Sustainable Tourism Optimization Based on an Improved Ramsey Model: A Case Study of Juneau

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Abstract. Tourism development has brought both economic vitality and environmental challenges to destinations worldwide. This essay addresses the issue of over-tourism in Juneau, Alaska, by constructing a sustainable tourism optimization model that integrates economic, social, and environmental factors. Using an improved Ramsey optimal growth model, this essay set social welfare as the objective function, constrained by tourist numbers, natural resource stock, and resident satisfaction. A hybrid method combining EWM-AHP and TOPSIS is employed to quantify resident satisfaction, while a tourism tax mechanism is introduced to model revenue feedback loops. The model yields an optimal tourist capacity of 1.63 million and a resident satisfaction level of 0.943 under maximum social welfare conditions. To test the model's adaptability, this essay generalizes it for other regions by replacing glacier retreat with a broader natural resource depletion rate and apply it to Kyoto and Banff as case studies. Results demonstrate that sustainable tourism policies must be tailored to local ecological and economic conditions. This model provides a scalable framework for guiding tourism policy toward long-term sustainability and balanced development.

Keywords: Over-tourism, Sustainable Tourism, Ramsey model, Resident satisfaction.

1. Introduction

In recent years, overtourism has emerged as a significant threat to the sustainability of many global destinations. Overtourism contribute to pollution, biodiversity loss, and the degradation of natural and cultural heritage sites [1, 2]. Socially, overtourism disrupts local communities by inflating housing costs, overloading public services, and reducing residents' quality of life. The term "tourism phobia" has been used to describe the growing resentment among locals in overvisited cities like Barcelona and Dubrovnik [1, 3]. The rapid influx of visitors often surpasses the capacity of transportation, waste management, and other essential services, leading to overcrowding and accelerated infrastructure wear [2, 4]. Despite growing awareness, efforts to manage overtourism are often fragmented and reactive. Many destinations lack the governance mechanisms necessary to implement effective limits, taxation systems, or adaptive management policies [4, 5]. These unresolved challenges underscore the need for a quantitative approach to sustainable tourism planning.

The issue of overtourism is particularly severe in Juneau, Alaska, USA. The city has a population of approximately 30,000, yet it welcomed 1.6 million cruise ship tourists in 2023. During the busiest periods, as many as seven large cruise ships docked simultaneously, bringing in up to 20,000 visitors at once [6]. While these tourists generated an estimated $375 million in revenue for the city [7], they also caused numerous problems, such as overcrowding and environmental degradation. Although the city has made efforts to limit the number of visitors, the issue remains unresolved. The situation in Juneau is quite typical, so this essay will take this city as the main research object, and then extend the model to other cities at the end.

To address overtourism, various scholars have proposed quantitative and model-based solutions tailored to specific sustainability goals. One influential line of research focuses on optimization models that dynamically balance tourism demand, environmental protection, and economic output. For example, Xu and Tan both applied evolutionary algorithms (NSGA-II and its variants) to determine sustainable tourism capacities and optimal investments in environmental and community infrastructure [8, 9]. Additionally, Qi. and Wang extended these methods by using improved genetic algorithms to optimize tourism route planning and dispersal strategies, reducing congestion and ecological stress through multi-objective frameworks [10]. Financial regulation via tourism taxes and entry fees represents another widely adopted method. Göktaş and Çetin used Tobit regression to evaluate tourists' willingness to pay for sustainable destinations, confirming the acceptability of well-communicated environmental taxes during peak seasons [11]. Expanding upon this, Bhattacharya and Bairagi employed dynamic bioeconomic optimization to co-optimize fishing taxes and tourism fees, emphasizing temporal feedback for ecosystem resilience and sustained revenue generation [12]. Beyond economic modeling, there is a clear shift toward integrating resident perceptions into policy. Steber and Mayer used qualitative interviews to highlight post-pandemic overtourism effects on resident well-being in rural areas, urging participatory governance models early in destination planning [13]. Qin and Shen employed structural equation modeling to quantify how perceived environmental and cultural thresholds determine local support for tourism in Chinese minority villages [14].

While previous studies have explored sustainable tourism from the perspectives of carrying capacity, optimization models, and taxation mechanisms, few have integrated environmental constraints, economic dynamics, and resident satisfaction into a unified, dynamic framework. This essay improves the Ramsey optimal growth model to simultaneously incorporate ecological regeneration, tourism tax feedback, and a multi-criteria evaluation of resident satisfaction using a hybrid EWM-AHP and TOPSIS method. Furthermore, the model's adaptability is tested across distinct tourism destinations, thereby offering a scalable and transferable policy tool. These contributions provide both theoretical innovation and practical insights into sustainable tourism planning.

2. Model of Juneau City Sustainable Tourism Development

This essay constructed a tourism model for the city of Juneau with the aim of exploring options for realizing sustainable tourism in the area, focusing on balancing the three dimensions of economic revenues, environmental sustainability, and resident satisfaction, and identifying their constraints and feedback mechanisms at the same time. In terms of economic revenues, the model focuses on influencing factors such as visitor numbers, tourist spending, and other additional costs; in terms of environmental impacts, we assess the pressures of visitor numbers on the environment, such as carbon emissions, waste generation, and degradation of attractions; and in terms of resident satisfaction, we focus on examining how to avoid the potential impacts of over-tourism on the quality of life of local residents. Finally, this essay introduced the factor of tourism tax in our model to study the impact of imposing a tourism tax on the tourism industry in the city of Juneau to assess the role of this policy on the sustainability of tourism. The mind map of Juneau city sustainable tourism development model is shown in Figure 1.

Figure 1. Mind map of Juneau city sustainable tourism development model

2.1. The Ramsey-type model of optimal growth

The Ramsey-type optimal growth model is a model that describes how to make an efficient allocation of resources to maximize welfare, which was proposed by Frank Ramsey in 1928. The model was originally developed to solve the problem of optimal consumption to maximize the welfare of the whole society.

This essay will base our research on this model with the aim of maximizing social welfare. Social welfare in this context means that tourism in the city of Juneau contributes to the growth of the local economy while maximizing the incomes of the local population and seeks to minimize the negative impacts on the natural environment as well as the disruption of the local community. In this case, the simplest formula for social welfare is:

$$W = \int_0^\infty e^{-\rho t} u\big(c(t)\big) dt \tag{1}$$

Where W is the social welfare, $u\big(c(t)\big)$ is the utility function of instantaneous consumption c(t), which is typically assumed to be concave, such as $u\big(c(t)\big) = \frac{c(t)^{1-\sigma}}{1-\sigma}$, where $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution. $c(t)$ is the consumption of the local population at time t, i.e., the expenditures of the local population on tourism activities (e.g., purchases of food raw materials, utilities, etc.), ρ is the time preference rate, i.e., the discount rate for future utility, t is time.

However, this essay still needs to correct the above formula, which still has some limitations, such as not considering the environmental impact on the economy or the consumption of local tourists. In the following, this essay will add other constraints to this model to fulfills the requirements.

2.2. Optimization of Ramsey-type Model

Next, this essay improves the model in terms of both economic and environmental constraints [15]. The economic constraints describe the impact of tourism capital, natural resources and the number of tourists on tourism revenues. It is assumed that the local population only provides tourism-related services (e.g., accommodation, food and beverage, basic leisure facilities, etc.) and that their economic activities are entirely dependent on the demand from the international tourism market, i.e., revenues are determined by the fees paid by tourists.

First, the tourism capital at moment t is formulated as follows:

$$k_t = y_t - c_t = A k_t^{\alpha} e_t^{\phi} z_t^{1-\mu} - c_t \tag{2}$$

Where e_t denotes the reserves of natural resources, z_t denotes the number of tourists, A is a scale parameter, α is a normalization function that measures the degree of tourists' preference for infrastructure, and Φ is a parameter between 0 and 1 that denotes tourists' preference for natural attractions.

The μ can reflect the tourist's spending preference for that tourist attraction. When $\mu > 1$, the growth rate of income is slower, i.e., for this attraction, the more tourists consume the less enthusiasm. When $\mu < 1$ the situation is reversed, the more tourists spend the more enthusiastic.

The interaction between tourism and natural resources determines environmental sustainability. As the number of tourists z_t increases, the natural resource stock et will be depleted and the dynamics of the natural resource stock can be described by the following equation:

$$\dot{e}_t = (r - \eta z_t)e_t \tag{3}$$

r is the rate of regeneration of natural resources and η is the coefficient of pressure of tourism on the environment.

This formula can be a good response to the relationship between the number of tourists and natural resources, too many tourists will increase the consumption of resources, leading to environmental degradation, thus affecting the local tourism economy.

In the end, the improved model is as follows:

$$\begin{aligned} \max_{c_t, z_t} \ W = & \int_0^{\infty} \frac{c_t^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt \\ s.t. \ k_t = & A k_t^{\alpha} e_t^{\phi} z_t^{1-\mu} - c_t \\ \dot{e}_t = & (r - \eta z_t) e_t \end{aligned} \tag{4}$$

It is important to note that if the demand for international tourism continues to grow, an unlimited increase in the number of tourists will not only have a negative impact on the environment, but also on the economy. Therefore, it is necessary to control the number of tourists to achieve a healthy economy. In particular, the number of tourists should not exceed the ecological carrying capacity, i.e. the maximum number of tourists that can be accommodated without triggering excessive environmental degradation. In our model, the carrying capacity consists of the maximum number of tourists $\tilde{z}_t$, [16] i.e.

$$\widetilde{z_t} = \frac{r}{\eta} \equiv \tilde{z} \tag{5}$$

Heat map of natural resources in relation to visitor numbers and regeneration ability is shown in Figure 2.

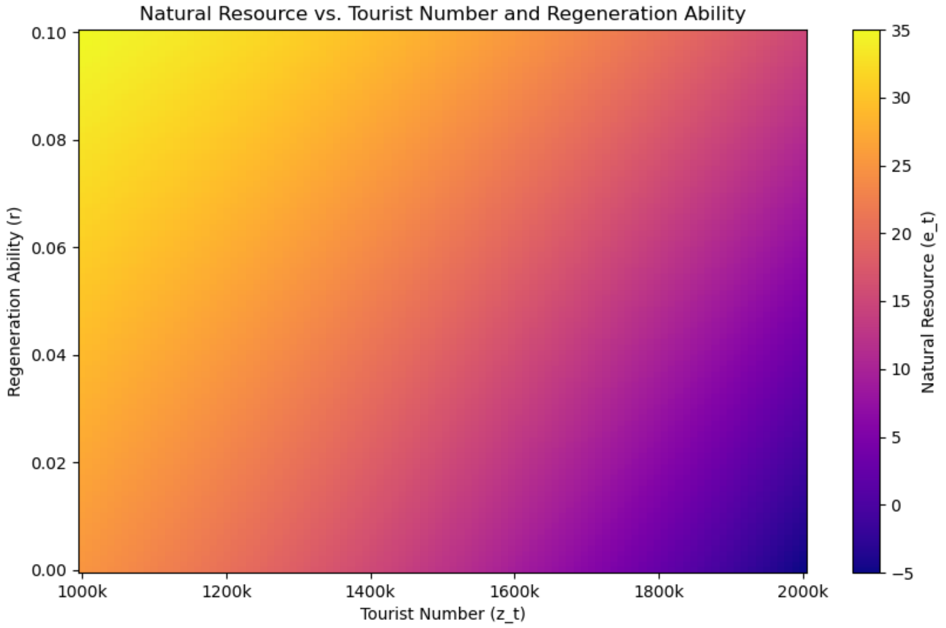

Figure 2. Natural Resource vs. Tourist Number and Regeneration Ability

Based on the above figure, this essay can conclude that the number of tourists is negatively correlated with the consumption of natural resources, and an increase in the number of tourists will aggravate the consumption of natural resources. This suggests that in Juneau's sustainable tourism plan, we need to control the number of tourists and ensure that the ecosystem has sufficient regenerative capacity to prevent natural resource depletion and environmental degradation to maximize welfare.

Subsequently, this essay generated the following Euler equation for the number of tourists based on necessary and sufficient conditions [17]:

$$\frac{\dot{z}_t}{z_t} = \frac{1}{\mu}\left[\Phi r + \frac{\Phi\mu}{1-\mu}\eta z_t - \alpha\frac{c_t}{k_t}\right] \tag{6}$$

In the next analysis, this essay wants to find the optimal number of tourists in the long-term steady state. We base this on the steady state equilibrium BGP model [5], which is designed to bring all the variables of the system (e.g., the number of tourists, consumption, tourism capital, etc.) to a constant level that will not change again. Therefore, setting the growth rate of the number of tourists to zero leads to the optimal number of tourists:

$$\bar{z} = \frac{(1-\mu)[(1-\alpha)\rho + (\sigma-1)\Phi r]}{\Phi\eta[\sigma(1-\mu)+\mu-\alpha]} \tag{7}$$

2.3. Residents' Satisfaction

In response to maximizing social welfare, we also need to develop a broadly applicable indicator to determine the level of resident satisfaction in the City of Juneau. By collecting data on 6 indicators affecting the satisfaction of residents in Juneau City, using EWM-AHP & TOPSIS [18] to establish an evaluation model to reduce the influence of subjective factors, determining the weights of each indicator, and then evaluating the level of resident satisfaction in Juneau City by calculation.

Next, we present the three first-level indicators (economic, environmental and social) and their corresponding six second-level indicators.

(1) Economic indicators

Relative tourism revenue X_1: defined as tourism revenue as a percentage of GDP. There is a strong correlation between residents' income and residents' satisfaction, so relative tourism income is chosen as the evaluation index.

Housing cost index X_2: defined as the ratio of house prices or rents to median household income. The cost of housing is closely related to the lives of residents, so the satisfaction of residents can be reflected in the housing cost index.

(2) Environmental indicators

Glacier Retreat Rate X_3: defined as the rate of glacier retreat over the course of a year, this indicator reflects the decay of the City of Juneau's tourism resources. Tourism is the mainstay of the City of Juneau and therefore affects resident satisfaction.

Other attraction development index X_4: defined as investment in other tourist attractions (e.g., rainforests, whale watching) as a proportion of total tourism revenue. This indicator captures the extent of tourism development in Juneau and is therefore related to resident satisfaction.

(3) Social indicators

Visitor density X_5: defined as the ratio of daily visitor cost to infrastructure capacity, also known as infrastructure pressure. It shows how visitors use up resources in terms of drinking water supply, sewage treatment, housing needs, traffic flow and other services, and therefore can reflect the level of resident satisfaction.

Environmental inputs X_6: defined as environmental inputs as a share of tourism tax revenue. Environmental inputs have a restorative effect on environmental damage caused by tourists and are positively related to resident satisfaction.

The determination of weights is the key to evaluating the indicators, and the traditional AHP determines the weights through the group decision method (GDM) using the expert comparison matrix; EWM calculates the weights based on the variability of the indicator data. To improve the credibility, this essay adopted a game-theoretic portfolio weighting method, which uses a combination of the two methods. First, this essay use AHP to calculate the weights W_1 for the 6 metrics. The AHP completes the construction of the judgment matrix by adopting nine-point scale method to score the indicators in pairwise comparison. Subsequently, the consistency test was conducted through the maximum eigenvalue λ_{max} of the judgment matrix to verify the consistency of the matrix, which was calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{8}$$

$$CR = \frac{CI}{RI} \tag{9}$$

When n = 6, RI = 1.24 and we can get CR = 0.0161. Thus, it passes the consistency test. Next, this essay uses the EWM method to calculate the weights of the six indicators W_2. First, the data of positive and negative indicators are normalized, and then the probability value of each indicator is calculated based on the normalization results, and based on the probability value, the entropy value and weight of the J_{th}indicator are further calculated with the following equations:

$$H_j = -\frac{1}{ln(m)} \sum_{i=1}^{m} X_i \, ln(X_i) \tag{10}$$

$$\lambda_j = \frac{1-H_j}{\sum_{j=1}^{n}(1-H_j)} = \frac{1-H_j}{n-\sum_{j=1}^{n} H_j} \tag{11}$$

$$w_j = \frac{w_j' \lambda_j}{\sum_{j=1}^{n} w_j' \lambda_j} \tag{12}$$

Finally, this essay uses the idea of game theory to combine the above two calculated weights to minimize the indicator combination weight W and seek the optimal linear combination coefficients. The objective function and constraints are as follows:

$$\begin{aligned} &\min(\| W - W_1 \|_2 + \| W - W_2 \|_2) \\ &= \min\left(\| (\lambda_1 W_1 + \lambda_2 W_2 - W_1) \|_2 + \| (\lambda_1 W_1 + \lambda_2 W_2 - W_2) \|_2\right) \\ &s.t. \lambda_1 + \lambda_2 = 1, \lambda_1, \lambda_2 \geq 0 \end{aligned} \tag{13}$$

According to the linear combination coefficients obtained from the differentiation principle, W_1 and W_2 are normalized to obtain the optimal combination of weights of assessment indicators. TOPSIS is a multi-criteria decision-making method that evaluates and ranks alternatives based on their distances to an ideal solution. This essay use data from 8 alternatives and 12 evaluation metrics to construct the matrix X, with the normalized matrix denoted as M. Define the distance between the client and the maximum value D_i^+.

$$D_i^+ = \sqrt{\sum_{j=1}^{12} W_j^* \left(M_j^+ - m_{ij}\right)^2} \tag{14}$$

Define the distance between the client and the minimum value D_i^-:

$$D_i^- = \sqrt{\sum_{j=1}^{12} W_j^* \left(M_j^- - m_{ij}\right)^2} \tag{15}$$

This essay then calculates the score for the i-th metric:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{16}$$

2.4. Tourism Tax

Tourism taxes are an important additional revenue component in the tourism model [19], so this essay will introduce them into our model in this section. Next, we will model the tourism tax in terms of two main factors: demand and price. And, starting from this section, the demand variables of our model will consider local demand.

The aggregate demand xi for good i can be written as the sum of two components, i.e.

$$x_i = x_i^D + x_i^T \tag{17}$$

Where x_i^D is the demand for good i by residents and x_i^T i is the demand for good i by tourists. Further, the ratio of tourist demand x_i^T to local demand x_i^D is determined by ψ_i, i.e.

$$x_i^T = (1 - \psi_i)x_i \tag{18}$$

Where ψ_i denotes the share of tourism demand in the total demand for goods, which is a dynamic variable that varies with price changes. Because price changes affect local consumers and tourists differently, ψ_i, adjusts accordingly.

The price elasticity of tourism demand is divided into two components: micro-elasticity and macro-elasticity. The micro-elasticity reflects the response of tourists' consumption demand at a given destination to changes in price, while the macro-elasticity reflects the response of the overall number of tourist arrivals to changes in price. Combining these two elasticities, this essay obtains the total elasticity of tourism demand [20]:

$$\varepsilon_i^{\psi} = (1 - \psi_i)\left[\left(\varepsilon_i^{x^T(\Omega)}\varepsilon_i^{\Omega(p_i)} + \varepsilon_i^T\right) - \varepsilon_i^D\right] \tag{19}$$

Typically, the imposition of a tourism tax on goods has an impact on the price of goods, which in turn affects consumer demand. Use the Ramsey inverse elasticity rule to represent the optimal tax rate. Use the Ramsey inverse elasticity rule to represent the optimal tax rate. According to the inverse elasticity rule, goods with less elasticity of demand are suitable for higher tax rates.

Based on the cited literature [20], this essay can derive the following equation to represent the relationship between the tourism tax rate and the price of the commodity, the elasticity of demand:

$$\frac{t_i}{p_i} = \frac{\tilde{\beta}}{\Delta}\left[\frac{1}{(1-\psi_i)\bar{\varepsilon}_i^D + \psi_i \bar{\varepsilon}_i^T}\right] \tag{20}$$

Where the tax rate and price of each good are denoted by the vector $\boldsymbol{t} = (t_0, t_1 \dots t_N)$ and $\boldsymbol{p} = (P_0, P_1 \dots P_N)$, Δ is the determinant of the Slutsky matrix, and $\tilde{\beta}$ is a constant related to the Lagrange multiplier $\tilde{\eta}$.

Subsequently, this essay defines the total tax revenue from tourism taxes per unit of consumption, i.e.

$$R(t) = \sum_{i=1}^{N} t_i\, x_i = \sum_{i=0}^{N} t_i \left(\frac{x_i^D}{1-\psi_i}\right) for\ \psi_i \neq 1 \tag{21}$$

At the same time, the tax revenue constraint suggests that total tax revenue R(t) must be greater than or equal to some given level $\bar{R}$, i.e.

$$R(t) \geq \bar{R}\ for\ \psi_i \neq 1 \tag{22}$$

And this will serve as the constraint.

As a result, this essay will describe this optimization problem by the following social welfare function whose objective is to maximize the benefits to residents:

$$\max_{p}\left[\max_{x_i^D} U(x_i^D)\right] \text{ subject to } p x_i^D = y^D \tag{23}$$

Where $U(x_i^D)$ is the utility function of the local population and y is the income.

As shown in Figure 3, there is an accelerating upward trend in commodity prices as taxes increase. Social welfare increases at lower levels of tourism taxes but declines when tourism taxes are too high. Regarding the number of tourists, the change in the number of tourists is relatively flat when the tax is low; however, when the tax reaches a certain level, the number of tourists shows a significant exponential decline, showing a strong sensitivity. At the same time, as taxes increase, aggregate demand gradually decreases, especially at higher taxes, where the downward trend in demand is more pronounced.

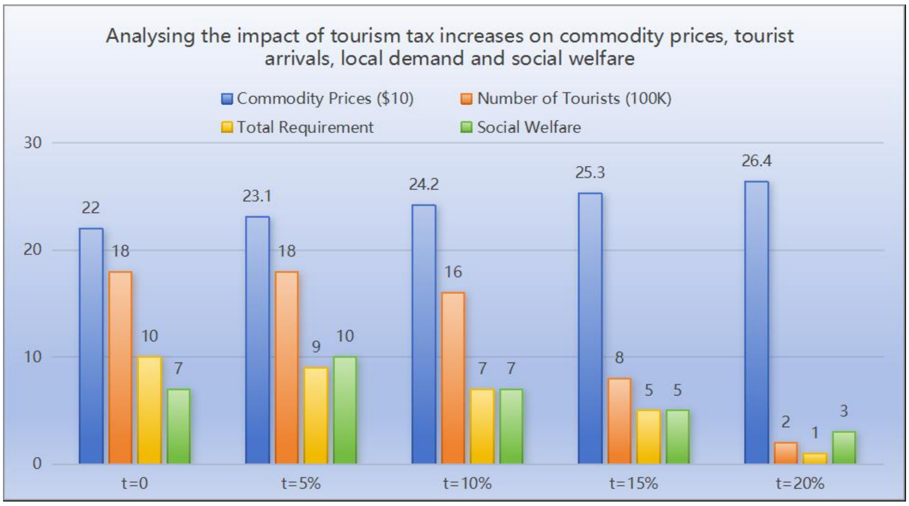

Figure 3. Impact of the increase in tourism tax on the tourism industry

3. Results

3.1. Results of Sustainable Tourism Development Model for the City of Juneau

In the above model of sustainable tourism development in the city of Juneau, the optimization objective is to maximize social welfare by optimizing the number of tourists, implementing tourism tax policies, protecting natural resources, maintaining infrastructure, and increasing tourism revenue. The constraints of the model include: the number of tourists, which must not exceed the ecological carrying capacity and infrastructure capacity; the stock of natural resources, which needs to be kept above a minimum threshold to avoid resource depletion; and resident satisfaction, through which the impact of tourism on the normal life of residents is limited by resident satisfaction. This essay built a comprehensive sustainable overall model by correlating the various formulas, writing the corresponding Python code, and calculating each parameter using the relevant data.

As Figure 4 shown, the final solution of maximizing social welfare was 10.7, the optimal number of tourists was 1625203, the maximum tourism benefit was 370796474.67, the residents' satisfaction was 0.943, and the stock of environmental resources was 20.03 million.

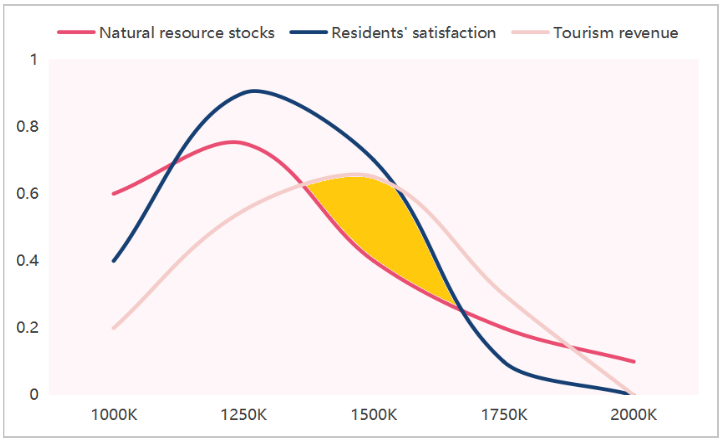

Figure 4. The trade-off between natural resource stock, resident satisfaction, and tourism revenue

3.2. Extended Sustainable Tourism Model and Application

In Model, the environmental factors mainly include natural resource stock, natural resource regeneration rate, pressure coefficient of tourists on the environment, carrying capacity of tourists, glacier retreat rate and other attraction development index. Among other things, this essay needs to adjust for the factor of glacier retreat rate, which is not applicable to tourism models for other regions because glaciers are not present in all tourist locations.

To characterize the consumption of resources by tourism activities in the extended model, this essay introduces here a model for the rate of consumption of natural resources to replace the rate of glacier retreat in the original model. The formula is as follows:

$$C(t) = \alpha \cdot z_t \cdot I(t) \tag{24}$$

Where $I(t)$ is the intensity of tourism activity at moment t.

This essay selects two typical sites, Kyoto and Banff National Park, one with a high number of tourists and one with a low number of tourists, to form a comparison to verify the rationality of the model and offer suggestions for the further development of tourism balance. First, identify 10 important parameters that influence the comprehensive benefits of the sites. Then, use non-linear optimize algorithm to solve the optimized parameters to maximize the benefits. Finally, the government should develop policies to keep these parameters as close to optimal as possible.

1) Over-tourist Site: Kyoto

Through the investigation and data collection, the parameters of Kyoto required for model analysis are shown in Table 1.

Table 1. Parameters of Kyoto

Parameter	Value	Parameter	Value
Z_t	200	t_i	5
r	2.5	A	1.2
η	0.8	α	0.6
$I(t)$	1.5	ϕ	0.4
$C(t)$	240	S_i	0.75

And the optimized parameters are shown in Table 2. The government's best course of action is to implement a tourism tax ($t_i^*\uparrow$) to regulate visitor numbers ($z_t^*\downarrow$) and reduce overcrowding, invest in resource regeneration ($r^*\uparrow$) and infrastructure upgrades ($A^*\uparrow$) to alleviate environmental strain (η^*, $z_t^*\downarrow$), balance tourist density ($I(t)^*\downarrow$) while preserving cultural heritage to maintain Kyoto's appeal, and ensure long-term ecological and social stability through sustainable tourism practices, achieving reduced resource consumption $C(t)^*\downarrow$) and enhanced economic resilience.

Table 2. Optimized parameters of Kyoto

Parameter	Value	Parameter	Value
z_t^*	150	t_i^*	12
r^*	3.2	A^*	1.5
η^*	0.6	α^*	0.7
$I(t)^*$	1.2	ϕ^*	0.5
$C(t)^*$	180	S_i^*	0.88

2) Lack-tourist Site: Banff National Park

Similarly, the parameters of Banff National Park required are shown in Table 3.

Table 3. Parameters of Banff National Park

Parameter	Value	Parameter	Value
z_t	40	t_i	3
r	5.0	A	0.8
η	0.3	α	0.4
$I(t)$	0.7	ϕ	0.6
$C(t)$	240	S_i	0.85

And the optimized parameters are shown in Table 4. The government's best course of action is to increase tourist numbers ($z_t^* \uparrow$) through controlled tourism intensity ($I(t)^* \uparrow$) and investments in natural attractions ($A^* \uparrow$), implement a balanced tourism tax ($t_i^* \uparrow$) to fund conservation efforts ($\eta^* \uparrow$) and infrastructure development, ensure economic growth while preserving the park's ecological integrity ($r^* \downarrow$), and create a sustainable future for both visitors and residents by avoiding the "low-tourism trap."

Table 4. Optimized parameters of Banff National Park

Parameter	Value	Parameter	Value
z_t^*	65	t_i^*	5
r^*	4.5	A^*	1.1
η^*	0.4	α^*	0.5
$I(t)^*$	1.0	ϕ^*	0.7
$C(t)^*$	65	S_i^*	0.92

4. Conclusion

In this study, this essay constructs a comprehensive sustainable tourism model that aims to maximize social welfare by balancing economic development, environmental protection and resident satisfaction. We adapted the classic Ramsey optimal growth model and combined the methods of EWM-AHP, TOPSIS and tax optimization theory to successfully quantify the complex relationship between the number of tourists, the consumption of natural resources and community well-being. Application of the model to the City of Juneau shows that an optimal visitor capacity of approximately 1.63 million visitors maximizes overall benefits while ensuring ecological and social stability.

Furthermore, by extending the model's environmental parameters-for example, replacing the glacier retreat rate with a generalized resource depletion rate-we demonstrate the model's adaptability to different geographic contexts, covering both over-touristed (e.g., Kyoto) and under-touristed (e.g., Banff) destinations. This highlights the broad applicability of the model as a strategic tool for regional tourism planning.

The research results indicate that the development of sustainable tourism requires dynamic management of tourist flows based on data, and the re-investment of tourism taxes into environmental protection, infrastructure construction, etc. However, the model still has some limitations and drawbacks: This model relies on high-quality data and may encounter the problem of local optimal solutions during the optimization process. This calls for caution when interpreting the results and necessitates improvements in future research.

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