Sustainable Tourism Analysis Based on System Dynamics Model

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Abstract. In recent years, the global tourism industry has grown rapidly, but over-tourism has led to environmental degradation, increased pressure on infrastructure, and a decline in residents' quality of life. This paper takes Juneau, Alaska, USA as an example to build a model to balance the relationship between economic benefits, ecological protection and social equity, so as to promote tourism from simple "quantitative expansion" to "sustainable development" . In Requirement 1, we develop a system dynamics model which aims to achieve sustainable tourism and address the issues caused by over-tourism. The model optimizes tourism economic benefits, environmental quality, and residents' happiness, overcoming the limitations of single-objective approaches. By setting constraints such as maximum visitor numbers, minimum environmental quality and maximum taxes, the model ensures that indicators remain within reasonable limits, preventing negative impacts of over-tourism. Additionally, we develop **recursive** equations using dynamically linked variables (such as visitor numbers, environmental quality, and infrastructure) to simulate the complexity of the real system. To further optimize the outcomes, we also create a spending plan that allocates additional tax revenues to three core areas: environmental restoration, infrastructure upgrades, and community development projects. These spending plans directly influence environmental quality, residents' happiness, and economic gains through the dynamic equations in the model. Based on the above analysis, we use NSGA-II algorithm to solve the model and obtain the Pareto optimal solution.Finally, we conduct sensitivity analysis to identify the most critical factors under different objectives, ensuring the model's practicality and accuracy. Finally, we analyze the advantages and disadvantages of the model. The model's strength lies in its comprehensive consideration of multiple factors, enabling more accurate predictions in a dynamic environment, and its operability, offering personalized optimization solutions for different tourist destinations. However, the model also has limitations, such as its dependence on data quality and quantity, which could constrain its application in real-world scenarios.

Keywords: sustainable tourism; system dynamics model; NSGA-II algorithm; sensitivity analysis.

1. Introduction

1.1.Background

In recent years, the global tourism industry has shown explosive growth driven by economic growth and consumption upgrading. According to the World Travel and Tourism Council (WTTC), tourism has become one of the fastest growing sectors of the global economy. However, behind this prosperity lies a profound contradiction of sustainable development: the excessive expansion of tourism has an increasingly prominent negative impact on the ecological environment, infrastructure and residents' quality of life, which may even undermine its own economic benefits. The case of Juneau, Alaska is a typical example of this paradox.[1] As a tourist city which is known for its glacial landscape, Juneau welcomed 1.6 million cruise visitors in 2023, peaking at more than 20,000 in a single day. Although tourism brings in about $375 million in annual revenue, it simultaneously exacerbates multiple crises: From an environmental perspective, the iconic Mendenhall Glacier has shrunk by about eight standard football fields since 2007 due to climate warming, directly affecting the city's tourist attraction; From a social perspective, drinking water supply and sewage treatment systems have been overloaded for a long time, housing prices have soared due to tourism investment and short-term rentals, and residents' living costs and happiness have decreased significantly; From an economical perspective, the divergence of interests between industry practitioners and ordinary residents has intensified.[2] In fact, such conflicts are not unique to Juneau.

Cities such as Venice and Reykjavik that rely on natural or cultural heritage also face the challenge of "overtourism". The core problem is the natural conflict of multi-dimensional objectives. For example, limiting the number of tourists can alleviate ecological pressure, but may reduce short-term economic benefits; Higher environmental or hotel taxes can finance environmental restoration, but may discourage tourists. Although the development of alternative scenic spots can divert tourists, it requires additional infrastructure investment, further squeezing resident resources. This complexity requires the construction of a dynamic quantitative model, including variables such as tourist scale, economic benefits, environmental costs and residents' well-being into a unified framework, so as to coordinate the balance of interests between the industry and residents.[3] Juneau's dilemma reveals a universal proposition: In the process of tourism shifting from "scale expansion" to "sustainable development", how to achieve the synergy of economic benefits, ecological protection and social equity through scientific decision-making models? The answer to this question is not just about the fate of individual cities, but also provides a policy design template for destinations all over the world facing similar challenges.[4]

1.2.Restatement of the Problem

1. Clearly define the optimization objectives and constraints to ensure that the model can comprehensively consider the number of tourists, total income and stable tourism measures.
2. Develop a distribution plan for the additional tax revenue and analyze its feedback effect on sustainable tourism.
3. Carry out the sensitivity analysis of the model to quantify the degree of influence of different factors on the model objectives, find out the key variable that is most sensitive to the system stability, and provide the reason for policy priority

1.3.Our Work

We have established a system dynamics model to solve requirements 1 and 2 through different parameter conditions. The specific process is as follows:

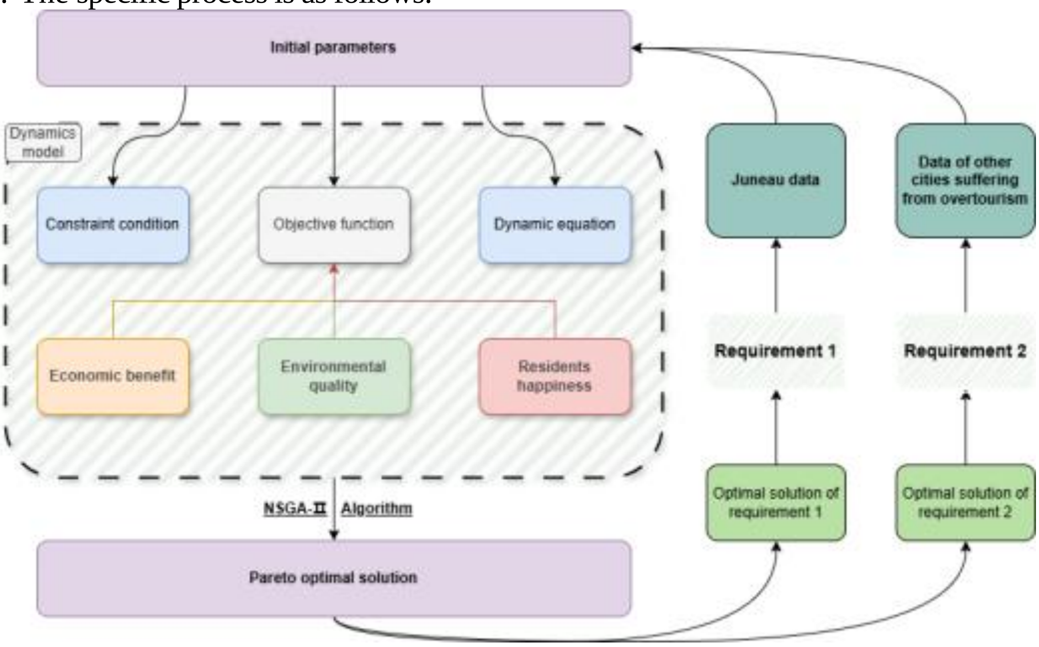

Figure 1. Flow chart of our work

2. Assumptions and Justifications

- Public Health Safety Assumption : Assume that no major infectious disease outbreak occurs dur- ing the study period.
- Natural Environment Stability Assumption**:** Assume that Juneau does not experience major natural disasters during the study period.

• Policy Continuity Assumption: Assume that the local government maintains basic continuity and stability in tourism policies during the forecast period.

• Neutrality of Technological Development Assumption: Assume that transportation and environmental monitoring technologies do not undergo disruptive innovations.

3. Notations

Table 1. Explanation of Key Symbols

Symbol	Definition
k	Per capita consumption
T	Maximum tax rate
N	Number of tourists
R	Economic benefit brought by tourists
H	Happiness index of residents
N0	Initial number of tourists in 2023
E	Environmental quality
E0	Initial environmental quality
Ebase	Baseline environmental quality
c	Per capita carbon emissions
I	Infrastructure level
I_0	Initial infrastructure level
M	NSGA-II population size
G	Maximum number of iterations
r_{2e}	Conversion rate from funds to environmental improvement
r_{2i}	Conversion rate from funds to infrastructure improvement
r_{2c}	Conversion rate from funds to community improvement

4. A sustainable tourism model

4.1.Modeling

Sustainable tourism not only focuses on environmental quality, but also needs to take into account multidimensional objectives such as economic gain and social well-being. However, there is a natural conflict between these objectives; for example, limiting the number of tourists to protect the ecological environment may reduce the economic income of local residents, and increasing the tax will also cause a decline in the willingness of tourists to travel, which will have a negative impact on the tourism

economy. At the same time, the number of tourists will also lead to an increase in the cost of living of the residents as well as a decrease in their sense of well-being, such as increasing urban congestion, housing costs, etc. This complex relationship makes the realization of sustainable tourism face many challenges. To simplify matters, here we focus on two typical groups: the industry and residents. The interests of these two are not entirely aligned: for the industry, the economic benefits of tourists are the most important concern, yet the average resident may be more concerned with issues such as the cost of living in the city.[5]

Figure 2. Connection between different factors

Based on the above analysis, we define two symbols R and H. Symbol R denotes the economic benefits brought by tourists, and symbol H represents the happiness of residents. R is positively correlated with the number of tourists: the more tourists there are, the higher the economic gains they bring. There are many factors affecting H, such as urban congestion, cost of living, and environmental factors, etc. The relationship between these factors and the number of tourists shows that an increase in the number of tourists leads to an increase in the degree of urban congestion and the cost of living, which in turn leads to a decrease in the sense of well-being.

Objective function The economic income brought by tourists is as important as the happiness of the residents, and the practice of considering only the economic income and neglecting the happiness of the residents is not recommended for sustainable tourism. Therefore we define the following objective function:

$$\int_{\infty} e^{-pt} [H + R] \, dt \tag{1}$$

where: t is the time period, and the integral represents the sum of net profits throughout all time periods from time 0 (today) to infinity. e^{-Pt} is a discount factor used to discount future returns or well-being to the present, indicating that the discount value of future profits decreases over time. P is the discount rate, which determines how much future returns are discounted relative to the current value.

Constraints Having defined the objective function, we need to consider the constraints faced in achieving sustainable tourism. These constraints reflect the complex relationship between economic, environmental and social well-being, as well as the different interests of the industry and residents.

Tourist capacity constraint: To ensure the effective utilization of urban tourism resources and to prevent excessive pressure on urban infrastructure and the environment, the government should strictly control the number of tourists within the city's carrying capacity to maintain order in urban tourism and enhance the visitor experience.

We use N_{max} to denote the maximum number of tourists and N to denote the number of visitors, so this constraint can be expressed as:

$$N < N_{max} \tag{2}$$

Environmental capacity protection constraint: in order to achieve long-term sustainable devel- opment of the tourism industry, it is necessary to ensure that the impact of tourism activities on the environment is kept to an acceptable minimum, and that the quality of the environment does not fall below a set minimum value throughout the time interval.

We use E to denote the environmental quality index, E_{min} denote the minimum, i.e. exceeding this limit will cause the environment to undergo irreversible deterioration, so this constraint can be expressed as:

$$E < E_{min} \tag{3}$$

Constraints on the rationality of additional tax policies: Adjustments to additional taxes should balance the need to promote tourism with the need to protect the economic interests of the population. The additional tax policy should not unduly discourage tourists from traveling so as not to affect the prosperity of the tourism industry.

The additional tax revenue, denoted by T, will be used to protect the environment, improve infrastructure, and develop community programs. We use T_e to denote the portion of the additional tax revenue that will be used to protect the environment, T_i to denote the portion of the additional tax revenue that will be used to improve infrastructure, and T_c to denote the portion of the additional tax revenue that will be used to develop community projects.

We use T to denote the specific rate of the tax ,T_{max} to denote the maximum limit of the additional tax, i.e. the limit beyond which would lead to a significant decrease in the willingness of tourists to travel, so that this constraint can be formulated as:

$$T = T_e + T_i + T_c < T_{max} \tag{4}$$

Based on the above objective function and constraints, the model can be expressed as:

$$\max \int_0^{\infty} e^{-Pt} [H + R]\, dt$$
$$\text{s.t.} \begin{cases} N \le N_{max} \\ E \ge E_{min} \\ T \le T_{max} \end{cases} \tag{5}$$

Dynamic equations: The above model is a formalized expression, and the specific mathematical forms of the parameters are as follows:

The dynamic equation on economic returns is:

$$R_{t+1} = N_{t+1} * k \tag{6}$$

Where: R_{t+1} and N_{t+1} are the residents' income and the number of tourists at the next moment, krepresents the per capita consumption of tourists. The formula indicates a positive linear relationship between income and the number of tourists: as the number of tourists increases, so does the income.

The equation on the happiness index of the population is:

$$H_{t+1} = T_c \cdot N_t \cdot k \cdot r2c - \frac{N_{t+1}}{I_{t+1}} \tag{7}$$

H_{t+1} represents the residents' happiness index at the next moment, which is determined by both a positive facilitating term and a negative inhibiting term. The first term establishes a positive relationship between community development investment and residents' well-being: T_c is the proportion of additional tax revenue allocated to community construction, N_t is the number of tourists at the current moment, k is the per capita consumption of tourists, and $T_c * N_t * k$ represents the funds used for community development projects. r2c reflects the efficiency of converting these funds into tangible well-being. The second term accounts for the negative impact of infrastructure strain caused by tourism expansion on residents' well-being. I_{t+1} denotes the state of infrastructure at the next moment, and N_{t+1}/I_{t+1} is the ratio of tourists to the infrastructure's maximum capacity, quantifying the mismatch between tourist numbers and infrastructure capacity. A larger ratio indicates more severe negative externalities, such as overcrowding and resource competition.

Tourist number equation:

Subject to the constraints, we establish the dynamic equation for the number of tourists as:

$$N_{t+1} = \min\left(N_{\max}, N_t \cdot \frac{E_t}{E_{\text{base}}} \cdot \left(1 - \frac{T}{T_{\max}}\right)\right) \tag{8}$$

Where N_{t+1} denotes the number of tourists at the next moment, N_{max} represents the maximum number of tourists limit, E_{base} is the base environmental index below which the attractiveness of the site to tourists decreases, leading to a reduction in the number of tourists, E_t is the current environmental index, and T_{max} is the maximum additional tax revenue.

The model formula reveals the dynamic coupling mechanism between environmental quality and tourist flow: when the environmental quality index exceeds the baseline threshold, it will generate a tourist gravitational effect, forming a positive growth in tourism scale; conversely, it will trigger a tourist avoidance response, leading to a negative decline in passenger flow. At the same time, the

environmental regulation tax variable introduced in the model has continuous damping characteristics, and its levy intensity will continue to produce the inhibition of passenger flow.

Environmental quality equation:

The dynamic equation on the environmental index is:

$$E_{t+1} = E_t + r_{2e} \cdot T_e \cdot N_t \cdot k - c \cdot N_t \tag{9}$$

Where E_{t+1} represents the environmental index atthe next moment, T_e isthe proportion of additional tax revenue allocated to environmental remediation, and $T_e * N_t * k$ represents the specific funds used for environmental remediation projects. r_{2e} is the environmental remediation conversion rate, reflecting the efficiency with which funds are transformed into actual environmental improvements. c is the coefficient that measures the impact of per capita carbon emissions on the environment.

Infrastructure equation:

The level of infrastructure development is a key indicator of a region's ability to provide public services, and its assessment dimensions include elements such as the degree of security of potable water supply, the efficacy of waste treatment, the level of housing supply and cost control, and the degree of spatial saturation (e.g., the degree of overcrowding). The evolution of the system follows the dynamic equation:

$$I_{t+1} = I_t + r_{2i} \cdot N_t \cdot T_i \cdot k \tag{10}$$

where the investment efficiency coefficient r_{2i} characterizes the parameter of the ability of fiscal inputs to translate into actual construction effectiveness, and T_i represents the budgetary allocation of additional tax revenues directed to infrastructure development. An increase in the level of infrastructure will directly enhance the amount of public service resources per unit of population (including permanent residents and mobile tourists).

In summary, the Multi-Objective Sustainable Tourism Dynamic Optimization Model can be expressed as:

$$\max \sum_{t=0}^{\infty} e^{-\rho t} \left(H_t + R_t\right)$$

$$\text{s.t.} \begin{cases} N \leq N_{max}, \\ E \geq \\ T \leq T_{max}, \\ R_{t+1} = N_{t+1} \cdot k, \\ H_{t+1} = T_c \cdot N_t \cdot k \cdot r2c - \dfrac{N_{t+1}}{I_{t+1}}, \\ N_{t+1} = \min\left(N_{\max},\ N_t \cdot \dfrac{E_t}{E_{\text{base}}} \cdot \left(1 - \dfrac{T_t}{T_{\max}}\right)\right), \\ E_{t+1} = E_t + r2e \cdot T_e \cdot N_t \cdot k - c \cdot N_t, \\ I_{t+1} = I_t + r2i \cdot T_i \cdot N_t \cdot k. \end{cases} \tag{11}$$

4.2.Model Solving

Model parameter acquisition

To establish a reasonable model, we base our analysis on the following data:

1. Per capita spending (k): In 2023, the city hosted 1.6 million cruise passengers, generating a total revenue of approximately $375 million. This gives

$$k = \frac{375,000,000}{1,600,000} = 234.38.$$

2. Maximum tax rate (T): The maximum tax rate is set as T = 50.

3. Number of tourists (N): The total number of tourists in 2023 is N_0 = 1, 670, 000.[6]

4. Environmental quality (E): The initial environmental quality is E_0 = 1000, with the baseline environmental quality E_{base} = 500.

5. Per capita carbon emissions (c): The glacier has retreated 800 meters, equivalent to 8 football fields. Over the years, a total of 17, 013, 400 tourists contributed to this change. Thus, the per capita impact on the environment is calculated as[6]

$$c = \frac{800}{17,013,400} \approx 0.000047.$$

6. Infrastructure level (I): The initial infrastructure level is set as I_0 = 2, 000, 000.

7. Money-to-environment conversion rate (r2e): $r2e$ = 0.0000005.

8. Money-to-infrastructure conversion rate (r2i): $r2i$ = 0.0001.

9. Money-to-community conversion rate (r2c): $r2c$ = 0.001.

Algorithm

In this model, we need to maximize the three objectives H, R, and E. We choose theNSGA-II algorithm to solve the model. The NSGA-II algorithm is a multi-objective optimization algorithm based on non-dominated sorting, which finds the optimal solutions for multiple objectives by simulating the process of natural selection. The algorithm first performs non-dominated sorting on the population, dividing the population into different front layers, with individuals in each front layer being non-dominated by each other in multiple objectives. Then, the algorithm maintains the diversity of the population through crowding distance, avoiding the concentration of solutions in local areas. Through iterative evolution, the NSGA-II algorithm can effectively explore the solution space and find a set of Pareto optimal solutions, thereby providing a comprehensive solution to the multi-objective optimization problem of the model. The detailed algorithm steps are shown in Algorithm 1 below.

Here are some details about using the NSGA-II algorithm to solve the model.

Algorithm 1: Optimization of Sustainable Tourism Strategies Based on NSGA-II

Input: M: population size (e.g., 50), G: maximum number of iterations (e.g., 1000), objective functions: maximize residents' happiness index H and economic income R, constraints: environmental index $E_t \geq E_{min}$, number of tourists $N_t \leq N_{max}$, tax rate distribution $T_e + T_i + T_c = T_{max}$

Output: Set of Pareto optimal solutions (set of tax allocation schemes) for sustainable tourism strategies **Initialization**:

- $t \leftarrow 1$
- Initialize the population $p_t = \{p_1, \ldots, p_M\}$, where each individual $p_i = (T_e, T_i, T_c, N_{max})$ satisfies $T_e + T_i + T_c = T_{max}$

Main Loop: **while** $t < G$ **do**

Generate offspring population Q_t:

- **Selection**: Use binary tournaments to select parent individuals based on non-dominated ordering and crowding distance.
- **Crossover**: Perform simulated binary crossover (SBX) on selected parents to generate offspring. Renormalize tax components after crossover to ensure $T_e + T_i + T_c = T_{max}$.
- **Variation**: Apply polynomial variation to the offspring, adjusting the tax components and finally renormalizing them.

Merged population: Merge parent p and child Q_t into R_t with total size 2M.

Non-dominated sorting:

- Perform fast non-dominated sorting on all individuals in R_t to obtain the hierarchical set $F = \{F_1, F_2, \ldots\}$, where F_1 is the non-dominated frontier.

Crowding distance calculation:

- Calculate the crowding distance for individuals within each frontier F_i to measure the distribution density of the solution in the target space.

Select new population p_{t+1}:

- Populate p_{t+1} by priority:
  - Prioritize frontiers with higher non-dominated hierarchies (e.g., F_1 is preferred over F_2).
  - Select individuals with greater crowding distances within the same frontier to maintain diversity.
- Continue until p_{t+1} reaches M individuals.

$t \leftarrow t + 1$

Termination:

- Output the final Pareto front F_1 as the optimal solution set.

1.Objective Function Calculation: For each individual p_i, the dynamic simulation model is run to compute the long-run discounted sum of H and R. Individuals that violate the constraint (e.g., $E_t < E_{min}$) are penalized with a term that reduces their fitness.

2. Non-Dominated Sorting Rules: A solution x dominates another solution y if and only if $H(x) \geq H(y)$ and $R(x) \geq R(y)$, with at least one of the objectives being strictly preferable.

3. Constraint Handling: During non-dominated ordering, priority is given to solutions that satisfy all constraints. Solutions that violate constraints are assigned to a lower non-dominated hierarchy.

4. Crossover and Variation Design: The crossover operation involves performing SBX crossover on the tax components (T_e, T_i, T_c), followed by scaling to ensure their sum equals T_{max}. For variation, a tax rate component is randomly perturbed, and the other components are adjusted to maintain a constant total sum.

4.3.Model Results

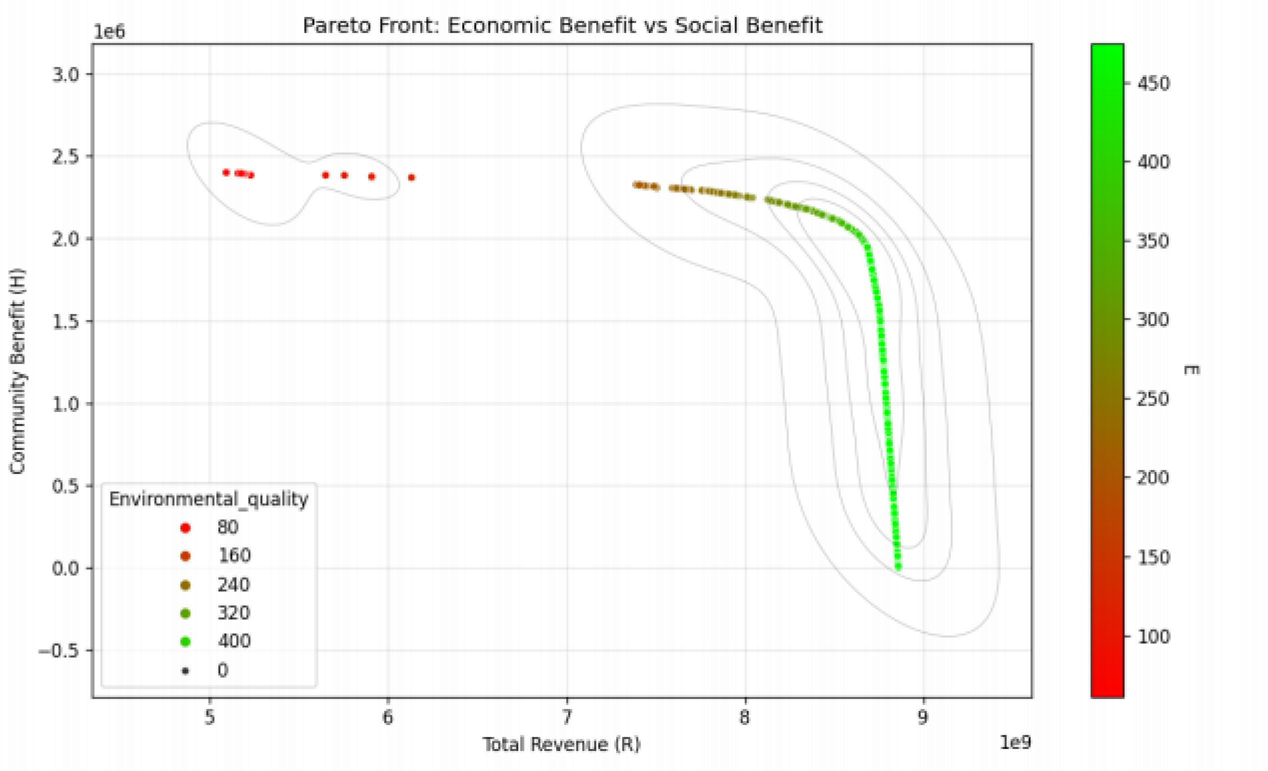

Figure 3. Pareto optimal solution visualization

Analysis of results: The results are shown in the figure 3, where the horizontal coordinate indicates economic income, the vertical coordinate indicates residents' happiness, and the color indicates the environmental quality index, with the greener representing the better environment.

The model results show that when the additional tax reaches 45.66 % and the maximum number of tourists per year is limited to 2, 000, 000, a better solution will be obtained. This solution can get a good result of both economic income and residents' well-being without excessive impact on the environment.

As shown in the figure 4: the model results show that, under the condition of keeping the total amount of tax revenue constant, the increase in the proportion of financial investment dedicated to environmental restoration will significantly improve the quality of the regional ecological environment (e.g., the environmental index will be increased by 20%-30%), which will lead to a significant increase in the economic benefits of tourism through the enhancement of the tourism attractiveness index (the size of tourists will increase by 15%-25%) (the marginal benefit is up to 1:5.8). However, the resulting pressure of tourist overload (12%-18% decline in infrastructure) and structural adjustment of public service investment (40%-60% reduction in the proportion of infrastructure and community development funds) will lead to a marginal reduction in the comfort of residents (22%-35% decline in the happiness index), resulting in an imbalance in the allocation of resources between ecological benefits and people's well-being.

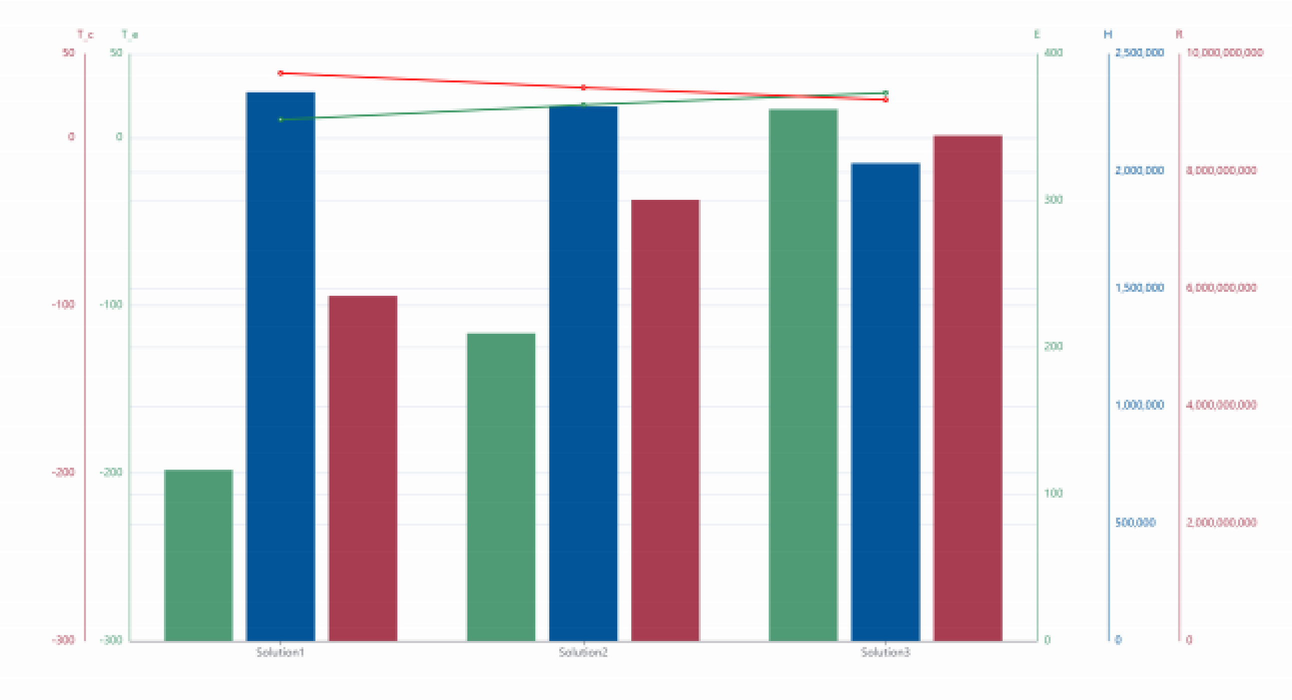

Figure 4. Increase the special revenue for environmental restoration

As shown in the figure 5, an increase in the proportion of funds dedicated to community development (e.g., from 30% to 50% of total tax revenues) can significantly improve the well-being of the population (marginal growth in well-being of 18%-25%), provided that the total amount of tax revenues is kept constant. However, the resulting compression of the environmental restoration budget (40%-60% reduction in the proportion of environmental protection investment) will lead to a decline in regional ecological quality (12%-15% annual average decline in the environmental index), which will weaken the attractiveness index of the tourist destination (20%-30% reduction in the scale of tourists), and ultimately lead to significant negative fluctuations in the economic returns of tourism (marginal loss of return coefficient of 1: 4.2). 4.2). This dynamic process reveals a resource substitution law between social welfare improvement and ecological capital depletion.

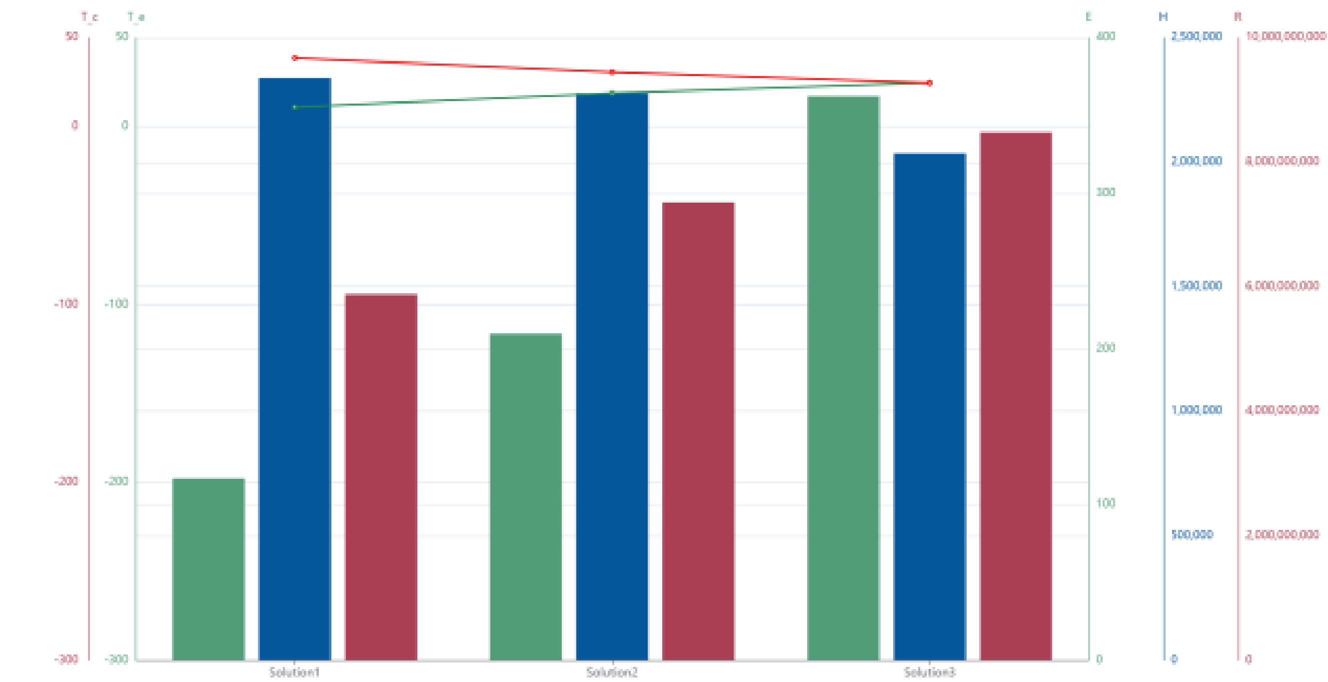

Figure 5. Increase the special revenue for community development

Plans for spending out of the additional revenue: a comprehensive analysis of the results shows that when the total tax revenue is close to the tax threshold and the proportion of the tax revenue used for environmental restoration is more than 50% and the proportion of the tax revenue used for the development of community projects is more than 45%, the quality of the environment, the happiness index of the residents, and the economic income generated by tourism reach the optimal value. When the above tax policy and tax allocation ratio are adopted, the environmental restoration capacity reaches its peak, ensuring that the environmental quality (e.g., glacier area, etc.) will not deteriorate; the happiness index of the residents increases, the economic income from tourism increases, the improvement of the infrastructure and community projects can effectively reduce the protest sentiment of the residents and increase the sense of well-being; and at the same time it can ensure that the number of tourists is within a reasonable range that can bring the maximum economic income.

4.4.Sensitivity Analysis

Parameter Selection

Select the key parameters, including the environmental restoration conversion rate (r2e), infrastructure conversion rate (r2i), community investment conversion rate (r2c), carbon emission coefficient (c), per capita tourist consumption (k), maximum tax rate (T), maximum number of tourists (N_{max}), initial number of tourists (N0), initial environmental quality (E0), and initial infrastructure level (I_0).

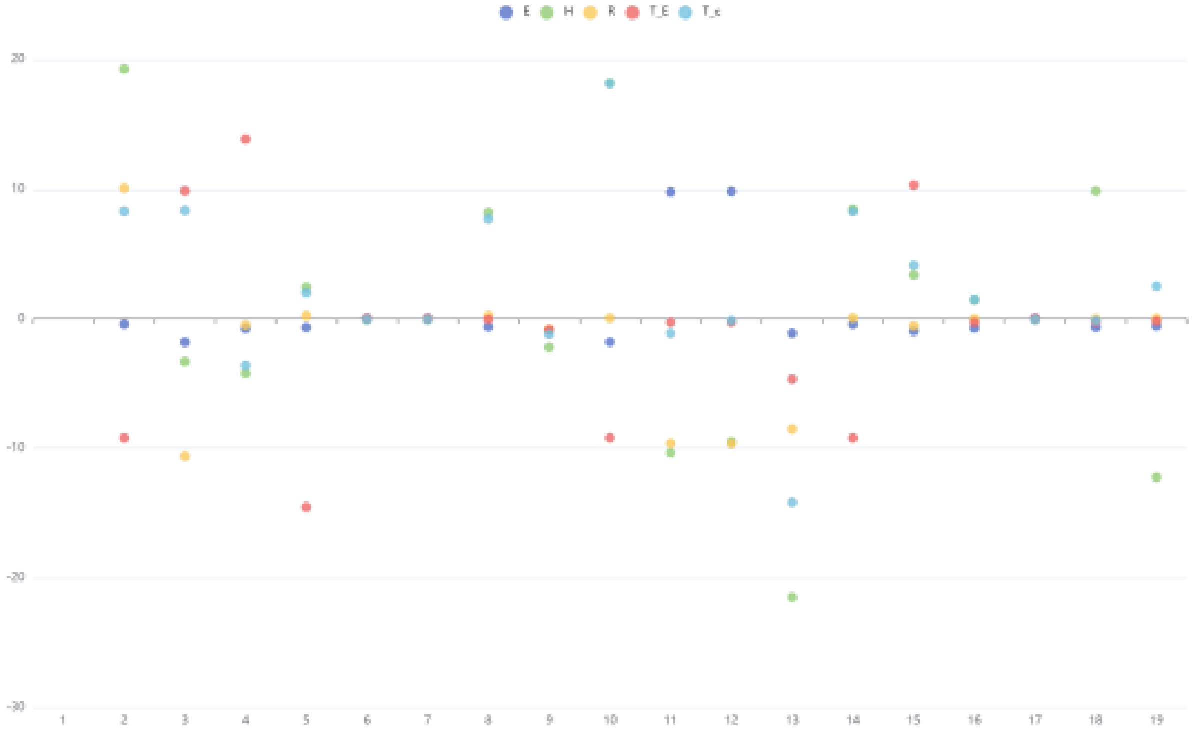

Figure 6. Sensitivity analysis result

Each parameter is adjusted by ±10 % from its baseline value, while keeping other parameters constant, and the adjusted objective function values are calculated.

Analysis results

The Fig 6 x-axis represents the changes in different parameters, while the y-axis shows the rate of change in the optimal solution. Different colors correspond to different result metrics. From the chart, we can observe that per capita carbon emissions affect the proportion of the environmental tax, while an increase in per capita tourist consumption boosts residents' happiness. Changes in other parameters have a minimal effect on the environment, indicating that our model ultimately leads to a sustainable development outcome.

The Fig 7 is a radar chart, where each dimension represents an indicator. By analyzing each dimension, we can identify the key factors influencing the objective function. The key factors affecting environmental quality are the initial environmental quality and the initial infrastructure level, as changes in these two cause noticeable fluctuations in environmental quality. The key factors affecting residents' happiness, in descending order, are: initial infrastructure level, initial environmental quality, per capita carbon emissions of tourists, and per capita tourist consumption. Fluctuations in these key factors cause significant changes in residents' happiness (H). The key factor influencing economic benefit is per capita tourist consumption, which is positively correlated with (R), as can be seen from its definition.

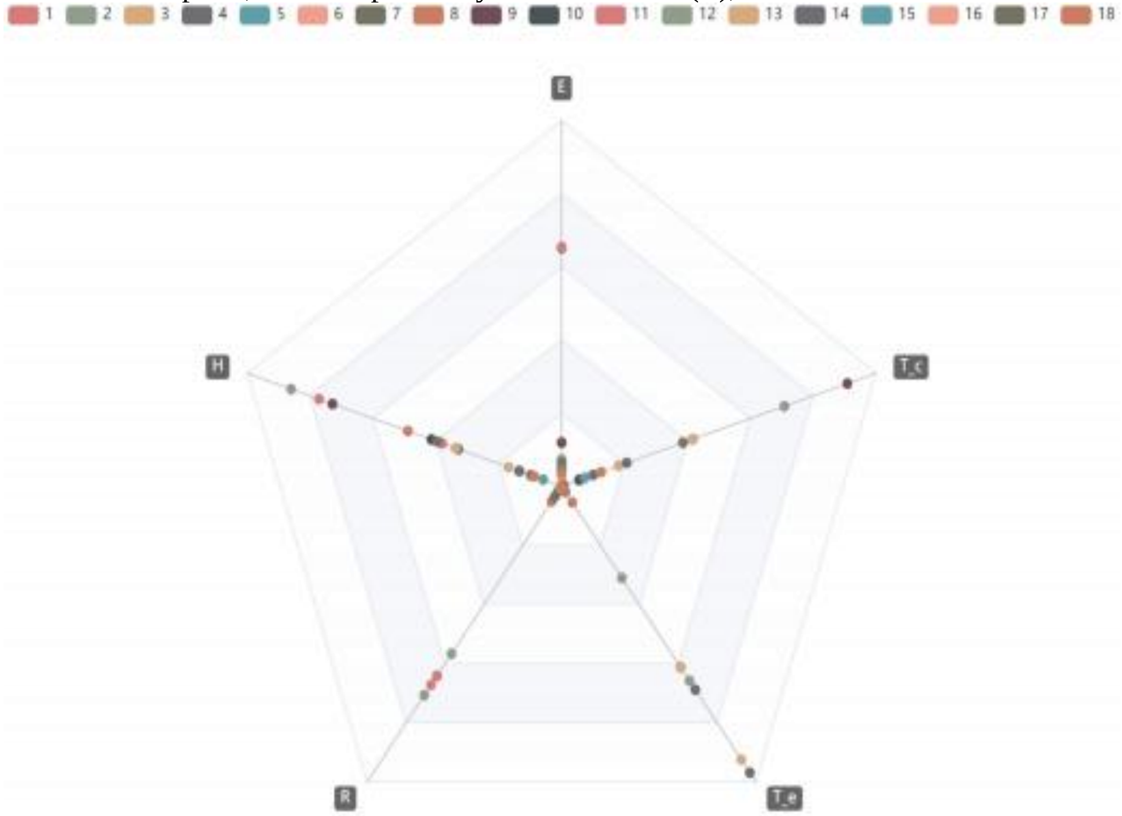

Figure 7. Key factors influencing the objective function

5. Strengths and Weaknesses

5.1.Strengths

• Our model simultaneously optimizes tourism economic benefits, environmental quality, and residents' happiness, avoiding the limitations of a single objective approach. Sustainable tourism not only includes environmental sustainability but also economic and social sustainability.

• Our model simulates the complexity of the formal system by dynamically interrelating variables such as tourist numbers, environmental quality, and infrastructure.

• By adjusting parameters like environmental baseline values, carbon emission coefficients, and infrastructure conversion rates, the model can be adapted to different types of tourist destinations. For destinations with fewer visitors, the model can also be applied to achieve a better balance.

• We have done enough visualization of the algorithms and results in this paper for easy under- standing.

• Most of our models are based on innovative ideas or improvements derived from the origi- nal theory and the problem addressed in this paper, making our models both theoretical and innovative.

5.2.Weaknesses

• The model is highly data-dependent: It requires a large amount of local data (such as tourist carbon footprints, environmental restoration efficiency, and residents' happiness surveys) for parameter calibration, making data acquisition costly and potentially biased.

• The model does not consider the impact of macroeconomic fluctuations, policy changes , and other external shocks.

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