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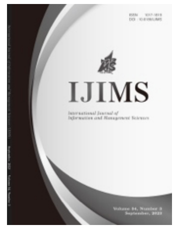

Fuzzy Evaluation Model based on Environmental Sacrifice Willingness in Online Travel Booking Platform (OTBP) for Green Tourism

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Keywords

Online travel booking platform; Green tourism; Environmental sacrifice willingness index; Corporate social responsibility; Fuzzy evaluation model

Abstract

Given the impact of global warming on Earth's environment, finding ways for humans to coexist with nature has become crucial. Beyond the manufacturing sector, various service and tourism industries also need to embrace corporate social responsibility (CSR) and contribute to efforts aimed at mitigating global warming. Therefore, urging green tourism to reduce ecological burdens caused by travel has gradually become a key issue for governments and the tourism industry worldwide. Online travel booking platform (OTBP) use digital tools to better coordinate and optimize travel resources, thereby minimizing fuel consumption and carbon emissions for achieving green tourism. When consumers use OTBP for green tourism, the willingness of related stakeholders and residents in tourist attractions to make environmental sacrifices is a critical factor in success. Therefore, this paper presents an environmental sacrifice willingness index (EI), derived from the environmental sacrifice willingness scale, to assess residents' readiness to make environmental sacrifices. Due to the index containing an unknown parameter, estimation must be conducted using sample data. Furthermore, the confidence interval of the environmental sacrifice willingness index is utilized to develop a fuzzy evaluation model for the environmental sacrifice willingness in green tourism based on recommendations from some studies. This fuzzy evaluation

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method can aid government agencies in promoting green tourism by assessing residents' willingness to make environmental sacrifices. If the results show that residents' willingness does not meet the necessary goals, it will be essential to propose countermeasures and plans to boost their willingness. This approach will enhance the effectiveness of encouraging green tourism and help tourism operators fulfill their social responsibility.

1. Introduction

As humans confront the effects of global warming on Earth, learning to coexist with the natural environment has become a crucial issue for all of us (Lura et al., 2025; Nikfar et al., 2025; Saikia et al., 2025). Moreover, addressing how to achieve economically and environmentally sustainable development is a serious topic that must be tackled collectively by governments and businesses worldwide (Islam, 2025; da Silva et al., 2025). Numerous studies have devoted themselves to issues related to the sustainable development of the manufacturing industry, establishing models for evaluation, analysis, and improvement of manufacturing process quality. These models assist the industry in boosting manufacturing product quality and efficiency, ultimately leading to energy savings and waste reduction. This also helps businesses fulfill their corporate social responsibility (CSR) while reducing their impact on society and the ecological environment (Chen et al., 2009; Yu et al., 2007; Chen & Chen, 2004).

Many studies indicate that human behavior is the root cause of rapid global climate change and various environmental problems. Therefore, it is essential to identify the motivations that drive human interaction with the natural environment (Sinha et al., 2024; Song et al., 2024; Carfora et al., 2024). In addition to the manufacturing industry, various service industries and institutions must also fulfill their corporate social responsibility and contribute their efforts to mitigating global warming (Laachach & Alhemimah, 2024; Tok et al., 2024). According to the study by Davis et al. (2011), empirical studies concerning the relationship between humans and the environment have been increasingly on the rise in recent years. Additionally, the study conducted by Arnocky et al. (2007) demonstrated that individuals with a higher level of self-construction regarding all living beings tend to exhibit more environmentally protective behaviors. The willingness to sacrifice for the environment reflects the extent to which individuals consider environmental welfare (Davis et al., 2011; Bökman et al., 2021). In other words, the more individuals pay attention to environmental welfare, the greater their willingness to make sacrifices for it.

As previously mentioned, in the context of global warming, companies must fulfill its CSR to mitigate the ecological burden associated with them. In various industries, there is an interactive relationship between tourism and the ecological environment. If the environment is damaged, the tourism appeal will be significantly reduced, which in turn affects the local economic development. Consequently, the promotion of green tourism has increasingly become a significant priority for governments and the tourism industry in various countries. Online travel booking platform (OTBP) is a digital tool designed to better coordinate and optimize travel resources, contributing to the realization of green tourism. By utilizing advanced technology, such platforms help reduce the environmental impact of travel by offering sustainable options, promoting eco-friendly accommodations, and encouraging low-carbon transportation choices. The success of these green tourism initiatives will largely depend on the "willingness to sacrifice for the environment" among relevant stakeholders and local residents at these tourist attractions.

Several studies point out that establishing performance evaluation models for various service operation systems can assist managers in identifying and improving service items that require enhancement, thereby boosting the operational performance of these systems (Chen & Chen, 2014; Chen & Yu, 2020). Clearly, developing a performance evaluation analysis model for the promotion of green tourism will enable the government to enhance the effectiveness of its green tourism initiatives. Since "willingness to sacrifice for the environment" is one of the key factors in the success of green tourism, this paper adopts a five-item scale to measure "willingness to sacrifice for the environment" based on the research by Jody et al. (2011) to gauge whether individuals are willing to prioritize environmental welfare over their own needs. The five items of the scale are described as follows:

1. I am willing to give things up that I like doing if they harm the natural environment.

2. I am willing to take on responsibilities that will help conserve the natural environment.

3. I am willing to do things for the environment, even if I'm not thanked for my efforts.

4. Even when it is inconvenient to me, I am willing to do what I think is best for the environment.

5. I am willing to go out of my way to do what is best for the environment.

Given that the index possesses an unknown parameter, it must be estimated using sample data (Chen et al., 2022; Yang & Chen, 2019). In addition, residents' willingness to sacrifice for the environment is often ambiguous, leading to uncertainty regarding the interviewees' true willingness. As a result, the sample size is typically not very large. Therefore, this paper utilizes the confidence interval of the environmental sacrifice willingness index to develop a fuzzy evaluation model for this index in the context of green tourism, drawing on suggestions from several studies (Chukhrova & Johannssen, 2022; Chen, & Lin, 2022). This fuzzy evaluation method can assist the OTBP entities responsible for promoting green tourism in evaluating residents' willingness to sacrifice for the environment. If the evaluation results show that residents' willingness to sacrifice for the environment does not meet the required target, then strategies and plans must be proposed to increase their willingness. Only in this way can the performance of green tourism initiatives be enhanced, thereby enabling tourism operators to fulfill their social responsibilities. Based on the above, the advantages of this article are as follows: (1) It proposes fuzzy testing for indicators based on confidence intervals to reduce the risk of misjudgment caused by sampling errors. (2) The adopted fuzzy method can incorporate past data experience, thereby improving the accuracy of evaluations. (3) This fuzzy evaluation method can assist government agencies in fostering green tourism by evaluating how willing residents are to make sacrifices for the environment. (4) This method can aid the OTBP in advancing green tourism by assessing the willingness of local residents to make environmental sacrifices. (5) This approach will improve the promotion of green tourism and support tourism operators in meeting their social responsibility obligations.

The subsequent sections of this paper are structured as follows. In Section 2, the previously mentioned five-item environmental sacrifice willingness scale is employed to construct an environmental sacrifice willingness index, examining the underlying characteristics of this index. In Section 3, the paper derives the 100% confidence interval for the environmental sacrifice willingness index, utilizing this interval to formulate a fuzzy evaluation model. Section 4 presents a case study to demonstrate the practical application of the fuzzy evaluation model developed in this research. Finally, Section 5 concludes the paper by summarizing the key findings.

2. Environmental Sacrifice Willingness Index

According to Chen et al. (2018), the previously discussed environmental sacrifice willingness (k) and its corresponding scale, as applied to green tourism, this paper proposes an environmental sacrifice willingness index for green tourism as follows:

$$EI = \frac{\theta - 1}{R} \tag{1}$$

where $R = k - 1$, and $\theta = (\mu_1 + \mu_2 + \mu_3 + \mu_4 + \mu_5)/5$, which represents the average value of five means pertaining to environmental sacrifice willingness in the context of green tourism. A higher average value corresponds to a greater *EI*. Using a 7-point scale as an example, the maximum value of the average θ is 7 while the minimum is 1. Therefore, the *EI* is constrained to a range between 0 and 1 ($0 \le EI \le 1$). Conversely, when the value of the *EI* equals 0, it indicates that residents have no willingness to sacrifice for the environment in the context of green tourism. When *EI* equals 1, it demonstrates that residents have a 100% willingness to sacrifice for the environment in green tourism. Obviously, when the government promotes green tourism at a certain scenic spot, the *EI* fully reflects the residents' willingness to sacrifice for the environment in the context of green tourism. If their willingness is not high, it is imperative for the government to come up with improved countermeasures and plans.

According to Chen et al. (2022), since the index has an unknown parameter of θ, it must be estimated from sample data. Let $X_{h,1},\ldots,X_{h,j},\ldots,X_{h,n}$ represent a random sample for item h, with a sample size of n, where $h = 1, 2,\ldots,5$. Then, the nature estimator for the *EI* can be expressed as follows:

$$EI^* = \frac{\bar{\bar{X}} - 1}{R} \tag{2}$$

where $\bar{\bar{X}}$ denotes the overall sample mean as follows:

$$\bar{\bar{X}} = \frac{1}{5n} \times \sum_{h=1}^{5} \sum_{j=1}^{n} X_{h,j} \tag{3}$$

The expected value of the overall sample mean is defined as follows:

$$\begin{aligned} E\left[\overline{\overline{X}}\right] &= E\left[\frac{1}{5n}\times\sum_{h=1}^{5}\sum_{j=1}^{n}X_{h,j}\right] \\ &= \frac{1}{5}\times\sum_{h=1}^{5}\left(\frac{1}{n}\sum_{j=1}^{n}E\left[X_{h,j}\right]\right) \\ &= \frac{1}{5}\times\left(\mu_1+\mu_2+\mu_3+\mu_4+\mu_5\right) \\ &= \theta \end{aligned} \tag{4}$$

According to the above formula, the expected value of the overall sample mean is equal to θ, then the expected value of the estimator EI^* is equivalent to the value of the *EI*. Consequently, EI^* serves as an unbiased estimator of the *EI*, denoted by $E\left[EI^*\right]=EI$. Similarly, the standard deviation of the unbiased estimator EI^* is expressed as follows:

$$\sigma_{EI^*}=\sqrt{Var\left[EI^*\right]}=\sqrt{\frac{Var\left[\overline{\overline{X}}\right]}{R^2}}=\frac{\sigma_{\overline{\overline{X}}}}{R} \tag{5}$$

Let the standardized random variable *Z* be defined as follows:

$$Z=\frac{EI^*-EI}{S_{EI^*}/\sqrt{5n}} \tag{6}$$

where $S_{EI^*}=S_{\overline{\overline{X}}}/R$ and $S_{\overline{\overline{X}}}$ represents the overall sample standard deviation. In addition, the estimator of $\sigma_{\overline{\overline{X}}}$ is expressed as follows:

$$S_{\overline{\overline{X}}}=\sqrt{\frac{1}{5n}\times\sum_{h=1}^{5}\sum_{j=1}^{n}\left(X_{h,j}-\overline{\overline{X}}\right)^2} \tag{7}$$

According to the central limits theorem (*CLT*), the distribution of the random variable *Z* approximates a standard normal distribution, denoted by $Z\xrightarrow[n>>0]{CLT}N(0,1)$ (Pishro-Nik 2014; Hogg & Tanis 2001). Adhering to the above principle, this paper derived the $100(1-\alpha)\%$ confidence interval of the *EI* below:

$$\begin{aligned} & p\left(-z_{\alpha/2}\le Z\le z_{\alpha/2}\right)=1-\alpha \\ \Rightarrow\ & p\left(-z_{\alpha/2}\le\frac{EI^*-EI}{S_{EI^*}/\sqrt{5n}}\le z_{\alpha/2}\right)=1-\alpha \\ \Rightarrow\ & p\left(EI^*-z_{\alpha/2}\frac{S_{EI^*}}{\sqrt{5n}}\le EI\le EI^*+z_{\alpha/2}\frac{S_{EI^*}}{\sqrt{5n}}\right)=1-\alpha \end{aligned} \tag{8}$$

where $z_{\alpha/2}$ denotes the upper $\alpha/2$ quantile of the standard normal distribution. Therefore, $\left[L_{EI},\ U_{EI}\right]$ represents the $100(1-\alpha)\%$ confidence interval of the environmental sacrifice willingness index (*EI*), defined as follows:

$$L_{EI}=EI^*-z_{\alpha}\frac{S_{EI^*}}{\sqrt{5n}} \tag{9}$$

$$U_{EI} = EI^* + z_\alpha \frac{S_{EI^*}}{\sqrt{5n}} \tag{10}$$

3. Fuzzy Testing Method of Environmental Sacrifice Willingness Index

To determine whether the value of the *EI* is greater than or equal to V, the null hypothesis H_0 and the alternative hypothesis H_1 at the significance level α are outlined below:

null hypothesis H_0: $EI \geq V$ (This indicates that local residents have a strong willingness to sacrifice for the environment in the context of green tourism.)

alternative hypothesis H_1: $EI < V$ (This indicates that local residents do not have a strong willingness to sacrifice for the environment in the context of green tourism.)

Let $x_{h,1},\dots,x_{h,j},\dots,x_{h,n}$ be the observed values of $X_{h,1},\dots,X_{h,j},\dots,X_{h,n}$. Then the observed values of $\bar{\bar{X}}$ and $S_{\bar{\bar{X}}}$ are defined respectively as follows:

$$\bar{\bar{x}} = \frac{1}{5n} \times \sum_{h=1}^{5}\sum_{j=1}^{n} x_{h,j} \tag{11}$$

and

$$s_{\bar{\bar{X}}} = \sqrt{\frac{1}{5n} \times \sum_{h=1}^{5}\sum_{j=1}^{n}\left(x_{h,j} - \bar{\bar{x}}\right)^2} \tag{12}$$

Based on the statistical testing rules outlined above and the method introduced by Chen and Yu (2020), this paper developed a fuzzy testing method based on the observed values of the lower confidence limit and the upper confidence limit for the EI. The observed value of L_{EI} and U_{EI} are L_{EI0} and U_{EI0}, defined respectively as follows:

$$L_{EI0} = EI_0^* - z_{\alpha/2} \frac{S_{EI_0^*}}{\sqrt{5n}} \tag{13}$$

$$U_{EI0} = EI_0^* + z_{\alpha/2} \frac{S_{EI_0^*}}{\sqrt{5n}} \tag{14}$$

where EI_0^* and $S_{EI_0^*}$ are the observed values EI^* and S_{EI^*}, described respectively as follows:

$$EI_0^* = \frac{\bar{\bar{x}} - 1}{R} \tag{15}$$

and

$$s_{EI_0^*} = \frac{s_{\bar{\bar{X}}}}{R} \tag{16}$$

This paper adopted the observed values U_{EI0} to establish statistical testing rules as follows:

If $U_{EI0} \geq V$, then do not reject H_0 and conclude that $EI \geq V$. This shows that local residents have a strong willingness to sacrifice for the environment in the context of green tourism, suggesting that there is no need to propose improvement measures and plans.

If $U_{EI0} < V$, then reject H_0 and conclude that $EI < V$. This indicates that residents do not have a strong willingness to sacrifice for the environment in the context of green tourism, suggesting that it is necessary to come up with improvement measures and plans. As described by Chen (2019), the α-cuts of the triangular-shaped fuzzy number EI_0^* can be calculated as follows:

$$EI_0^*[\alpha] = \begin{cases} \left[EI_{01}^*(\alpha), EI_{02}^*(\alpha)\right], \textit{for } 0.01 \leq \alpha \leq 1 \\ \left[EI_{01}^*(0.01), EI_{02}^*(0.01)\right], \textit{for } 0 \leq \alpha \leq 0.01 \end{cases} \tag{17}$$

where

$$EI_{01}^*(\alpha) = EI_0^* - z_{\alpha/2}\frac{S_{EI_0^*}}{\sqrt{5n}} \tag{18}$$

and

$$EI_{02}^*(\alpha) = EI_0^* + z_{\alpha/2}\frac{S_{EI_0^*}}{\sqrt{5n}} \tag{19}$$

Obviously, when $\alpha = 1$, then $z_{\alpha/2} = 0$, and $EI_{01}^*(1) = EI_{02}^*(1) = EI_0^*$. The fuzzy number is denoted by $EI_0^* = \Delta(EI_L, EI_0^*, EI_R)$, where $EI_L = EI_{01}^*$ (0.01) and $EI_R = EI_{02}^*$ (0.01) can be expressed as follows:

$$EI_L = EI_0^* - z_{0.005}\frac{S_{EI_0^*}}{\sqrt{5n}} \tag{20}$$

and

$$EI_R = EI_0^* + z_{0.005}\frac{S_{EI_0^*}}{\sqrt{5n}} \tag{21}$$

Thus, the membership function of EI_0^* is defined as

$$\zeta(x) = \begin{cases} 0, \textit{ if } x < EI_L \\ \alpha_1, \textit{ if } EI_L \leq x < EI_0^* \\ 1, \textit{ if } x = EI_0^* \\ \alpha_2, \textit{ if } EI_0^* < x \leq EI_R \\ 0, \textit{ if } EI_R < x \end{cases} \tag{22}$$

where α_1 and α_2 are determined by $EI^*_{01}(\alpha_1)=x$ and $EI^*_{02}(\alpha_2)=x$ respectively. The fuzzy membership function $\zeta(x)$ and the vertical line $x= V$ are depicted in Fig. 1 below.

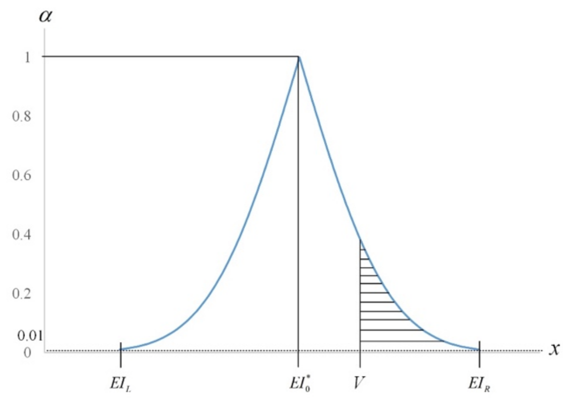

Fig.1 The Fuzzy Membership Function $\zeta(x)$ and the Vertical Line $x= V$

According to Chen and Yu (2021), let set ST be the area in the graph of the fuzzy membership function $\zeta(x)$ and set SR be the area in the graph of the fuzzy membership function $\zeta(x)$ but to the right of the vertical line $x= V$, then

$$ST=\left\{(x,\alpha)\middle| EI^*_{01}(\alpha)\le x\le EI^*_{02}(\alpha),0\le\alpha\le 1\right\} \tag{23}$$

and

$$SR=\left\{(x,\alpha)\middle| V\le x\le EI^*_{02}(\alpha),0\le\alpha\le a\right\} \tag{24}$$

where a such that $EI^*_{02}(a)= V$. According to Chen et al. (2019) and Eqs. (23) and (24), $d_R = EI_R - V$ and $d_T = EI_R - EI_L$. Then

$$\frac{d_R}{d_T}=\frac{EI_R-V}{EI_R-EI_L} \tag{25}$$

As noted by Chen et al. (2019), we can let $0< \phi \le 0.5$. The decision rules for the fuzzy testing method are explained below:

If $d_R/d_T \le \phi$, then reject H_0 and conclude that $EI\ge V$. This demonstrates that local residents have a strong willingness to sacrifice for the environment in the context of green tourism, indicating that there is no need to propose improvement measures or plans.

If $d_R/d_T > \phi$, then do not reject H_0 and conclude that $EI< V$. This means that local residents do not have a strong willingness to sacrifice for the environment in the context of green tourism, suggesting that it is necessary to develop improvement measures or plans.

4. An Application Example

Attempting to illustrate the application of the above model, this paper demonstrated the evaluation process with an example. Moreover, to determine whether the value of the EI exceeds or equals 0.6 (V = 0.6), the null hypothesis H_0 and the alternative hypothesis H_1 at the significance level $\beta = 0.01$ are explained below:

null hypothesis H_0: $EI \geq 0.6$ (This indicates that local residents have a strong willingness to sacrifice for the environment in the context of green tourism.)

alternative hypothesis H_1: $EI < 0.6$ (This reveals that local residents do not have a strong willingness to sacrifice for the environment in the context of green tourism.)

To evaluate residents' willingness to make sacrifices for the environment in the context of green tourism, 30 questionnaires were administered and collected (n=30). The observed values are $x_{h,1},\ldots,x_{h,j},\ldots,x_{h,30}$, h= 1, 2, 3, 4, 5 and the observed values of $\bar{\bar{X}}$ and $S_{\bar{\bar{X}}}$ are respectively calculated as follows:

$$\bar{\bar{x}} = \frac{1}{150} \times \sum_{h=1}^{5} \sum_{j=1}^{30} x_{h,j} = 4.310$$

and

$$s_{\bar{\bar{X}}} = \sqrt{\frac{1}{150} \times \sum_{h=1}^{5} \sum_{j=1}^{30} \left(x_{h,j} - \bar{\bar{x}} \right)^2} = 1.449$$

Next, the observed values of EI^* and S_{EI^*} are respectively calculated as follows:

$$EI_0^* = \frac{\bar{\bar{x}} - 1}{6} = 0.552$$

and

$$s_{EI_0^*} = \frac{s_{\bar{\bar{X}}}}{R} = 0.241$$

Based on Eq. (13) and Eq. (14), the observed values of the lower confidence limit and the upper confidence limit with 99% confidence level for the EI are derived as follows:

$$L_{EI0} = EI_0^* - 2.576 \times \frac{S_{EI_0^*}}{\sqrt{150}} = 0.501$$

$$U_{EI0} = EI_0^* + 2.576 \times \frac{S_{EI_0^*}}{\sqrt{150}} = 0.603$$

Given $EI_L = EI_{01}^*(0.01) = L_{EI0}$, $EI_L = 0.501$; given $EI_R = EI_{02}^*(0.01) = U_{EI0}$, $EI_R = 0.603$. Thus, the membership function of EI_0^* is defined as follows:

$$\zeta(x) = \begin{cases} 0, \ if \ x < 0.501 \\ \alpha_1, \ if \ 0.501 \le x < 0.552 \\ 1, \ if \ x = 0.552 \\ \alpha_2, \ if \ 0.552 < x \le 0.603 \\ 0, \ if \ 0.603 < x \end{cases}$$

Based on Eq. (23), Eq. (24) and Eq. (25), we have

$d_R = EI_R - 0.6 = 0.0028$

And

$d_T = EI_R - EI_L = 0.1016$

Then

$$\frac{d_R}{d_T} = \frac{EI_R - 0.6}{EI_R - EI_L} = 0.027$$

As noted by Chen et al. (2019), this paper assumes $\phi = 0.1$. According to the decision rules of fuzzy tests, if $d_R/d_T \le 0.1$, then reject H_0 and conclude that $EI < V$. This indicates that residents do not have a strong willingness to make sacrifices for the environment in green tourism, and therefore, OTBP is necessary to propose improvement strategies and plans.

5. Conclusions

OTBP use digital tools to better coordinate and optimize travel resources. To face global warming, promoting green tourism to reduce the ecological burden caused by tourism has gradually become a crucial issue for governments and the tourism industry worldwide. Since the willingness of tourism stakeholders and residents to make sacrifices for the environment is a critical factor in success, this paper established the *EI* using a five-item scale to evaluate residents' willingness to make sacrifices for the environment. When the value of the *EI* is equal to 0, it indicates that residents have no willingness to make sacrifices for the environment in the context of green tourism. Conversely, when the *EI* is equivalent to 1, it signifies that residents have a 100% willingness to make such sacrifices. Obviously, when OTBP promotes green tourism at a certain scenic spot, the *EI* can fully reflect the residents' willingness to make sacrifices for the environment in the context of green tourism. Since the index possesses an unknown parameter, it must be estimated using sample data. According to the central limit theorem, this paper derived the $100(1-\alpha)\%$ confidence interval of the environmental sacrifice willingness index and employed this confidence interval to develop a fuzzy evaluation model. Subsequently, this paper used the confidence interval of the environmental sacrifice willingness index to establish the fuzzy evaluation model of the environmental sacrifice willingness index for green tourism based on suggestions from some studies. Finally, this paper provided an application example to explain the application of the fuzzy evaluation model proposed in this paper. This fuzzy evaluation method can assist the OTBP to promote green tourism in evaluating local residents' willingness to make environmental sacrifices. When the evaluation results reveal that local residents' willingness does not meet the desired targets, strategies and solutions must be proposed to increase their willingness. By doing so, the effectiveness of green tourism promotion can be enhanced, thereby helping tourism operators fulfill their social responsibilities.

Furthermore, considering that if the average values of the five items, μ_1, μ_2, μ_3, μ_4, and μ_5, differ significantly from each other, using θ to establish EI might cause bias. Therefore, future research could compare μ_1, μ_2, μ_3, μ_4, and μ_5 to serve as a reference for policy improvement.

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