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Carbon Footprint Analysis and Tourist Satisfaction of 4As at an Ex-situ Conservation Institution

Ratna Sari Hasibuan[1,2*], Rinekso Soekmadi[3], Herry Purnomo[4], Nur Budi Mulyono[5]

[1] Department of Natural Resource and Environmental Management Science, IPB University, Bogor, Indonesia
[2] Faculty of Forestry, University of Nusa Bangsa, Bogor, Indonesia
[3] Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia
[4] Department of Forest Management, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia
[5] School of Business and Management, Bandung Institute of Technology, Bandung, Indonesia
[*] Corresponding Author. Email address: ratna02sylva@gmail.com; pslratna@apps.ipb.ac.id

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ABSTRACT

Taman Safari Indonesia (TSI), an ex-situ conservation institution in Puncak, Bogor, has developed the 4A framework to attract more tourists and enhance visitor satisfaction and loyalty, while increasing visits revenue. It has also raised the carbon footprint of tourist transportation. This study aims to analyze the vehicle emissions of tourists and their satisfaction with 4A components to predict the likelihood of repeat visits and the subsequent rise in carbon emissions. Emissions were calculated using the IPCC 2006 Guidelines (Tier 2), and the relationship between tourist satisfaction and loyalty was assessed using the structural equation model partial least squares (SEM-PLS) method. The results indicated that CO_2 emissions from tourist vehicles during holidays reached 1,482,261.96 g.CO_2/h, significantly higher than the 552,732.81 g.CO_2/h recorded on weekdays. The analysis also revealed that tourist satisfaction and loyalty towards the 4A components significantly positively impacted the intention to revisit, as demonstrated by the T-statistics of 5.437 and P-values of 0.000, where the more satisfied the tourists are, the more loyal they are to return to TSI.

1. Introduction

The fundamental components of tourism—Attraction, Accessibility, Amenities, and Ancillary—are collectively referred to as the 4A components (Andrianto and Sugiyama 2016; Cooper et al. 2008; Gunn 1988). Tourist destinations must provide high-quality and diverse facilities within these components to foster visitor satisfaction and encourage repeat visits. Similarly, Ismail and Rohman (2019) emphasized that product performance and service quality significantly influence customer satisfaction and loyalty. Based on the results of the study, the attraction has a significant effect on the loyalty of Gili Ketapang visitors with a t-statistic value between tourist attractions and visitor attitude loyalty of 2.132, t-statistic $\geq$ 1.96 with a probability value $\leq$ significance level (α = 5%). This shows a significant positive influence between tourist attractions and visitor loyalty attitudes. It also highlighted that various attractions increase visitor numbers and revisits while easy and suitable access simplifies travel, enhancing visitor satisfaction.

The availability of comprehensive facilities and infrastructure at tourist sites significantly affects tourist satisfaction and the likelihood of repeat visits, positively influencing the tourism industry.

The tourism industry supports rapid economic growth and contributes significantly to the global economy, aligning with Sustainable Development Goals (SDGs) 1 and 2. In 2019, tourism accounted for 10.3% of the global GDP, equivalent to USD 8.9 trillion, and supported 330 million jobs (WTTC 2022). In Indonesia, tourism generated an IDR of 280 trillion in foreign exchange in 2019, a 3.7% increase from 2018 (Kemenparekraf 2020), contributing 4.25% to GDP, which rose to 4.80% in 2019. However, growth in tourism-related GDP has also resulted in increased CO_2 emissions, primarily due to transportation. According to Jaafar et al. (2020), CO_2 and greenhouse gas (GHG) concentrations are escalating daily, owing to human-induced carbon emissions from fossil fuel combustion. KESDM (2020) identified the transportation sector as a primary emission source in Indonesia, accounting for 157,326 g.CO_2e in 2019, an average annual increase of 7.17%. Among transportation modes, land transportation, particularly private vehicles, is the most significant contributor, accounting for 77% of the total transportation emissions (Raihan and Tuspekova 2022; Zhang and Batterman 2013).Although the connection between tourism and CO_2 emissions has been thoroughly studied, little study has been done on how the 4A framework—attractions, accessibility, amenities, and ancillary services—influences tourist satisfaction and environmental sustainability. This gap is especially noticeable in ex-situ conservation areas, where balancing ecological responsibility and tourism development is essential. Understanding how each element of the 4A framework affects sustainability initiatives and visitor experiences may help enhance conservation tourism strategies while reducing their negative environmental effects.

The insights gained provide pathways for enhancing environmental sustainability while maintaining visitor enjoyment. The 4As—Attractions, Accommodations, Amenities, and Accessibility—are pivotal in shaping visitor experiences and perceptions, each offering unique opportunities and challenges for reducing the carbon footprint. Hence, this study aims to analyze the vehicle emissions of tourists and their satisfaction with 4A components to predict the likelihood of repeat visits and the subsequent rise in carbon emissions.

2. Materials and Methods

2.1. Study Area

This research was conducted at Taman Safari Indonesia (TSI) was carried out in April–June 2023 with an area of 200 ha with coordinates 6°43'13"S 106°57'02"E – 6.7203156°S 106.9505096°E located in Cibeureum Village, Cisarua District, Bogor Regency, West Java, Indonesia (**Fig. 1**).

2.2. Data Collection

Research steps are described as follows:

1. Calculation of emissions from tourist vehicles

   The first stage involved quantifying the emissions from tourist vehicles by recording the number of vehicles entering Taman Safari Indonesia (TSI). Vehicle counts were conducted using a tally sheet. Data were collected from May 16 to 21, 2023, between 9:00 a.m. and 3:00 p.m., with counts between weekdays (May 16–18) and weekends (May 19–21). Fridays were classified as weekend days, as interviews indicated a notable increase in tourists on Fridays.

Vehicles were categorized into motorbikes, gasoline-powered cars, diesel-powered cars, and buses to facilitate a comprehensive emission analysis.

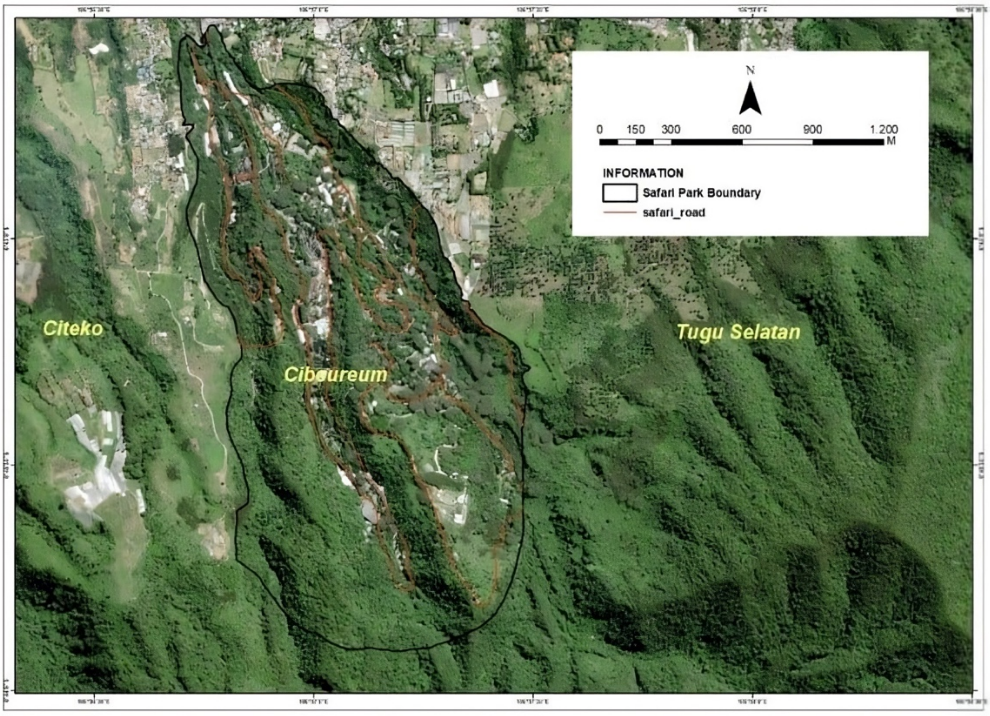

Fig. 1. Maps of Taman Safari Indonesia in Cisarua District, Bogor, Indonesia.

2. Data Collection through Questionnaires
   a. Sampling and Respondent Selection
   In this stage, visitor satisfaction and loyalty were assessed through interviews with 384 tourists. The sample size was calculated using Cochran's formula based on the average number of visitors to the TSI from 2015 to 2022. The Cochran formula is used because of the large population size, considering the confidence level and precision to make the results more accurate and representative. Respondents were selected according to two criteria: they had to visit the TSI at least once, ensure they had adequate knowledge of the site's tourism features, and be at least 15 years old. This age threshold was chosen because individuals aged 15 and above typically exhibit structured and abstract thinking skills and the ability to assess and understand values.

   b. Questionnaire Design
   A structured questionnaire was used, employing a 4-point Likert scale, with scores ranging from 1 ("strongly disagree") to 4 ("strongly agree"). The decision to use a 4-point scale aimed to prevent neutral or ambiguous responses, thus increasing the reliability of the collected data.

2.3. Data Analysis

2.3.1. Analysis of emissions

The method used in this study is IPCC 2006 Tier 2 to estimate emissions generated by tourist vehicles, especially CO_2 emissions. The data required includes the number of vehicles per hour collected over one week to analyze the differences in CO_2 emissions between weekdays and holidays. Data on the number of tourist vehicles entering TSI is analyzed using (Intergovernmental Panel on Climate Change, IPCC (2006) Guidelines Tier 2 method using Equation 1:

$$Emision(Q) = n \times FE \times KE \times PJ \tag{1}$$

The amount of carbon dioxide (CO_2) emissions can be calculated based on the following variables: n is the number of vehicles passing (expressed in units of SMP/hour), FE is the vehicle emission factor (expressed in grams of CO_2 per liter of fuel), KE is the specific energy consumption of the vehicle (expressed in liters per 100 kilometers), and PJ is the length of the road traveled (expressed in kilometers).

The emission factor was the average value of an air pollutant parameter emitted by a specific source. This study uses emission factors from IPCC (2006), evaluated from the vehicle and fuel type, as presented in **Table 1**.

Table 1. Emission factors (IPCC 2006)

No	Transportation Type	CO_2 (g/L)	CO(g/L)	N_2O(g/L)	NO_x	CH_4(g/L)
1	Motorcycle	2,597.86	427.25	0.04	7.12	3.56
2	Car (gasoline)	2,597.86	462.63	0.04	21.35	0.71
3	Bus and car (diesel)	2,924.9	35.57	0.12	39.53	0.24

Specific Energy Consumption was determined by adopting the IPCC (2006) method, as detailed in **Table 2**. The use of fuel oil in the transportation sector, especially gasoline, has led to the emergence of compounds such as carbon monoxide (CO), total hydrocarbons (THC), dust (TSP), nitrogen oxides (NOx), sulfur oxides (SOx) and carbon dioxide (CO_2) (Zhang and Batterman 2013; Zhang dan Liu 2019).

Table 2. Specific energy consumption (IPCC 2006)

No	Transportation type	Specific energy consumption (L/100km)
1	Motorcycle	2.66
2	Car (gasoline)	11.79
3	Bus and car (diesel)	16.89

2.3.2. Analysis of the 4-A components of tourist satisfaction and tourist loyalty

The purpose of employing Structural Equation Modeling-Partial Least Squares (SEM-PLS) in this study is to examine the relationships among critical variables: Attraction, Accessibility, Amenities, and Ancillary. Specifically, this study aims to determine the influence of these variables on tourist satisfaction and loyalty to revisit Taman Safari Indonesia (TSI). Data were analyzed using Structural Equation Modeling (SEM) version 3.0 software (Hair et al. 2010). One advantage of using PLS-SEM is that it accommodates nominal, ordinal, and continuous measurement scales and does not require data to be normally distributed. Additionally, PLS-SEM is efficient, allowing the results to be obtained in a single run.

The research variables analyzed in this study include educational tourism attractions, diversity of tourism objects, accessibility, availability of transportation facilities, cleanliness, accommodation, security, comfort, responsiveness in service delivery, and effective management control (**Table 3**).

Table 3. Variables in the model

Variable	Indicator	Information	Reference
Attractions	A1	Educational tourist attraction	(Panduputri and Novani 2021)
	A2	Diverse attractions	(Dirjen PHKA 2003)
Accessibility	B1	Easy to reach the location	(Dirjen PHKA 2003)
	B2	Availability of transportation facilities	(Dirjen PHKA 2003)
Amenities	C1	The Indonesian Safari Park is very clean	(Dirjen PHKA 2003)
	C2	There is accommodation	(Dirjen PHKA 2003)
Ancillary	D1	Security and comfort at tourist locations	(Dirjen PHKA 2003)
	D2	Quick response in providing services	(Dirjen PHKA 2003)
	D3	There is control by the tour manager	(Dirjen PHKA 2003)
Tourists Satisfaction	E1	Management attention to visitors	(Dirjen PHKA 2003)
	E2	Readiness to receive attractions in virtual	(Panduputri and Novani 2021)
	E3	Prices match the services provided	(Jung et al. 2015)
Tourists Loyalty	F1	The commitment of visitors to come back	(Jung et al. 2015; Panduputri and Novani 2021)
	F2	Commitment to recommend TSI	(Jung et al. 2015; Panduputri and Novani 2021)
	F3	Commitment to purchase the goods/services provided	(Jung et al. 2015; Panduputri and Novani 2021)

The model tested in this study is illustrated in **Fig. 2**. For the validation of variables, items with values less than 0.7 were removed, following the guidelines set by (Hair et al. 2010). Average Variance Extracted (AVE) analyses were conducted to ensure questionnaire validity and reliability. Hair et al. (2010) state that an AVE greater than 0.5 is considered acceptable. Significance testing was performed using bootstrapping in PLS-SEM software, with a 95% confidence level (α = 5%) and t-statistics with a minimum threshold of 1.96 (Hair et al. 2010).

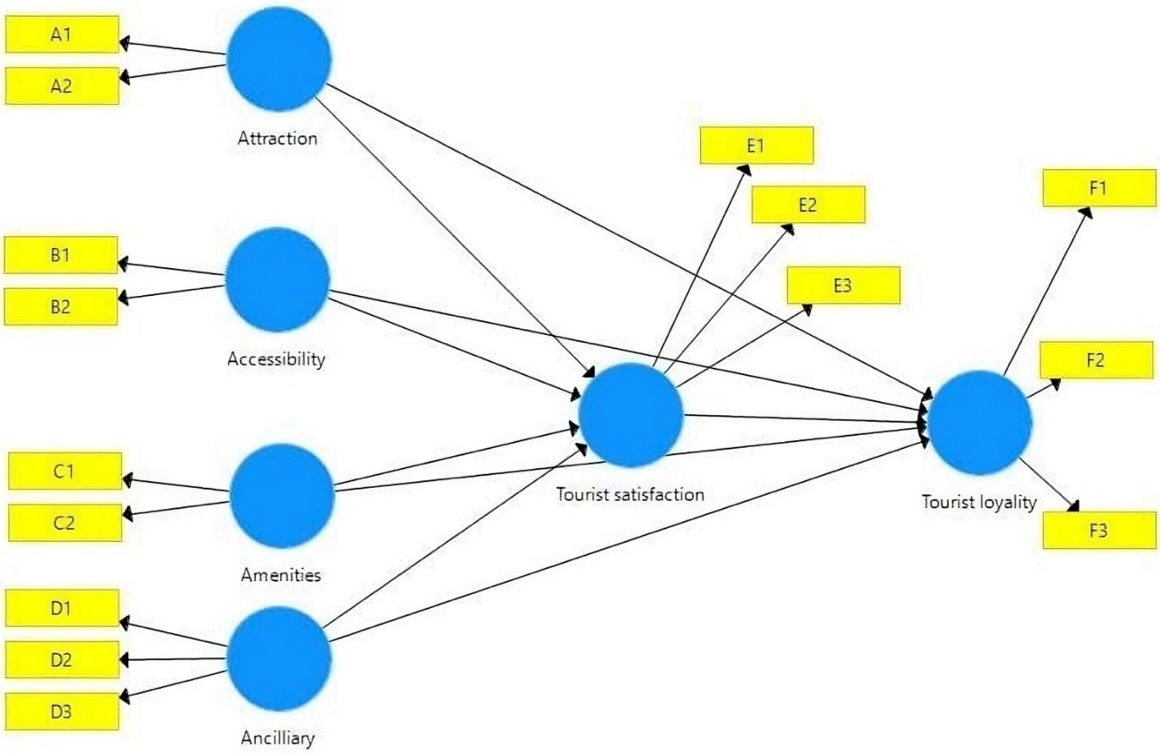

Fig. 2. Research model to determine satisfaction and loyalty.

3. Results and Discussion

3.1. General Information about Taman Safari Indonesia

Taman Safari Indonesia (TSI) is a conservation institution established under the Minister of Environment and Forestry Number Regulation P.22/MENLHK/SETJEN/KUM.1/5/2019. TSI is spread over at least 50 ha and houses animals from three or more taxonomic classes in open areas. Visitors can explore TSI using private four-wheeled or management-provided vehicles to ensure a safe distance from the animals. Taman Safari Indonesia (TSI) boasts approximately 2,500 animal species, including several endemic animals. The main attractions include the Safari Journey, Baby Zoo, Panda Palace, Safari Track, Jaksa Waterfall, Camping Ground, and a variety of animal shows featuring elephants, tigers, dolphins, and birds. Safari Journey offers a unique experience where visitors can observe animals close to their private vehicles or buses, as the TSI provides. Visitors can also interact with animals by feeding them approved food items such as carrots and bananas.

The extensive use of private vehicles by tourists traveling to destinations significantly contributes to air pollution from fossil-fuel combustion. While a higher number of visits enhances revenue and tourist satisfaction and loyalty, it also increases the carbon footprint of transportation. The TSI is easily accessible, located approximately 99.2 km from Soekarno-Hatta International Airport and 28 km from Bogor City. Visitors traveling from the airport by private vehicles can take the Jagorawi Toll Road and follow the signage to reach Taman Safari Bogor. Public transportation is also available: tourists can take route two from Bogor City to Sukasari and continue their journey towards Cisarua. TSI offers supporting facilities, such as tour guides, interactive photo sessions with animals, tour buses, vehicle rentals, souvenir shops, and curated tour packages.

3.2. Estimated Emissions

The results of the vehicle count indicated that 992 vehicles were recorded on weekdays and 2,746 on weekends, as presented in **Table 4**. The higher number of vehicles on weekends reflects increased tourist visits, with more people using motorized vehicles during these periods than on weekdays.

Table 4. Number of vehicles entering tourist destinations

No	Transportation type	Date					
		16 May	17 May	18 May	19 May	20 May	21 May
1	Motorcycle	35	35	45	50	56	71
2	Car (gasoline)	169	154	145	357	498	910
3	Bus and car (diesel)	47	235	127	274	384	146
	Amount	251	424	317	681	938	1127

The emissions analysis revealed that CO_2 emissions were 552,732.81 g/h on weekdays and 1,482,261.96 g/h on weekends (**Fig. 3**). Regarding CO_2 emissions, on weekdays, recorded 543,032.78 g/h, while on weekends, recorded a significantly higher level of 1,604,209 g/h. This increase in emissions on weekends is attributed to the more significant number of tourists traveling for leisure compared to weekdays.

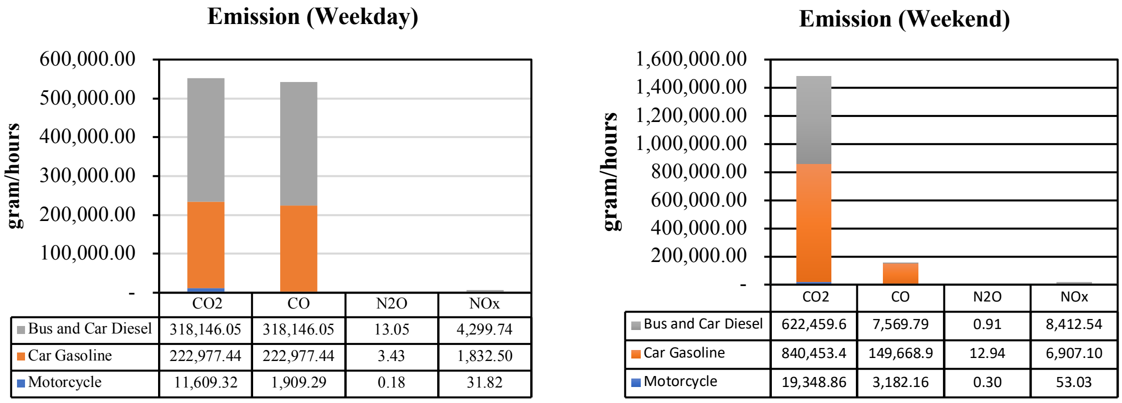

Fig. 3. The emissions produced are based on motorized vehicles entering the tourist destination on weekdays and weekends.

Approximately 60% of the exhaust gases from fossil fuel-powered vehicles consist of Carbon Dioxide (CO_2). The concentration of CO_2 emissions correlates with increased traffic volume and reduced vehicle speed, indicating that higher traffic density leads to elevated emissions. The activity level of motorized vehicles plays a crucial role in the concentration of CO_2 gas in the atmosphere; the denser the traffic, the more emissions are produced (Raihan et al. 2022; Zhang and Batterman 2013; Zhang dan Liu 2019).

Raihan et al. (2022) state that Singapore's economic growth has increased energy consumption and carbon emissions. A 0.50% increase in CO_2 emissions is associated with a 1% increase in tourism activity over time. Furthermore, a positive and statistically significant correlation for energy consumption indicates that a 1% long-term increase in energy consumption is associated with a 0.88% increase in CO_2 emissions. To encourage sustainable development and a low-carbon economy, policies for emission reduction and promoting ecologically responsible and sustainable tourism while increasing renewable energy technologies are recommended.

3.3. The 4-A Components of Tourist Satisfaction and Tourist Loyalty

Table 5 highlights that the *accessibility* (B2, the availability of transportation facilities) and *amenities* (C1, cleanliness of the Indonesian Safari Park) received the highest scores. Taman Safari Indonesia (TSI) has collaborated with key stakeholders, including the Transportation Agency and the local community, to enhance accessibility by providing alternative routes. The factor that most significantly influences tourist satisfaction is *E3*, the appropriateness of price relative to service quality, achieving a high score of 0.835. This includes service costs, such as entrance fees of IDR 230,000 for domestic tourists and IDR 400,000 for international visitors, which are aligned with the variety of attractions and comfort. Tourists expressed satisfaction with diverse offerings, including safari journeys, baby zoos, panda palaces, safari tracks, Jaksa waterfalls, and camping grounds.

Understanding the interplay among the 4As—*Attractiveness*, *Accessibility*, *Amenities*, and *Activities*—is crucial for assessing tourist satisfaction, especially within conservation organizations. The *attractiveness* of TSI, which encompasses unique and well-managed environmental features and attractions, plays a pivotal role in drawing visitors and enhancing their experiences. *Accessibility* is equally essential; efficient and well-maintained transportation options enable more accessible access to TSI. The quality of *amenities* such as dining options, rest facilities, and educational resources also significantly impacts tourists' overall perceptions. By synergistically enhancing these components, tourist satisfaction can be improved, fostering a deeper connection between TSI's conservation mission and the surrounding environment.

Table 5. Outer loading value research

	Accessibility	Amenities	Anciliar	Attraction	Tourists Satisfaction	Tourists Loyalty
A1				0.719	0.010	0.115
A2				0.979	0.010	0.115
B2	1.000				0.097	0.052
C1		1.000			0.177	0.085
D1			0.743		0.254	0.155
D2			0.766		0.254	0.155
D3			0.759		0.254	0.155
E2					0.761	0.292
E3					**0.835**	0.292
F1						**0.910**
F2						0.711

Meanwhile, the highest tourist loyalty value was in F1, that is, the commitment of tourists to return (0.910). This indicates the possibility of tourists returning in the future. Artuğer et al. (2013) and Fitrizal et al. (2021), tourist loyalty influences return visits, positive reviews, and recommendations. In addition to analyzing the model, observations were made on the Average Variance Extracted (AVE) value to determine the model's validity, as presented in **Table 6**.

Table 6. Construct validity and reliability values

	Average Variance Extracted (AVE)	Decision
Accessibility	1.000	Valid
Amenities	1.000	Valid
Anciliar	0.572	Valid
Attraction	0.738	Valid
Tourists Satisfaction	0.637	Valid
Tourists Loyalty	0.667	Valid

Based on **Table 6**, all AVE values are above five, so they are considered valid. Al Badi and Khan (2020), Hair et al. (2010), Hair et al. (2019), Sulistiowati et al. (2023), and Sulistyorini et al. (2018)an AVE value > 0.5 was used as a measure of validity. Bootstrapping was then performed to determine the significance level of the variables (**Fig. 4**).

The study results in **Fig. 4** and **Table 7** show a T-statistic value of 5.437 and a P value of 0.000 at a 95% confidence level. Tourist satisfaction is directly proportional to loyalty and repeat visits to TSI, and tourist satisfaction significantly affects tourist loyalty.

Examining tourist loyalty through the 4A framework—Attractions, Access, Facilities, and Additional Services—offers a holistic approach to evaluating visitor experiences at conservation institutions. Attractions, which include unique features and engaging experiences, are critical to shaping visitor loyalty. The same thing was mentioned by Murniati et al. (2025) and Sulistyorini et al. (2022), who stated that the uniqueness of a tourist destination can make tourists come to that destination. Tourists are often drawn to novel and educational encounters with nature, making it a key determinant of satisfaction and future visits.

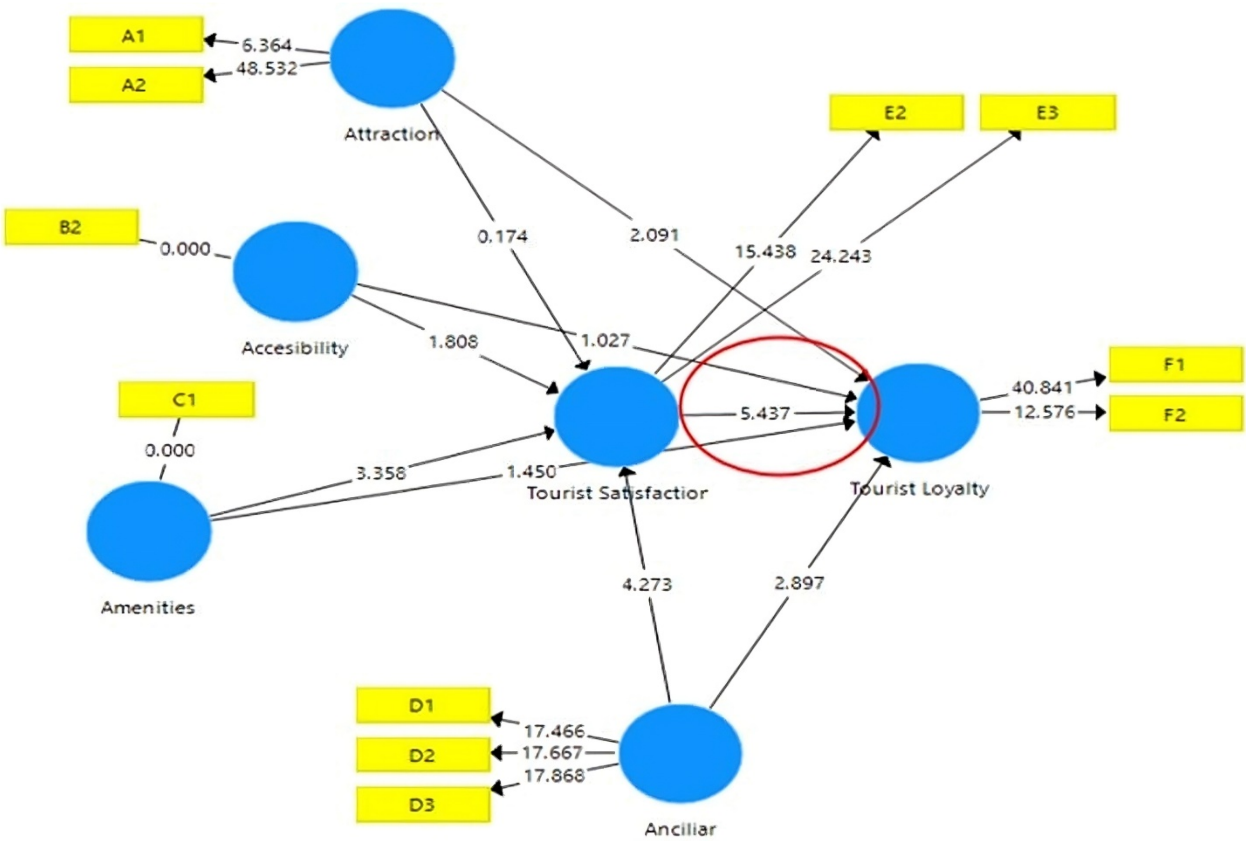

Fig. 4. Results of research bootstrapping.

Access, comprising both the physical ease of reaching the destination and the availability of relevant information, profoundly impacts visitor perceptions. Efficient and convenient transportation options and clear communication can contribute to positive experiences. Amenities, such as quality accommodation, dining options, and other essential facilities, ensure a comfortable and enjoyable stay and enhance visitor satisfaction. Meanwhile, Ancillary Services, such as guided tours and educational programs, deepen visitor engagement and understanding of the institution's conservation mission.

The interplay between these components forms a comprehensive view of visitor loyalty, highlighting that neglecting any single element can adversely affect perceptions of value and enjoyment. This nuanced understanding is crucial, particularly because conservation institutions strive to balance ecological preservation with tourism. By carefully managing and integrating these aspects, these institutions can foster stronger visitor connections while upholding their environmental commitment (Paul et al. 2002).

3.4. The Connection of 4As Satisfaction, Loyalty And Carbon Emissions

The interaction between the 4A components—Attractions, Access, Amenities, and Support Services—and tourist satisfaction, repeat visits, and vehicle emissions shows a unidirectional relationship influencing environmental outcomes. As Ismail and Rohman (2019) show, attractions, amenities, and accessibility significantly increase tourist satisfaction. The uniqueness of attractions where tourists can feed animals and take selfies with animals can increase tourist satisfaction. This satisfaction, in turn, increases tourist loyalty and the likelihood of repeat visits, contributing to higher emissions from fossil fuel-powered vehicles.

Table 7. Path coefficient values

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values	Decision
Accessibility -> Tourists Loyalty	0.052	0.050	1.027	0.305	Not Significant
Accessibility -> Tourist Satisfaction	0.097	0.054	1.808	0.071	Not Significant
Amenities -> Tourists Loyalty	0.085	0.059	1.450	0.148	Not Significant
Amenities -> Tourists Satisfaction	0.177	0.053	3.358	0.001	Significant
Anciliar -> Tourists Loyalty	0.155	0.054	2.897	0.004	Significant
Anciliar -> Tourist Satisfaction	0.254	0.060	4.273	0.000	Significant
Attraction -> Tourists Loyalty	0.115	0.055	2.091	0.037	Significant
Attraction -> Tourists Satisfaction	0.010	0.059	0.174	0.862	Not Significant
Tourists Satisfaction -> Tourists Loyalty	0.292	0.054	5.437	0.000	Significant

The findings in **Fig. 4** and **Table 7** confirm that tourist satisfaction significantly affects loyalty. As satisfaction increased, so did the frequency of repeated visits. This trend exacerbates carbon emissions and underscores the need for strategic environmental management. However, the analysis also revealed that the coefficient of the accessibility variable was not significant (T-statistic = 1.808, P-value = 0.071), likely due to frequent traffic congestion leading to discomfort among tourists and longer travel times. These delays diminish the visitor experience and increase the emission of pollutants from idling vehicles.

Addressing these environmental concerns necessitates a collaborative approach among stakeholders, including transportation agencies, local authorities, tourism managers, environmental organizations, and the community. Steps such as prohibiting the sale of land in Puncak Bogor from being used as a tourist area, housing, or villas, encouraging tree planting to absorb emissions, implementing visitor quotas on holidays or religious holidays, encouraging the use of electric vehicles to be important, and providing incentives for tourists who carpool or use environmentally friendly transportation. TSI managers and KLHK planted trees for animal feed on December 30, 2023 (KLHK 2023). Successful examples of the implementation of electric vehicles are Taman Mini Indonesia Indah and Ancol, which have begun to provide incentives for the use of electric vehicles (Nugraha 2023), this needs to be emulated by TSI management.

Moreover, embracing technological advancements to offer virtual tourism experiences can reduce the carbon footprints of physical visits. However, this shift requires substantial investment in technology and human resources. According to Sun (2016), although new technologies can mitigate emissions, tourism growth often outpaces technological innovation.

By implementing deliberate policies to reduce emissions, conservation institutions can align their operational strategies with environmental sustainability while enhancing tourist satisfaction. Institutions should serve as models of eco-friendly tourism by adopting practices that protect biodiversity and reduce environmental impact. Analyzing carbon footprints is integral to operational planning, influencing the visitor experience and the institution's conservation goals.

Strategic recommendations include raising visitors' awareness of sustainability practices, integrating eco-friendly transportation options, and developing initiatives to promote environmental responsibility. This approach ensures that conservation and tourism coexist harmoniously, enhancing visitor engagement while reinforcing the institution's commitment to ecological stewardship.

4. Conclusions

Better-developed 4A components are strongly correlated with higher tourist satisfaction and loyalty, as evidenced by the T-statistic of 5.437 and P-value of 0.000. This suggests that destinations with more attractive, accessible, and complete facilities are more likely to encourage repeat visits. However, this positive trend also leads to an unintended consequence: increased carbon emissions due to greater reliance on fossil fuel-powered private transportation. This study highlights the need to analyze mitigation strategies. To address these environmental impacts, TSI has implemented various sustainability initiatives, including extensive reforestation programs and encouraging tourist participation in conservation efforts. Implementing visitor quotas on holidays or religious holidays. Potential solutions include implementing a green transportation system (such as electric shuttle buses or incentives for low-emission vehicles), promoting carpooling or public transportation partnerships, and introducing regulatory measures like progressive entry fees for fossil-fueled vehicles or carbon offset programs to encourage sustainable tourism behavior.

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Author Contributions

R.S.H.: Conceptualization, Methodology, Investigation, Writing – Original Draft, Formal analysis; R.S.: Supervision, Writing – Review and Editing; H.P. and N.B.M.: Supervision.

Conflict of Interest

There is the authors reported no potential conflict of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation

This manuscript uses ChatGPT only to improve from Indonesian to good and correct English. After using this tool/service, the author reviews and edits the content as needed and is fully responsible for the publication's content.

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