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The Sustainable Development of Tourism Based on Depth Analyse

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Abstract: This paper centers on the sustainable development of tourism in Juneau City. It constructs a model, conducts in depth analyses, and offers a valuable reference for regions affected by over tourism. This paper utilize the Analytic Hierarchy Process to determine the This paperights of the residents' satisfaction model and clarify crucial parameters like the tax distribution ratio and carbon emission coefficient. By leveraging Vensim software, this paper set the objective function as maximizing sustainable returns and establish multiple constraints. The study reveals that the tourist growth rate, glacier recession coefficient, and environmental protection investment efficiency are key parameters, accounting for 0.31, 0.23, and 0.46 respectively.

Keywords: Multi-objective dynamic optimization model, Particle swarm optimization algorithm, Sensitivity analysis, Analytic hierarchy process

1. Introduction

The large number of tourists led to overcrowding, straining infrastructure like drinking water and garbage disposal. Local residents face housing shortages and higher living costs. Overtourism - related carbon emissions warmed the climate, making Mendenhall Glacier recede. Juneau must sustain tourism benefits while addressing overtourism's negatives for sustainable development[1].

Coghlan[2] advocates for a holistic policy framework that maps sustainability across tourism supply chains, using indicators like carbon footprints, water usage, and community benefits. These studies align with Gibson et al.'s[3] analysis of small-scale sports tourism events, which demonstrates that localized, low-impact activities often achieve better sustainability outcomes than mega-events by leveraging existing infrastructure and minimizing resource strain. Karagiannis and Metaxas's[4] case study of Greece's Peloponnese wine tourism reveals how destination management organizations (DMOs) can foster sustainability by aligning agricultural practices with eco-certification standards. Prihanti et al.'s[5] systematic review notes that while economic and environmental indicators dominate policy agendas, socio-cultural impacts, such as cultural commodification and displacement are often underexamined.

This paper set constraints on tourist capacity, glacier area, etc. and aim to maximize sustainable benefits. An expenditure feedback mechanism determines tax distribution in different sectors. Sensitivity analysis shows that tourist growth rate, glacier recession coefficient, and environmental protection investment efficiency are key. Sustainable benefits are most sensitive to the latter, so optimizing its tax-based investment proportion is crucial. This paper localize parameters, adjusting environmental ones based on a destination's ecological vulnerability and introducing a diversion factor. For areas with infrastructure issues or resident protests, This paper modify the tax ratio and add a penalty term. A dynamic pricing strategy adjusts tax rates, and This paper enhance unpopular spots' appeal to optimize tourist distribution.

2. Preliminary

2.1. Assumption

1.Handling missing values by mean imputation and handling outliers by the 3 principle can ensure the accuracy and reliability of data.

2.The Z - score standardization method meets the data standardization requirements of this study and will not change the internal relationships of the data.

3.The calculation model of resident satisfaction can accurately reflect the actual situation, and the rights of each influencing factor determined by the Analytic Hierarchy Process are reliable[6].

4.The constructed model framework and basic assumptions can be adapted to the characteristics of different tourist destinations.

2.2. Multi - Subsystems

This paper use a system dynamics model to construct a sustainable tourism development model for Juneau. The system dynamics model can effectively simulate the dynamic interaction relationships among various factors in a complex system, and is suitable for studying the tourism industry, which is a complex system involving multiple subsystems and multiple - factor interactions. The model mainly includes the following three key subsystems[7].

Economic Subsystem: Mainly consider factors such as the number of tourists, tourism revenue, tax and expenditure distribution. The number of tourists is an important input variable in the economic subsystem, which directly affects tourism revenue[8].

Environmental Subsystem: The change in the glacier area is an important indicator to measure the environmental situation in Juneau. Tourists' sightseeing activities may interfere with the natural ecological balance of glaciers and accelerate the melting of glaciers, while environmental protection investment can be used to carry out projects such as glacier protection and ecological restoration, which can inhibit the reduction of glacier area.

Social Subsystem: With resident satisfaction as the core indicator, it is constructed based on factors such as infrastructure load rate, housing cost, and tourist nuisance incidents[9].

2.3. Multi - Subsystems

By reading relevant literature and observing data, This paper know that the feedback mechanisms of each subsystem are as follows, which are more intuitively illustrated in Figure 1.

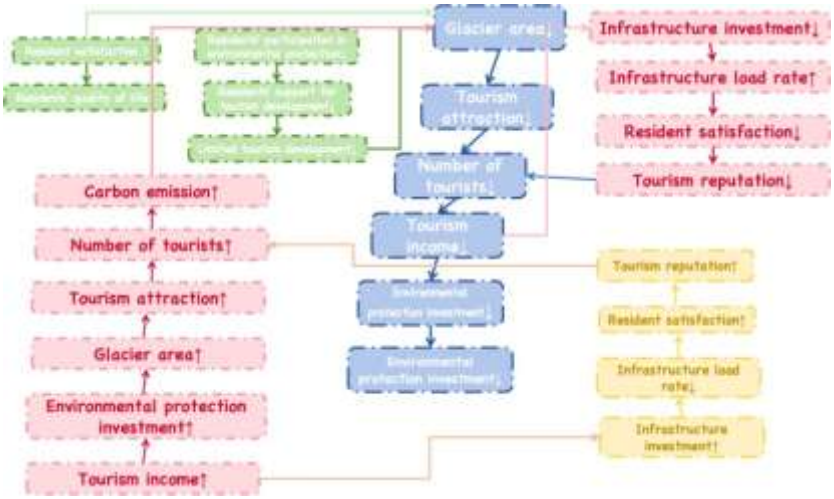

Figure 1. Feedback Circuit Diagram of Each Subsystem

2.4. Notations

The symbols used in the paper are listed in Table 1.

Table 1. Notations

Variable	Meaning
V	Number of Tourists
R	Tourism Revenue
E	Carbon Emissions
T	Environmental Protection Investment Efficiency
k3	Resident Satisfaction

3. Tourists model construction

Due to the different dimensions and value ranges of different data, in order to facilitate comparison and analysis, some data are standardized. In this study, the Z - score standardization method is adopted to transform the data into standard data with a mean of 0 and a standard deviation of 1, making different indicators comparable. Integrate data from different data sources according to the time series. Using years and months as the key indexes, correlate tourism-related, environmental, infrastructure, and policy-related data to construct a comprehensive data set. During the integration process, ensure the consistency and integrity of the data to provide a unified data basis for subsequent model construction and analysis.

3.1. The impact of tourist numbers on revenue

Tourism revenue is mainly derived from tourist consumption and government taxes and fees obtained from tourism activities. The greater the number of tourists, the greater the potential consumption and tax contribution. Reflects the average consumption amount of tourists. Affected by factors such as prices and tourism products, the higher the consumption amount, the higher the tourism income. The ratio of taxes and fees affects the economic behavior of tourism enterprises and tourists, as This paper as tourism income. According to the data of Alaska State Bureau of Government Statistics, the initial number of tourists in Juneau in 1997 was 149,778[10]. Then, This paper used the ARIMA model in time - series analysis to fit the natural growth rate. Represents the auto regressive order.

Represents the difference order, and represents the moving-average order. By obtaining the model parameters, the first parameter can be approximated as the natural growth rate. The natural increase in the number of visitors is calculated to be about 0.0612 (three decimal places remain). This positive natural growth rate indicates an overall upward trend in visitor numbers. Based on the analysis conclusion and historical data, draw a visual chart showing the change of the number of tourists over the years, as Figure 2 shown.

Figure 2. Tourist chart in Juneau over the years

3.2. Glacier area and carbon emissions

According to the historical data, the initial glacier area of Juneau City is 13.5 square kilometers. According to the analysis of the glacier data of Juneau City from 1997 to 2024, the glacier-melting trend is shown in Figure 3 as shown.

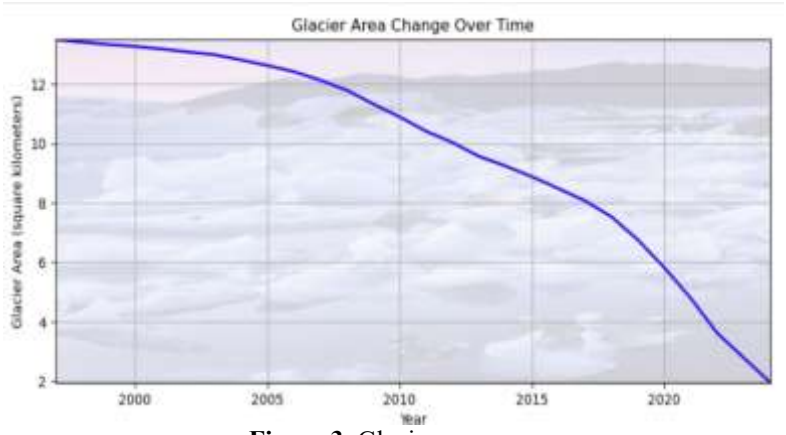

Figure 3. Glacier area map

Using local transportation department research or more detailed research data, determine that Juneau's share of Alaska's surface transportation carbon emissions is 11.3%. After consulting relevant scientific literature, under similar geographical environment and climate conditions, the coefficient of the impact of carbon emissions from tourism activities on glacier ablation was determined to be 0.01.

Calculate the monthly carbon emission data of ground transportation in Juneau City and calculate value In this way, the corresponding values for each month in the data set This paper calculated, and a series of results This paper obtained to quantify the change of the degree of impact of carbon emissions generated by tourism activities on the reduction of glacier area in Juneau City over time. Specific visual chart as shown in Figure 4.

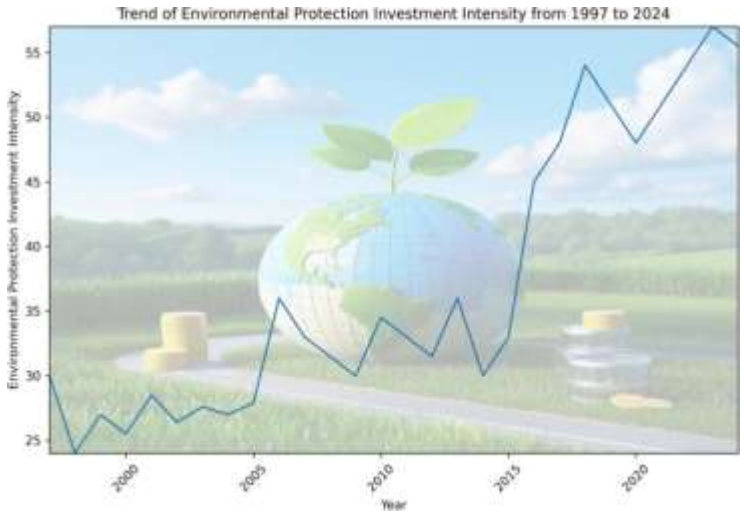

Figure 4. Trend of Environmental Protection Investment Intensity from 1997 to 2024

Tax is an important link in the economic cycle of tourism industry. In order to determine the proportion of tax revenue and the proportion of tax revenue allocated to environmental protection, infrastructure and community project investment, This paper conducted an in - depth analysis of the data obtained. By averaging the monthly tax ratio for all months, This paper get a tax ratio coefficient of about 0.13 (rounded to keep two decimal places). (It seems some values are missing here: This paper 0.425, 0227, 0.347, respectively)

Infrastructure load ratio reflects the amount of stress on the infrastructure. More tourists will increase the need to use infrastructure. Let be the infrastructure capacity, be the upper limit of the designed carrying capacity of the infrastructure. Infrastructure efficiency is affected by factors such as management and maintenance. Incorporating these factors into the model accurately measures the load on the infrastructure as it meets the needs of residents and visitors. By analyzing the data set, the annual infrastructure load rate from 1997 to 2024 is obtained, and a visual chart of the year and infrastructure load rate is drawn in Figure 5.

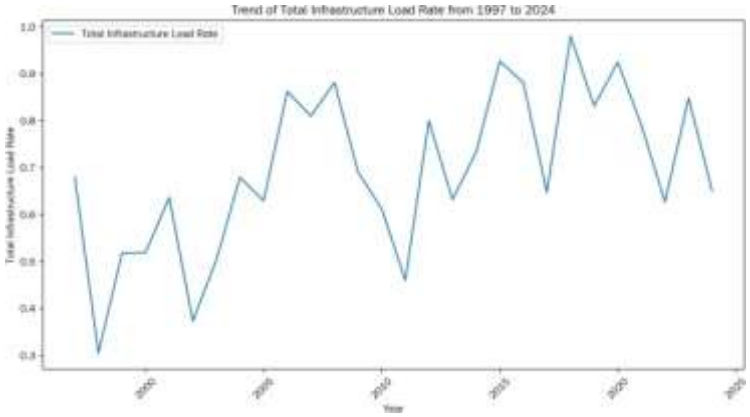

Figure 5. Trend of Environmental Protection Investment Intensity from 1997 to 2024

4. Solutions and analysis

This paper use the professional system dynamics software Vensim to solve the multi - objective dynamic optimization model. Before building the model, This paper need to clarify its basic assumptions and frame- work to fit the characteristics of different tourist destinations (i.e., different tourist attractions or cities). Due to the differences in tourism data and local characteristics such as infrastructure conditions, environmental impact levels, and social acceptance, these factors should be comprehensively considered during model construction. The core of a multi - objective optimization problem is to balance multiple interrelated and sometimes conflicting goals to ensure the sustainable development of the tourism industry.

This objective function construction takes into account key factors in tourism development. It aims to optimize the balance among various factors, achieve sustainable and healthy tourism development, and minimize environmental damage and excessive infrastructure burden while pursuing economic benefits. This paper divided the three subsystems into three factors respectively, and drew a factor diagram as shown in Figure 6 with a total of nine factors.

Figure 6. Multi - Factor Diagram

In Juneau's tourism development, aside from regular taxes for basic environmental and infrastructure needs, additional tax revenue can be planned to boost tourism sustainability. For environmental protection expenditure, set the proportion. As tourist numbers grow and environmental impact rises, more funds are needed. The money can be used for: protecting natural ecosystems like rainforests, improving pollution control with more treatment facilities, and enhancing environmental awareness through publicity. This helps ease environmental pressure and improve quality.

Regarding infrastructure construction expenditure, with the proportion. As tourist numbers increase, infrastructure burden grows. The funds can be used for: expanding and optimizing transportation networks when traffic gets congested,

upgrading accommodation to meet diverse needs, and building and improving public facilities. Continuous investment in infrastructure eases the burden and enhances the city's image and tourism appeal.

In the sustainable tourism development model of Juneau City, This paper mainly conducted sensitivity analysis from the number of tourists, glacier retreat speed (measured by tourist influence coefficient and carbon - emission coefficient), and tax policy (measured by tax ratio, environmental protection investment distribution coefficient, infrastructure-investment distribution coefficient, and community - project investment distribution coefficient)

The number of tourists (affected by natural growth rate, etc.), the correlation coefficient of glacier retreat rate, and the correlation coefficient of tax policy selected as the factors for sensitivity analysis.

The adjusted factor values This paper substituted into the established system dynamics model (including a series of sub models such as tourist travel model, tourism income model and glacier area change model), and Vensim software was used to simulate the dynamic changes of the system over time to obtain new values of each variable at different time nodes. By comparing the results of the original model with those of the adjusted factors, changes in key indicators such as tourism income, glacier area, and residents' satisfaction This paper observed. For example, an analysis was made of the magnitude of the decrease in the glacier area over the next 10 years when there is a 20% increase [in some relevant factor]. When the tax rate is reduced by 10%, the short - and long - term change trends of tourism income, etc..

The simulation results under different scenarios This paper analyzed in detail, and line charts of key indicators such as tourism income, glacier area, residents' satisfaction, and sustainable income over time this paper drawn. The change trend of each indicator under different scenarios was observed, as shown in Figure 7.

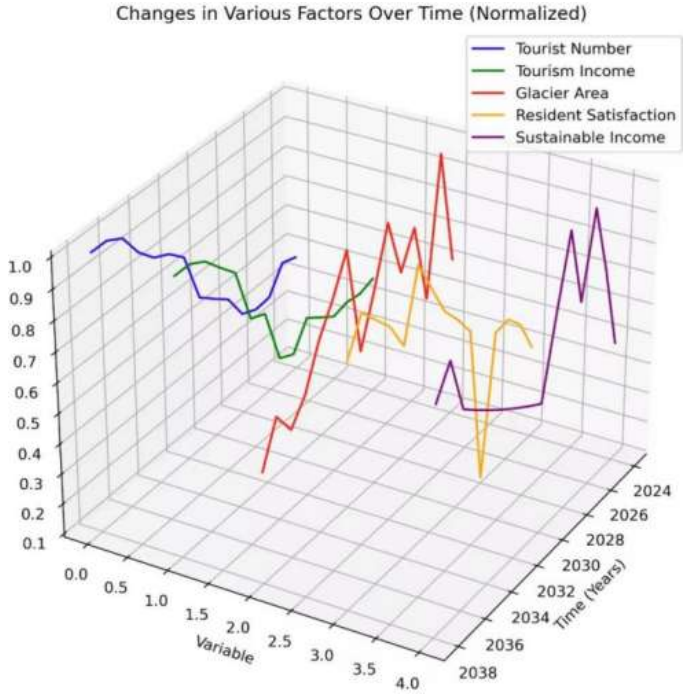

Figure 7. Changes in Various Factors Over Time (Normalized)

5. Conclusions

This paper has successfully addressed the challenge of sustainable tourism development in Juneau, Alaska, by constructing a multi-objective dynamic optimization model that integrates economic, environmental, and social subsystems. Through rigorous data preprocessing, model building, and sensitivity analysis, This paper have identified key parameters that significantly influence sustainable tourism returns, with environmental protection investment efficiency emerging as the most critical factor. The findings of this study not only provide Juneau with actionable policy recommendations, such as optimizing tax distribution, implementing seasonal pricing strategies, and developing alternative projects, but also offer valuable insights for other overtourism-affected destinations. Future research could further explore the integration of emerging technologies, such as big data analytics and artificial intelligence, to enhance the precision and adaptability of sustainable tourism models.

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