Y - \text{minimum of } Y)$ 
16: /* Perform Sobol Analysis */
17: Si = sobol.analyze(problem, Y)
18: Print results
19: Visualize results
20: return Si

```

The results are shown in the figure below:

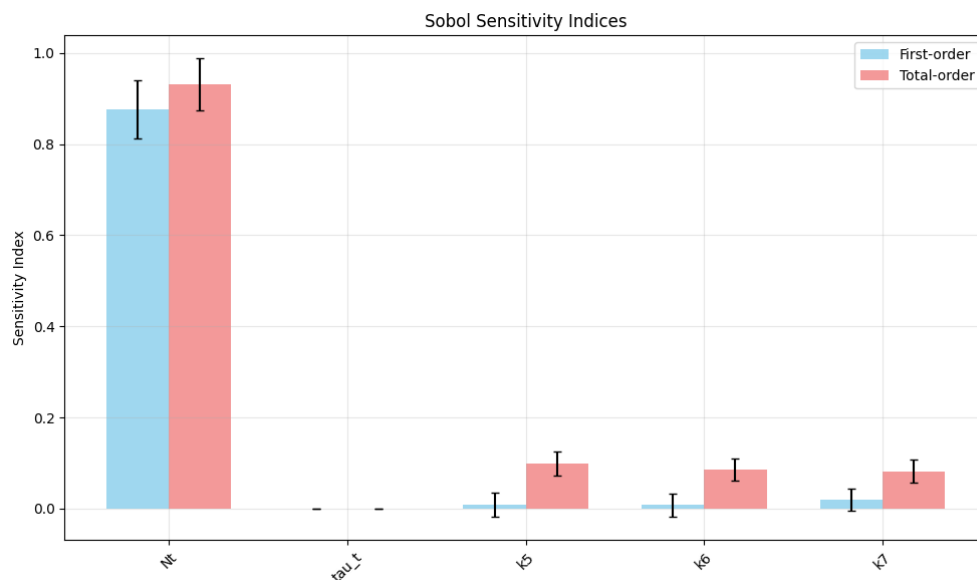


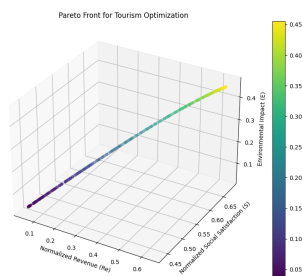
Figure 4: Sensitivity Analysis

From the figure, it is clear that the number of tourists is the most critical variable, with

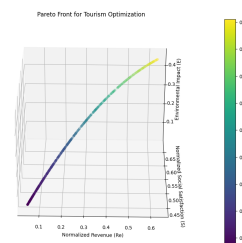
its local and global sensitivities reaching 0.877 and 0.932, respectively, far greater than the other input variables. This also aligns with the objective fact that, as a tourist city, Juneau's income is heavily influenced by the number of tourists.

3.3 Model Validation

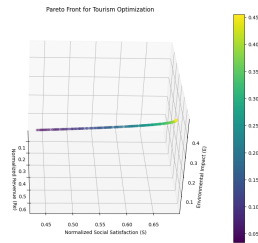
In Section 3.1, we used a multi-starting point hybrid optimization strategy to calculate our established sustainable tourism development model, and conducted sensitivity analysis in Section 3.2. Although our calculation results were relatively consistent with reality, we still raised some doubts about 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.



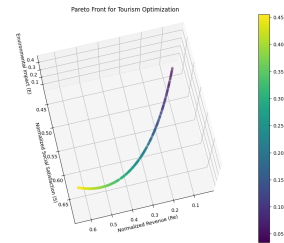
(a) Pareto Front 1



(b) Pareto Front 2



(a) Pareto Front 3



(b) Pareto Front 4

4 Solution to Problem2

为了展示模型是如何适应另一个受过度旅游影响的，我们经过数据的查找和收集决定选择位于中国四川省的九寨沟风景区来进行分析。

4.1 数据收集

因为每个地方的基础设施压力，人均消费等都大不相同，我们需要经过数据调研修改相应的参数后才能使用当前的模型进行预测。

通过对官网数据的收集 [6]，我们可以得出九寨沟县每年的收入和九寨沟风景区之间的关系。但是由于官方网站缺乏相应的满意度调查等信息，我们根据社会上的普遍评价对这些值进行了简单的估计，通过修改相应的限制条件，如水资源的人均消耗量，废物的人均产生量，水资源和废物处理的承载能力，游客人均消费水平，我们可以将模型适用于九寨沟的情况。

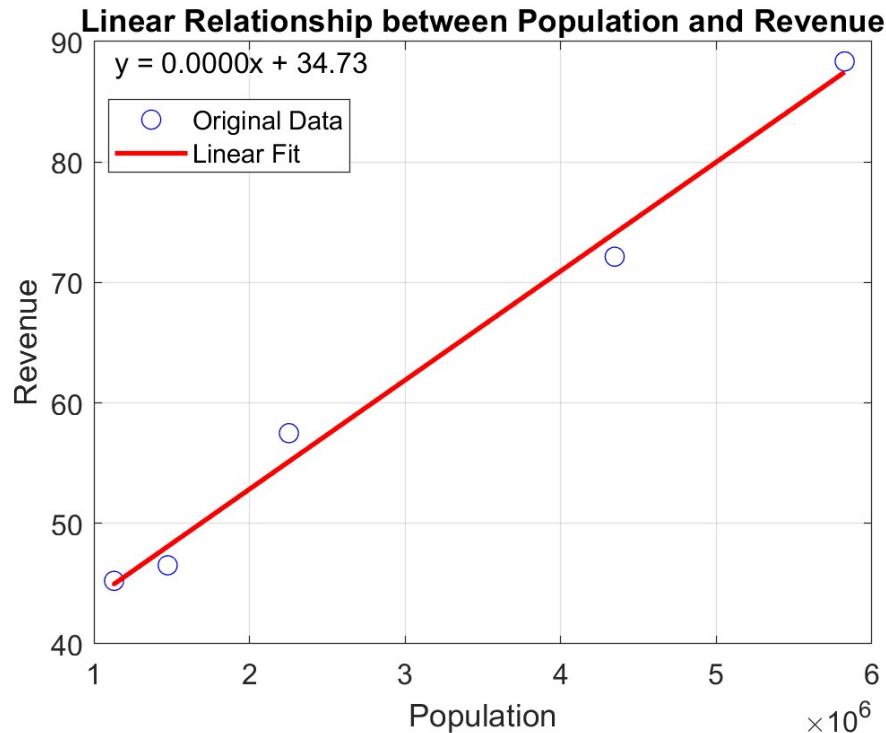


Figure 7: The Relationship between Tourism Revenue and Number of Visitors in Jiuzhaigou Scenic Area

4.2 结果展示

根据我们模型跑出来的最佳结果显示, N_t 为 3747368, P_e 为 2248421052.70 元, $S_{residents}$ 为 65.10, k_5 为 0.169, k_6 为 0.123, k_7 为 0.108。这些结果与往年数据相比较具有合理性。

5 Solution to Problem3

5.1 生成不同景点的可持续发展模型

为了进行不同景点之间分流, 我们需要获取各个景点的可持续发展模型以确定发展策略, 便于获取在某个实际游客数量下的综合收益。因此, 我们需要获得具体每个景点的相关数据。因为不同景点的环境条件、人均消费、基建承载量等不同, 游客人数导致的基建压力和社会满意度也大不相同, 所以我们需要修改模型一的参数以来适应不同景点的实际情况。

我们主要考虑对朱诺市的两个人们景点门登霍尔冰川和赏鲸雨林进行分析。在模型一的基础上, 我们搜集了赏鲸的相关数据, 包括赏鲸项目的年游客人数、平均游客消费等, 并对相关的参数进行了调整, 由于参与赏鲸景点的游客同样主要在朱诺市附近活动, 我们考

考虑赏鲸景点的最大承载量等与门登霍尔冰川的近似，同时，由于赏鲸项目并未面临很严重的环境问题，我们上调了最大碳排放量，以及环境投资的回报系数，以更好地模拟实际的情况。我们对两个模型分别进行了单独的优化计算，获取到了最优游客人数，最优税收以及最优的支出分配策略，接着，我们构建了分流模型以优化实际的分流人数。

5.2 建立分流模型

假设模型中有 n 个子模型，代表了具体的 n 个景点。每个模型中的实际人数为 N_{ti} ，最优人数为 N_{ei} 。对于实际人数大于最优人数的景点 n_i ，我们希望将超出最优人数的部分分流去实际人数较少的景点 n_j ，则 $C_{i-j} = C_{pi-j} * \Delta N_{i-j}$ ，代表此次分流的总成本等于将一个人从 n_i 分流到 n_j 的宣传成本乘以分流走的人数，则宣传成本总共为 $C = \sum_{i,j} C_{i-j}$ ，故决策变量为：

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

目标函数为：

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

其中， C_{std} 是估计的最大宣传成本，用于进行归一化去除宣传支出的量纲。

5.3 计算结果

这里以朱诺市两个景点门登霍尔冰川和赏鲸景点为例来具体展示分流模型的结果。我们希望将游客从门登霍尔冰川分流至赏鲸景点以减少冰川面临的环境压力，我们首先对两个子模型进行了分别的优化，计算出了最佳人数、税率与支出分配比例，并将其作为输入调整分流模型。紧接着我们估计了分流每人大致宣传成本，输入到分流模型中完成了模型的构建。具体的，我们采用模拟退火算法进行求解。通过设定一个初始温度，控制步长大小，模拟固体退温的过程，以求解模型的全局最优解。经过计算，我们得出分流人数在 329888 人左右最佳，分流比例达到在百分之二十左右。参考我们模型的结果，朱诺政府可以考虑采取更好的宣传策略，以获取更好的总体收益。

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.

参考文献

- [1] <https://abc7.com/post/juneau-alaska-cruise-ship-limits-overtourism/15048713/>
- [2] <https://juneau.org/wp-content/uploads/2024/01/CBJ-Cruise-Impacts-2023-Report-1.22.24.pdf>
- [3] <https://alaskapublic.org/2023/08/07/crammed-with-tourists-juneau-wonders-what-will-happen-as-mendenhall-glacier-recedes/>
- [4] *A simple, easy L^AT_EX template for MCM/ICM: EasyMCM.* (2018). Retrieved December 1, 2019, from <https://www.cnblogs.com/xjtu-blacksmith/p/easymcm.html>
- [5] <https://earthobservatory.nasa.gov/images/151682/alaskas-mendenhall-glacier>
- [6] <https://www.jiuzhai.com/news/number-of-tourists/>

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.