An Exploration of Tourism Development Based on Genetic Algorithm and EWM-CRITIC

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Abstract. The purpose of this paper is to explore the tourism development model based on genetic algorithm and EWM-CRITIC to cope with the situation facing sustainable tourism development. The STD model is constructed to measure the level of sustainable development of tourism by considering the economic income data, environmental status indicators, residents' quality of life parameters and resource accommodation thresholds. In the study, genetic algorithm is used to optimize the model, entropy weight CRITIC (EWM - CRITIC) method is used to evaluate and model different factors, and economic data dimensions, ecological and environmental vectors, and social and livelihood matrices and their interrelationships are considered to construct the Sustainable Tourism Development Index (STDI). The advantage of this study is that the established STD model is comprehensive and universal, and the sustainable development level of tourism in other regions can be measured by adjusting parameters or indicators. At the same time, the model is adjusted according to the actual situation of different regions, which improves the adaptability of the model.

Keywords: STD model, EWM – CRITIC, genetic algorithm.

1. Introduction

This paper focuses on the tourism development situation [1], takes the over-touristed area as the research object, and constructs the STD model to measure the level of sustainable tourism development by comprehensively applying the computer-related algorithms, such as Genetic Algorithm [2] and EWM - CRITIC [3]. Through this model, the influence of factors such as the number of tourists, additional income expenditure and distribution on local sustainable tourism was studied [4]. Meanwhile, the genetic algorithm was used to optimize the model and clarify the key factors. And the model was applied to other regions to adjust the parameters according to the actual situation and explore the sustainable tourism development strategies in different regions [5]. The advantage of the research in this paper is that the constructed STD model is comprehensive and general, which provides an effective and scalable method for the sustainable development of tourism in different regions [6].

2. Sustainable Tourism Analysis

2.1. Calculation of Sustainable Tourism Development Index Based on STD Modeling

2.1.1. Tourism Sustainability Index

The Sustainable Tourism Development Index (STDI) is an important indicator for evaluating the level and prospects of sustainable tourism development and can be used to strike a better balance. It is a trade-off between economic, environmental and social perspectives. This paper uses a multi-objective optimization model that employs a methodological approach to assign different contributions from economic, environmental and social dimensions to the index.

$$STDI = \omega_1 \cdot GTI + \omega_2 \cdot TCF + \omega_3 \cdot RHI + \omega_4 \cdot SRCC \tag{1}$$

The model is mainly determined by four variables in these three dimensions, i.e. Gross Tourism Income (GTI), Tourism Carbon Footprint (TCF), Resident Happiness Index (RHI) and Social Resource Carrying Capacity (SRCC).

2.1.2. Calculation of Gross Tourism Income

$$GTI = C \cdot N \tag{2}$$

This part simplifies the calculation of Gross Tourism Income (GTI) by directly multiplying the number of tourists in a year and the per capita tourism expenditure (C), which is a variable that can be derived to a specific value from the per capita tourism expenditure data of each region.

2.1.3. Calculation of Tourism Carbon Footprint

$$TCF = 0.623 \cdot GTI - (\alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot E_{TCF}^2) \tag{3}$$

This section measures the local carbon footprint in two ways. On the one hand, the consumption behavior of tourists directly contributes to the increase of carbon footprint; on the other hand, the part of additional tax revenue used by the government for environmental protection plays an important role in reducing the carbon footprint.

(1) Tourist Consumption Behavior

It is assumed that the carbon emissions of tourists are basically the same throughout the consumption process of tourism products. It can be calculated and compared in a uniform manner. The main factors affecting carbon emissions from tourism activities are tourist arrivals, tourism consumption levels and energy consumption of tourism-related industries. The calculation method is as follows:

$$TCF_1 = CO_2 \cdot Y \tag{4}$$

Where TCF_1 is the carbon footprint of tourism generated by tourists in that year, and Y is the total tourism income in that year, i.e. GTI. and is the carbon dioxide emission intensity of the tourism industry, and CO_2 is 0.623 kilograms per dollar.

So, the equation ends up as:

$$TCF_1 = 0.623 \cdot GTI \tag{5}$$

(2) Environmental Expenditures

This section starts with an analysis of individual utility maximization to obtain a significant positive correlation between government expenditures on environmental protection in terms of carbon footprint, and finally constructs a suitable model to fit the entire carbon footprint.

This section use $U(\bullet)$ to represent an individual's instantaneous utility, $C(t)$ to denote the level of individual consumption, $CF(t)$ to denote the level of carbon footprint, EU to denote energy use, and ρ to denote the discount rate of one's subjective time preference, which is the rate at which an individual discounts the relative importance of a future event when evaluating future gains or losses. Then U has a positive correlation with $C(t)$ and a negative correlation with TCF. Considering that in continuous time, the total individual utility is:

$$W = \int_0^\infty U(C,P) \cdot e^{-\rho \cdot t} dt \tag{6}$$

To examine the dynamics of individual utility, the following section will examine the dynamics of TCF and energy reserves. To finally get the role of government environmental protection expenditure in reducing carbon footprint, this section introduces the variables E_{TCF} for the Expenditure on TCF generated by additional revenue (E_{TCF}) and δ for CO_2 the rate of decay of reserves. Then the dynamics of TCF and s is:

$$\overline{TCF} = \varepsilon \cdot EU - \mu \cdot E_{TCF} - \delta \cdot TCF \tag{7}$$

$$\bar{s} = -E \tag{8}$$

Next, examine the individual utility maximization decision:

$$max \int_0^\infty U[C(t),TCF(t)] \cdot e^{-\rho \cdot t} dt \quad (9)$$

$$s.t. \begin{cases} TCF = \varepsilon \cdot EU - \mu \cdot E_{TCF} - \delta \cdot TCF \\ \bar{s} = -EU \\ TCF(0) = TCF_0 > 0 \\ s(0) = s_0 > 0 \end{cases} \quad (10)$$

Here constructs the present value Hamiltonian function:

$$H = U(C,TCF) + \lambda_1 \cdot (\varepsilon \cdot EU - \mu \cdot E_{TCF} - \delta \cdot TCF) + \lambda_2 \cdot (-EU) \quad (11)$$

Here λ_1 and λ_2 are Lagrange multipliers. From the Lagrange multiplier maximization condition, the individual utility is maximized when $\frac{\partial H}{\partial E_{TCF}} = \frac{\partial H}{\partial EU} = 0$.

From $\frac{\partial H}{\partial E_{TCF}} = 0$ we get:

$$\frac{\partial H}{\partial TCF} \cdot \frac{\partial TCF}{\partial E_{TCF}} - \lambda_1 \cdot \mu - \lambda_1 \cdot \delta \cdot TCF \cdot \frac{\partial TCF}{\partial E_{TCF}} = 0 \quad (12)$$

Thus (office):

$$\frac{\partial TCF}{\partial E_{TCF}} = \frac{-\lambda_1 \cdot \mu}{\lambda_1 \cdot \delta \cdot TCF - U'_{TCF}} \quad (13)$$

Where, since U is negatively correlated with CF, U'_{TCF} is constant negative, then $\frac{\partial TCF}{\partial E_{TCF}}$ is constant negative. From this, it can be concluded that government spending on environmental protection can bring about a reduction in carbon footprint. On this basis, construct the model:

$$TCF_2 = \alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot {E_{TCF}}^2 \quad (14)$$

(3) Least Squares (Estimates)

The least squares method is used here to determine the coefficients in the model. Assume that the carbon footprint of period i is $TCFi$ and the expenditure on environmental protection is E_{TCFi}. Consider the error function:

$$L = \sum_{i=1}^{m} \{TCF_i - [(0.623 \cdot GTI - (\alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot E_{TCF}^2)]\}^2 \quad (15)$$

2.1.4. Calculation of the Population Happiness Index

$$RHI = \frac{W \cdot T}{H \cdot G \cdot U \cdot S \cdot (CPI \cdot 100)} \quad (16)$$

Where W is the income index, T is the transportation facility accessibility index, H is the environmental pollution index, G is the Gini coefficient, U is the unemployment rate, S is the tourism risk index, and I is the consumer price index, which needs to multiply by 100.

2.1.5. Calculation of the Carrying Capacity of Social Resources

$$SRCC = \frac{TRLI}{TRCI} \quad (17)$$

To measure the sustainability index of tourism in a tourist city, this section considers constructing an indicator SRCC to measure the city's tourism resource carrying capacity.

(1) Determination of Indicators

In terms of social resources, this paper considers the number of tourists, N, as an indicator of the consumption of social resources, which incorporates factors such as pressure on infrastructure, and uses the portion of additional revenues from taxes that are spent on infrastructure development, E_{IP}, and the employment rate in the local tourism industry, $0.2(1-u)$ (u is the unemployment rate, and 0.2 is the ratio of employment in the tourism industry to employment), to represent the social resource

Carrier. As for natural resources, this paper mainly considers the local glacier melt rate (GMV) and glacier stock (GS).

(2) Determination of GMV

The rate of glacier ablation is mainly determined by the regional temperature.

$$GMV = k \cdot T^{\phi} + \tau \tag{18}$$

Here k represents the sensitivity coefficient of glacier to temperature change, T is the regional temperature, β represents the accelerating effect of temperature on glacier melting, and τ is the background melting rate, i.e., the part that is not affected by temperature. This paper finally deduces that:

$$GMV = 0.147 \cdot ln(66.13 \cdot N + 1) - 0.372 \tag{19}$$

(3) SRCC Expression

Based on the above discussion, the following model was developed:

$$SRCC = \frac{\gamma_1 \cdot N + \gamma_2 \cdot GMV}{\beta_1 \cdot E_I + \beta_2 \cdot 0.2 \cdot (1-u) + \beta_3 \cdot GS} \tag{20}$$

Where N is the number of tourists, this paper argues that it shows a linear relationship with the consumption of social resource pressure, so here use N to denote the social resource load. GMV is the glacier melting rate.α_1, α_2 are the weight of N vs. GMV in measuring $TRLI. E_I$ portion of additional expenditure on infrastructure development for tax purposes, $0.2(1-u)$ is the share of local tourism services employment in the total population and GS is the glacier stock. β_1, β_2 *and* β_3, respectively, are the weights of E_I, $0.2(1-u)$ *and* GS in measuring $SRCC$.

2.1.6. Total Expenditure for Calculation of Additional Income

$$TE = E_{TCF} + E_{RHI} + E_{SRCC} \tag{21}$$

Based on the **assumption** that Total Expenditure (TE) generated by the additional revenue are fully utilized for environmental conservation (lowering Tourism Carbon Footprint (TCF)), community programs building (improving the Resident Happiness Index (RHI) and infrastructure improvements (increasing Social Resource Carrying Capacity ($SRCC$).

2.2. Constraint- Based Expenditure Plan (CBEP)

This part of the overall use of multi-objective optimization ideas, through Entropy Weight Method (EWM) and Criteria Importance Through Intercriteria Correlation of the four objectives to give a weight, converted into a single objective.

First, according to the local tourism-related data, the least squares regression model and AHP model were used to calculate the internal coefficients of each objective.

Secondly, the evaluation weights of the four objectives on STDI were found respectively.

Lastly, after finding the weights $\omega_1, \omega_2, \omega_3, \omega_4$, the optimal number of tourists and the optimal expenditure allocation plan to TCF, RHI, and $SRCC$ are found by maximizing the $STDI$.

$$STDI = \omega_1 \cdot GTI + \omega_2 \cdot TCF + \omega_3 \cdot RHI + \omega_4 \cdot SRCC \tag{22}$$

Of these, the average spending of tourists is shown in Fig. 1.

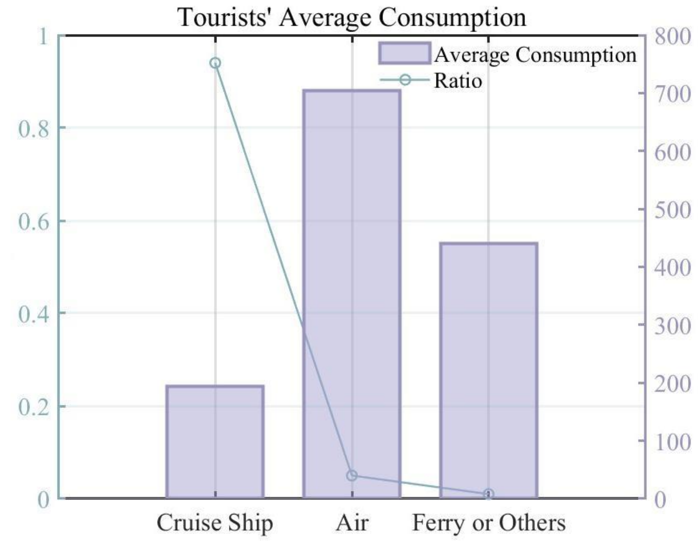

Figure 1. Average tourist spending

2.2.1. Internal Coefficients to be Assessed for Each Objective

Average expenditures by category are shown in Fig. 2.

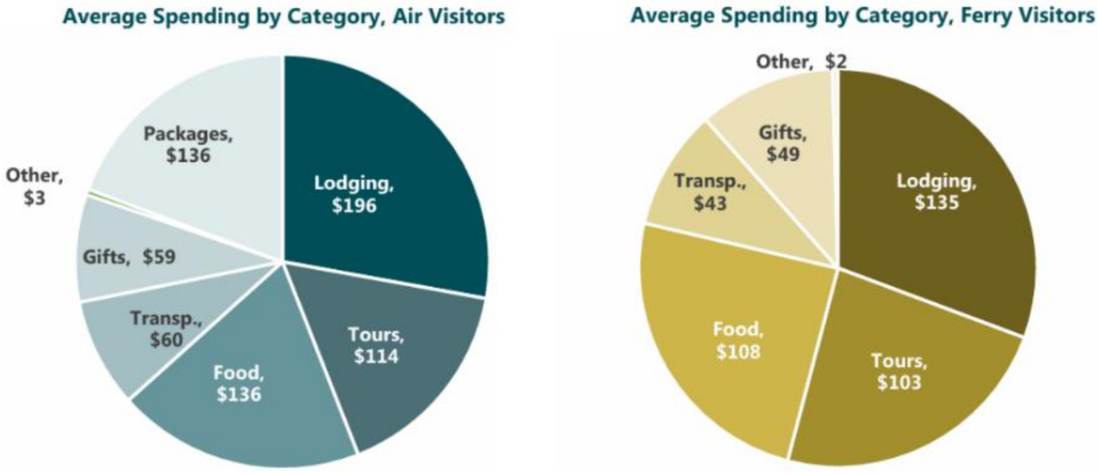

Figure 2. Average expenditure by category

GTI:

$$GTI = C \cdot N \rightarrow C \tag{23}$$

TCF:

$$TCF = \alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot {E_{TCF}}^2 \rightarrow \alpha_0, \alpha_1, \alpha_2 \tag{24}$$

SRCC:

$$TRCI = \beta_1 E_I + \beta_2 \cdot 0.2(1-u) + \beta_3 GS \rightarrow \beta_1, \beta_2, \beta_3 \tag{25}$$

$$TRLI = \gamma_1 \cdot N + \gamma_2 \cdot GMV \rightarrow \gamma_1, \gamma_2 \tag{26}$$

(1) Calculate C

$$GTI = C \cdot N \tag{27}$$

Visitor ratio:

$$cruise\ ship : air : ferry\ or\ others = 94:5:1 \tag{28}$$

$$\begin{aligned} &\textit{Average consumption of cruise ship tourists} \\ &= \frac{\textit{total consumption of cruise ship tourists}}{\textit{number of cruise ship visitors}} \\ &= \frac{320,000,000}{16500,000} = \$194 \end{aligned} \tag{29}$$

So:

$$C = 194 \times 94\% + 704 \times 5\% + 440 \times 1\% = \$217.6 \tag{30}$$

(2) Calculate $\alpha_0,\ \alpha_1,\ \alpha_2$

The least squares method is used here to determine the coefficients in the model. Assume that the carbon footprint of period i is TCF_i and the expenditure on environmental protection is E_{TCFi}. Minimize the error function:

$$L_{min} = \sum_{i=1}^{m}\{TCF_i - [(0.623 \cdot GTI - (\alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot E_{TCF}^2)]\}^2 \tag{31}$$

After regression with Stata 17 (which is the only regression), the final output is:

$$\alpha_1 = -1174.3845, \alpha_2 = 156.0584, \alpha_3 = -5.1346 \tag{32}$$

(3) Calculate $\beta_1,\ \beta_2,\ \beta_3$

Here uses hierarchical analysis to determine the indicator weights.

It is required to measure the relative importance of each indicator in terms of residents' opinions, and the comparison matrix that can be derived after pairwise comparisons between indicators U.

$$U = (u_{ik})_{3*3} = \begin{pmatrix} u_{11} & u_{12} & u_{13} \\ u_{21} & u_{22} & u_{23} \\ u_{31} & u_{32} & u_{33} \end{pmatrix} \tag{33}$$

According to the analytic hierarchy process, the weights of each load indicator can be calculated by the following equation:

$$\lambda_i = \frac{\overline{W_i}}{\sum_{i=1}^{3} W_i} \tag{34}$$

Included among these:

$$\overline{W_i} = \sqrt[3]{\overline{M_i}} \tag{35}$$

$$M_i = \prod_{k=1}^{3} u_{ik} \tag{36}$$

Eventually this paper gets the respective weights of infrastructure expenditure, tourism services employment, and glacier stock as 58.126%, 10.959%, and 30.915%.

The result is:

$$\beta_1 = 58.126\%, \beta_2 = 10.959\%, \beta_3 = 30.915\% \tag{37}$$

(4) Calculate $\gamma_1,\ \gamma_2$

Considering that the weights of infrastructure expenditure, employment in tourism services, and glacier stock are 58.126%, 10.959%, and 30.915% respectively, this paper believe that the weights of social resource pressure and glacier depletion should be assigned to 0.67 and 0.33 respectively.

The result is:

$$\gamma_1 = 67\%, \gamma_2 = 33\% \tag{38}$$

2.2.2. Assessment Weights for the Four Goals ($\omega_1, \omega_2, \omega_3, \omega_4$)

This section combines two approaches: Entropy Weight Method (EWM) and Criteria Importance Through Intercriteria Correlation (CRITIC Weight Method)

1. Entropy Weight Method

Data standardization:

For the normalized matrix denoted Z.

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{39}$$

Since our objective function may have negative numbers.

$$\tilde{Z} = \frac{x - min\{x_{1j}, x_{2j}, \ldots, x_{nj}\}}{max\{x_{1j}, x_{2j}, \ldots, x_{nj}\} - min\{x_{1j}, x_{2j}, \ldots, x_{nj}\}} \tag{40}$$

Calculate the probability matrix P.

Calculating the weight of the ith sample under the jth indicator p_{ij}:

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}} \tag{41}$$

Calculating entropy weights:

$$e_j = -\frac{1}{lnn} \cdot \sum_{i=1}^{n} p_{ij} \cdot ln(p_{ij})\ (j = 1,2,\ldots,m) \tag{42}$$

$$d_j = 1 - e_j \tag{43}$$

$$w_j = \frac{d_j}{\Sigma_{j=1}^{m} d_j} \tag{44}$$

2. CRITIC Weight Method

This is an objective empowerment method. The idea lies in the use of two indicators, namely, comparison intensity and conflict indicators.

(1) Indicator Positive and Negative Processing:

There are M objects to be evaluated and N evaluation indicators, which can form the data matrix $X = (x_{ij})_{M \cdot N}$, and let the elements within the data matrix be x_{ij} after the positive and negative normalization process.

Positive indicator: $x_{ij} = \frac{x_{ij} - \min\{x_j\}}{\max\{x_j\} - min\{x_j\}}$;

Negative indicator: $x_{ij} = \frac{\max\{x_j\} - x_{ij}}{\max\{x_j\} - min\{x_j\}}$.

(2) Calculation of Comparison Intensity

Denote the strength of comparison of the ith indicator by the standard deviation σ_j:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{M}(x_{ij} - \bar{x}_j)}{M-1}} \tag{45}$$

(3) Calculation of Conflict Indicators

The magnitude of conflict between indicator j and the remaining indicators is f_j:

$$f_j = \sum_{i=1}^{M}(1 - r_{ij}) \tag{46}$$

(4) Calculation of Information Carrying Capacity

Setting indicator j and information carrying capacity as C_j:

$$C_j = \sigma_j \cdot f_j \tag{47}$$

(5) Calculation of CRITIC Weight

The greater the information carrying capacity, the greater the weight can be, and the weight is w_j:

$$w_j = \frac{C_j}{\sum_{i=1}^{N} C_j} \tag{48}$$

Eventually, the result is:

$(\omega_1 = 0.19098, \omega_2 = 0.28036, \omega_3 = 0.20075, \omega_4 = 0.3279)$.

2.2.3. Optimal Spending Plan

1.Target: Sustainable Tourism Development Index (STDI)

This paper will elucidate the expenditure plan for the additional income through the maximization of STDI and describe how these expenditures contribute to the feedback of the model to promote sustainable tourism:

$$max\, STDI = \omega_1 \cdot GTI + \omega_2 \cdot TCF + \omega_3 \cdot RHI + \omega_4 \cdot SRCC \tag{49}$$

2. Binding

(1) GTI

Ensure that there is a corresponding lower bound on the economic income generated by tourism.

$$GTI \geq GTI_{min} \tag{50}$$

(2) TCF

The carbon footprint should also have a corresponding upper limit.

$$TCF \leq TCF_{max} \tag{51}$$

(3) RHI

The residents' happiness index should have a corresponding lower limit.

$$RHI \geq RHI_{min} \tag{52}$$

(4) SRCC

The capacity of social resources should have a corresponding lower bound.

$$SRCC \geq SRCC_{min} \tag{53}$$

(5) N

An upper limit on the number of visitors must be determined.

$$N \leq N_{max} \tag{54}$$

(6) E_{TCF}, E_{RHI} and E_{SRCC}

The total expenditure for these three categories should not exceed the limit, and in addition, there should be a corresponding lower limit for the expenditure of additional income.

$$E_{min} \leq E_{TCF} + E_{RHI} + E_{SRCC} \leq E_{max} \tag{55}$$

3. Genetic algorithms for solving optimal solutions

Due to the construction of the $STDI$ involving numerous discrete decisions and the establishment of nonlinear functions, a genetic population is formed here as the individuals within the model. The planning objectives serve as the fitness function, which can be addressed through genetic algorithms and the adaptation of constraints to balance the number of tourists in sustainable tourism and the expenditure plan for additional income.

Combining the previous evaluations or regression analysis with the collected data, the results can be as shown in the table 1.

Table 1. Solution Results

Variable	N	E_{TCF}	E_{RHI}	E_{SRCC}
Value	1, 561, 210	\$2, 224, 496	\$2, 224, 480	\$2, 888, 712

3. Further Applications of the STD Model

3.1. Model Improvement

The indicator SW was introduced to represent solid waste and each equation in the original model was optimized as follows.

$$TCF = -(\alpha_0 + \alpha_1 \cdot E_{TCF} + \alpha_2 \cdot {E_{TCF}}^2) + \gamma \cdot GTI + \eta SW \tag{56}$$

η Indicates the cost of disposal per unit of solid waste.

$$SRCC = \frac{TRLI}{TRCI} \tag{57}$$

$$TRLI = \gamma_1 \cdot N + \gamma_2 SW \tag{58}$$

$$TRCI = \beta_1 \cdot E_{IP} + \beta_2 \cdot 0.2 * (1 - U) + \beta_3 E_{TCF} \tag{59}$$

In TRLI, SW replaces glacier melt rate in the original model; in $TRCI$, E_{TCF} replaces glacier stock. This change allows the $SRCC$ indicator to closely reflect the local resource carrying capacity.

$$STDI = \omega_1 \cdot GTI + \omega_2 \cdot TCF + \omega_3 \cdot RHI + \omega_4 \cdot SRCC \tag{60}$$

$$GTI = C \cdot N \tag{61}$$

$$RHI = \frac{GTI \cdot E_{RHI}}{TCF \cdot G \cdot U \cdot (CPI \cdot 100)} \tag{62}$$

3.2. Solving the Model

With the introduction of the new metrics, the genetic algorithm will be equally applied to optimize the STDI for Venice.

Combining the previous assessments or regression analyses with the collected data, the results can be shown in table 2.

Table 2. Solution Results

Variable	N	E_{TCF}	E_{RHI}	E_{SRCC}
Value	5, 217, 705	\$6, 475, 325	\$11, 572, 789	\$6, 475, 099

4. Conclusion

Based on genetic algorithm and EWM-CRITIC, this paper explores tourism development in depth. In terms of research methodology, the STD model is constructed by considering multiple factors such as tourism income and environmental protection. The Sustainable Tourism Development Index (STDI) is constructed by combining economic, ecological, and social relations, using the improved RHI calculation method, borrowing the TRCC calculation method, and evaluating the modeling with the entropy CRITIC method, and then optimizing it with the genetic algorithm. The core achievement is to clarify the relationship between the number of tourists, the distribution of additional income and expenditure and sustainable tourism. As for the application of the model, the STD model was successfully applied to specific cities, and the optimal solution was obtained by adjusting it according to the local reality. The study provides a quantitative analysis tool for sustainable tourism development, and its comprehensive and generalized STD model can help to formulate reasonable tourism development strategies for different regions and help to balance the distribution of tourists.

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