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ANALYZING AND RESOLVING THE CONSEQUENCES OF TOURIST INFLUXES ON ENVIRONMENTAL METRICS AT A TOURIST DESTINATION

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ABSTRACT

The primary objective of this paper is to examine the impacts of tourist influxes on environmental metrics and to develop strategies for enhancing sustainability awareness among tourists, thereby minimizing the adverse effects of tourist influxes. The tourist data were collected from: 1) the portals of the Ministry of Tourism of India, to obtain arrival data for the past eight years; and 2) an environmental sustainability questionnaire designed to gather tourists' demographic profiles, resource consumption, waste generation, and behavioral or knowledge-related data in Agra; 3) The designed SWOT questionnaire to get the rankings of SWOT groups and factors. This data is used to analyze resource consumption and waste generation patterns using explanatory analysis, the correlation between the demographic and behavior and knowledge to understand their sustainability awareness level, and use TOWS analysis to design strategies for reducing the negative consequences of tourist influxes. The results show that age group is a strong predictor for water consumption, energy consumption, and waste generation. The large effect size, R2 values, and VIF analysis indicated excellent fit and strong predictive performance. The awareness questionnaire analysis showed a gap between the behavioral factors and the knowledge level. Fifteen strategies are designed to improve the sustainability awareness of tourists coming to Agra. This study will enable destination managers to better understand tourists' waste reduction and resource consumption behaviors, and to make long-term oriented decisions to conserve the tourist destinations for future generations same as earlier generations.

KEYWORDS: tourist influxes; environmental metrics; environmental sustainability awareness; explanatory analytics; TOWS analysis.

JEL: Z32, Q56, Q01, C83

INTRODUCTION

Tourism is widely recognized as a high-energy and water resource-demanding activity. Tourists often consume significantly more energy and water per day than residents, with usage patterns in recreational activities, transportation, and accommodations creating substantial ecological footprints (Belsoy, Korir & Yego, 2012), which harm the environment (Bhat et al., 2014; Villanthenkodath, Mahalik & Arafath, 2022; and Adebayo et al., 2023).

One main threat of tourism growth is increasing pressure on freshwater resources, thereby increasing water scarcity (Veldkamp et al., 2017). The flexible travel access, leading to an increase in the number of tourists, sharpens the vulnerability of the destination towards water insufficiency (Stoyanova, 2025). For example, water use on a per-guest-night basis is found to differ substantially, with water usage being highest (Becken, 2014). Tourists consume plenty of water in activities like ski tourism, winter tourism, using spas, swimming pools, or wellness areas (Gössling, 2002). Maintaining hotel gardens, developing tourism infrastructure, and producing food and fuel place a demand on freshwater resources (Gössling et al., 2012).

Secondly, tourist growth acts as a driver for increased energy consumption to support increased demand for hospitality, leisure activities, transportation, and infrastructure (Nepal, Al Irsyad & Nepal, 2019; Raihan et al., 2023). Furthermore, economic expansion drives energy usage through tourism expansion, and tourist activities (Pablo-Romero, Sánchez-Braza & García-Soto, 2023).

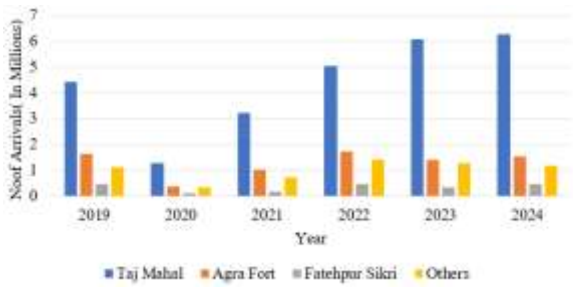
Thirdly, tourist arrivals also contribute substantially to solid waste generation (Diaz-Farina, Díaz-Hernández & Padrón-Fumero, 2020). The impact of this waste generation is large and increasing (Murava & Korobeinykova, 2016), which in some regions is double that of a resident (Shamshiry et al., 2011). Plastic pollution remains a major global environmental concern, forming a significant share of plastic debris. Managing this plastic waste, particularly during periods of increased tourist arrivals, has become very challenging (Senarathna & Mahagamage, 2025). Thus the need is to analyze the impact of tourist arrival at a destination to maintain its sustainability.

1. Vulnerabilities of tourism in Agra city

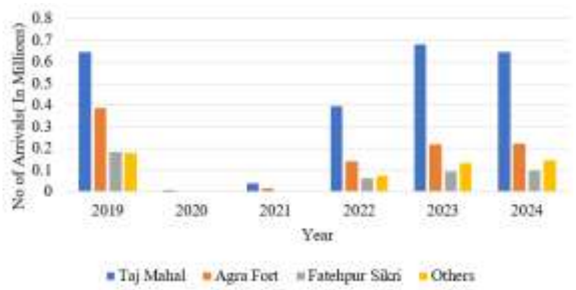
India is a globally renowned tourist destination due to its prominent attractions such as the Taj Mahal, the Himalayan ranges, and the royal palaces of Rajasthan. According to the India Tourism Data Compendium (2025), India recorded 20.94 million foreign tourist arrivals in 2024, an 8.84% increase from the previous year, and domestic tourists increased by 17.51% in 2024.

Agra, a city in India, is widely recognized as one of the most artistically inspiring cities around the world and is a perfect example of authenticity. It is a significant tourist destination as it houses UNESCO World Heritage sites: The Taj Mahal, Agra Fort, and Fatehpur Sikri. Every year, many domestic as well as international tourists visit this historically important destination (Figure 1).

Figure 1. Tourist arrivals in Agra



Domestic tourists visiting Agra.



Foreign tourists visiting Agra.

Source: India Tourism Data Compendium, 2025

In Agra, high arrival rates lead to key vulnerabilities including environmental degradation (such as excessive air pollution, waste generation, unsustainable pressure on water, sanitation, and accommodation facilities, and resource depletion (Sharma & Bisht, 2019; and Srivastava & Srivastava, 2020)), infrastructure strain, overcrowding, severe traffic congestion, social disruption, and inefficient management (Lal et al., 2016; Guttikunda et al., 2019; Yadav & Gangal, 2024; and Yadav & Prakash, 2025). A structured survey was conducted by the authors of this paper to assess the spatial concentration of tourist activity. Consequently, the collected data contributed to identifying patterns of overtourism at the Taj Mahal, as shown in Figure 2 (self-observation, in January 2024). Such impacts can cause the loss of authenticity and imply a significant risk to the future attractiveness of the destination, therefore putting it at existential risk (Peeters et al., 2018). Thus, preventing long-term sustainability of tourism in Agra requires immediate and coordinated efforts for better management.

Figure 2. Overtourism surrounding the Taj Mahal, Agra

Source: self-created

The goal of this study is to analyze the consequences of tourist influxes at Agra and to generate strategies for increasing environmental sustainability awareness among tourists to minimize the negative consequences of tourist influxes. The research questions addressed in this study are as follows:

RQ1: What are the dominant patterns of resource consumption and waste generation exhibited by tourists, and how do these patterns relate to the demographics and behavior of tourists?

RQ2: Are tourists aware of environmental sustainability, and do tourists' knowledge of environmental sustainability align with their actual behaviors?

RQ3: What measures can be taken to increase environmental sustainability awareness of tourists?

A methodological framework for performing a cohort study and explanatory data analytics is developed to answer these research questions by determining resource consumption and waste generation patterns and analyzing the environmental sustainability awareness level of tourists. This is done by integrating statistical techniques with SWOT analysis to analyze sustainability behavior and awareness level of tourist and to design strategies for reducing negative consequences of tourist influxes.

The presentation of the study is organized in the following manner. In the second section, the role of tourist influxes on environmental metrics is reviewed. The third section outlines the development steps of the methodology. The fourth section presents the results and discussion. In the fifth section, the conclusion is reported.

2. LITERATURE REVIEW

A significant amount of work has been done by researchers to understand the resource consumption and waste generation patterns. Gonzalez-Perez, Martín, Martínez & Pachón (2023) determined water consumption patterns of tourists and showed that overnight stays not recorded in the official statistics affect the real impact of tourism on the environment. MacAskill, Becken & Coghlan (2023) argued that hotels overconsume resources like electricity, gas, and water. By taking quantitative resource consumption and occupancy data from hotels, it was shown that guest numbers are significantly correlated with water consumption. Water challenges in areas facing overtourism are detailed by Lanquar (2025), and strategies to ensure sustainable tourism are designed.

Tourism growth has resulted in increased energy consumption. Nepal, Al Irsyad & Nepal (2019) assessed the short-run and long-run relationships between tourist arrivals, emissions, and energy consumption in tourist accommodations in Nepal. Using time-series econometrics, it was shown that energy consumption is affected by tourist arrivals. Zhang & Zhang (2020), Khan & Hou (2021), Rauf et al. (2021), Pata & Balsalobre-Lorente (2022), Pablo-Romero, Sánchez-Braza & García-Soto (2023), and Satrovic & Adedoyin (2023) presented methods to examine the relationships between tourism energy consumption, destination management, and sustainable tourism. Strategies for sustainable energy consumption were designed to reduce energy-related problems due to tourism. Díaz Pérez et al. (2022) detailed how overtourism impacts energy consumption and concluded that the reason for increased energy consumption is overnight stay.

Tourism growth also contributes significantly to waste generation (Diaz-Farina, Díaz-Hernández & Padrón-Fumero, 2020). Iuras, Raiter, Korobeinykova & Poberezhna (2020) detailed the impact of factors responsible for generating waste within tourist destinations by using regression analysis and also predicted the amount of waste generation due to tourist activities. Martins & Cró (2021) estimated the impact of tourist activities on solid waste generation and concluded that tourist activities are responsible for almost 42% to 47% of solid waste generation in Madeira. Wang, Filimonau & Li (2021) used an exploratory survey to determine the amount of food wasted by tourists in Lhasa, China. The role of food consumption-related factors and various socio-demographic factors was discussed. Nayanarangani, Mudiyanselage & Himalika (2022) quantified and characterized waste types in major tourist destinations of Sri Lanka and concluded that solid waste generation in touristic locations depends on the season and the prevailing environmental legislation of the country. The correlations between plastic waste and the tourism industry were established by de Oliveira, Sampaio & Sampaio (2023), Pandey, Dhiman, Chopra & Adlakha (2023), Yuxi, Filimonau, Ling-en & Linsheng (2023), Al Muqsit, Setiadi & Lo (2024), and Arbulú, Rey-Maquieira & Sastre (2024). Chhikara et al. (2025) described the solid waste management issues of rural areas, considering accommodation choices, tourist demographics, and consumption patterns as key factors that increase different types of waste.

Analyzing the influence of tourist influxes on environmental sustainability in terms of demographics and behavior can also provide useful understandings, as discussed by researchers. By analyzing trends based on age, gender, travel purpose, and stay duration, valuable insights can be gained to offer responsible tourism (Jain & Sharma, 2021). Rodríguez, Jacob & Florido (2020) showed that older tourists have a higher pro-environmental attitude in hotel establishments than younger ones, with most of these tourists realizing the importance of the hotel to have an energy-saving policy. Adam (2022) characterized tourists' behavioral response to single-use plastic waste by using unique environmental values and socio-demographic and travel characteristics, including age, gender, education, tourist type, and repeat visit status. Uçgun & Narcı (2022) investigated the role of tourists' sex, age, education, and income level on tourists' sustainability consciousness to understand their perspective on sustainable tourism practices in accommodation facilities. Forleo & Bredice (2025) investigated the knowledge, opinions, and behavior among the Italian GenZ in relation to coastal and marine tourism as well as the environment. Findings showed that the area of residence and gender significantly affected the respondents' knowledge of marine sustainability.

Torres-Bagur, Ribas & Vila-Subirós (2020) analyzed water-saving practices among guests at various accommodation types in a river basin and showed that these differences are due to visit purpose, geographic origin, and accommodation type. Gabarda-Mallorquí, Garcia, Fraguell & Ribas (2021) showed that stay duration significantly and positively influenced water conservation habits. Casado-Díaz, Sancho-Esper, Rodriguez-Sanchez & Sellers-Rubio (2023), in a hotel, examined guests' water conservation behavior when they are on vacation and showed significant gender differences with specific factors affecting the water conservation behavior of guests. The impact of environmental concerns on water conservation behaviors among Gen Z tourists in Iranian desert regions was examined by Torabi, Hall, Azarniou & Borzu (2025).

The literature review reveals that prior research has addressed the environmental impacts of tourism growth with respect to a single environmental metric, which may miss some valuable insights. Moreover, the differential impacts of tourist flows, combined with limited attention to environmental awareness factors, represent key areas of under-exploration. This study aims to address these gaps by modeling the relationship between tourists' demographic and behavioral factors and environmental metrics using a mixed-method approach.

3. RESEARCH DESIGN

This study combines multivariate analysis with TOWS analysis to achieve the research study goal. A team of experts was formed in this study to interpret the data and design the questionnaire and policies for enhancing the validity and reliability of research findings. The criteria to choose experts were their experience, domain knowledge, availability, and compatibility. The background of the experts is given below:

- Three tourism experts with tourism management degrees are from the Heritage Institute of Hotel & Tourism, Agra. These experts helped in approving tourist demographic and behavioral data, collecting data for the study, designing the questionnaire, and developing policies.

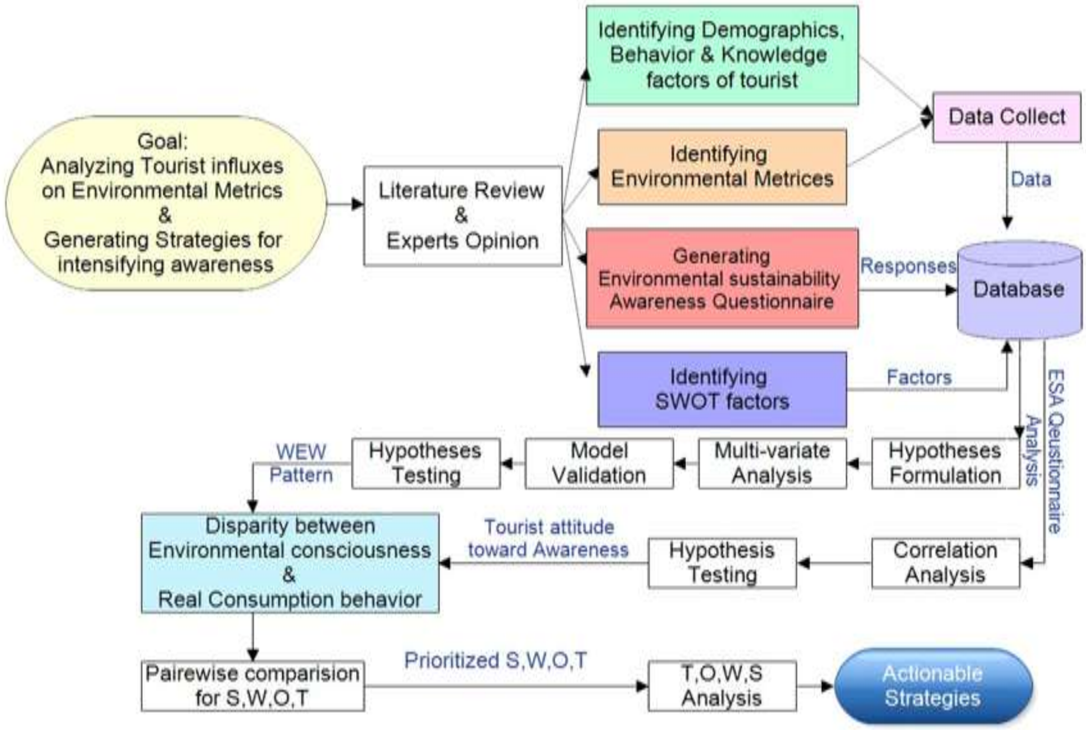
- Two environmental experts are professors in the Department of Botany and Chemistry, Dayalbagh Educational Institute, Agra, who helped in verifying environmental metrics and generating an awareness questionnaire.

The methodological framework consists of the following phases (Figure 3).

A. Collecting Data

The relevant demographic and behavioral factors are identified by the literature review. The tourist influx data is gathered from India Tourism Data Compendium Key Highlights. (2025). The sample is limited to the annual time-series statistics, spanning 08 years (from 2017 to 2024) to produce a variety of datasets that highlight patterns and effects related to tourist influxes in Agra.

Figure 3. The conceptual framework.



Source: *Own*

An Environmental Sustainability Awareness (ESA) questionnaire is prepared to determine the awareness level of tourists. The questionnaire is generated using the Delphi method (Skulmoski, Hartman & Krahn, 2007). The stability in reviewing the responses reached in the third round of the Delphi exercise. A structure survey was conducted to get the questionnaire filled out. Tourists visiting the Taj Mahal and Agra Fort were approached and invited to participate in this survey by filling out a Google form. This methodological approach facilitated direct engagement with tourists. The respondents in this study are tourists (government employees, businessmen, university students, and holidaymakers) who came to Agra for travel purposes.

Out of the 240 individuals, 209 provided complete responses. Some individuals declined to participate due to personal reasons, and a few hotels did not permit the survey to be conducted on their premises. Despite these challenges, the survey achieved a high response rate, and the data collected offer valuable insights into tourist awareness towards sustainability. 7 hotels (two 5-star, three 2-star, and three budget hotels) were selected at random to get the questionnaire filled. The sample size of 209 is considered adequate based on guidelines by Tabachnick and Fidell (1991) and Hogarty et al. (2005).

B. Formulating hypotheses

The selection of common predictors was based on their direct and observable influence on resource consumption behaviors during tourism activities. These variables are consistently available across all records and provide a standardized basis for comparison across models.

Directional hypotheses for each dependent variable—water consumption, energy consumption, and waste generation (WEW)—based on tourist demographic and behavioral factors (age-group, gender, visit intent, stay duration, and awareness) as independent variables are formulated to provide more precise and focused predictions. Each research hypothesis (RH) includes the expected direction of the effect based on prior literature.

RH1: There is a directional difference in mean energy consumption across groups defined by visit intent, stay duration, age group, or gender.

RH1A: Tourists staying longer consume more energy than those with shorter stays.

RH1B: Tourists visiting for leisure and business purposes consume more energy than those visiting for other reasons.

RH1C: Older age groups consume more energy due to higher activity levels.

RH1D: Female tourists consume more energy than male tourists.

RH2: There is a directional difference in mean water consumption across groups defined by visit intent, stay duration, age group, or gender.

RH2A: Tourists with longer stays consume more water than those staying for shorter durations.

RH2B: Leisure and business tourists consume more water than eco-friendly tourists.

RH2C: Older and younger tourists (more active or outdoor-oriented) use more water than adults.

RH2D: Female tourists consume more water than male tourists.

RH3: There is a directional difference in mean waste generation across groups defined by visit intent, stay duration, age group, or gender.

RH3A: Tourists with longer stays generate more waste.

RH3B: Leisure tourists generate more waste compared to business tourists.

RH3C: Older tourists generate more waste than younger tourists.

RH3D: Female tourists generate more waste than male tourists.

RH4: Tourists with low environmental awareness show higher waste generation.

C. Multi-variate analysis

Multiple regression models are developed to identify significant predictors that result in resource depletion and waste generation. The formulated regression models are:

$$Y_{EC} = \beta_{01} + \beta_{11}X_{Age} + \beta_{21}X_{gender} + \beta_{31}X_{PV} + \beta_{41}X_{LS} + \varepsilon_1 \quad (1)$$
$$Y_{WC} = \beta_{02} + \beta_{12}X_{Age} + \beta_{22}X_{gender} + \beta_{32}X_{PV} + \beta_{42} X_{LS} + \varepsilon_2 \quad (2)$$
$$Y_{WG} = \beta_{03} + \beta_{13}X_{Age} + \beta_{23}X_{gender} + \beta_{33}X_{PV} + \beta_{43} X_{LS} + \varepsilon_3 \quad (3)$$

Where

Y_{EC}: energy consumption model, Y_{WC}: water consumption model, Y_{WG}: waste generation model,

X_{Age}: age group, X_{gender}: gender, X_{pv}: visit intent, X_{LS}: stay duration,

β_{ij}: regression coefficients for each dependent variable (i=1,…,4, j=1,…,3), β_{0j}: intercept, and

ε_j: error terms.

One-hot encoding is used to convert the categorical variables (visit intent, age group, and gender) into numerical forms. The model can now be formulated as

$$Y_j = \beta_{0j} + \sum_{i=1}^{4} \beta_{ij} X_i + \varepsilon_j \quad (4)$$

The ordinary least squares method is utilized to estimate the regression coefficients β_{ij}:

$$SSE = \sum_{i=1}^{4} \left(Y_i - \hat{Y}_i\right)^2 \quad (5)$$

where Y_i are actual observed values, and $\hat{Y}$ are predicted values.

Formula (6) is utilized to compute the estimated regression coefficients.

$$\beta_{ij} = (X^T X)^{-1} X^T Y \quad (6)$$

Where the matrix of independent variables is represented as X, and the vector of dependent variables is Y.

To check that the model is statistically significant, the F-test is performed using formula (7) as

$$F = \frac{(\text{ExplainedVariance})/p}{(\text{UnexplainedVariance})/(n-p-1)} \quad (7)$$

Where p: number of predictors and n: number of observations

For each regression coefficient β_{ij}:

$$H_0: \beta_{ij} = 0 \text{ (No effect)} \quad (8)$$

$$H_1: \beta_{ij} \neq 0 \text{ (Significant effect)} \quad (9)$$

t-statistic is utilized to determine the substantial impact of WEW.

$$t = \frac{\beta_{ij}}{SE(\beta_{ij})} \quad (10)$$

and $$SE(\beta_{ij}) = \sqrt{Variance(\beta_{ij})} \quad (11)$$

A p-value < 0.05 for β_{ij} shows that the variable β_{ij} is significant. The accuracy of the model is evaluated by computing R^2 and Adjusted R^2 values and mean square error. The models are validated using the 5-fold cross-validation method and VIF analysis.

C. Analyzing the ESA questionnaire

The ESA questionnaire consists of three sections. The demographic information of tourists is provided in section 1 to show the socioeconomic variation that may impact their knowledge and behavior. Section 2 contains questions related to evaluating the knowledge of environmental sustainability of tourists, and questions about assessing their behavior towards sustainability are included in Section 3 (Table 1).

Table 1. The ESA questionnaire.

Sect.No	Questionnaires Items	Questions
2.	Environmental sustainability knowledge	I prefer guided tours and nature walks.
		I am aware that sustainable development demands reducing all sorts of waste.
		I am familiar with local environmental guidelines.
		I understand the importance of protecting local heritage.
		I understand the meaning of environmental signage at the destination.
		I understand overcrowding, pollution, and habitat destruction are common problems at destinations.
		I know responsible waste disposal practices.
		I know that plastic pollution is a global problem.
		I am aware of the rules in protected areas.
		I understand visitor capacity management.
3.	Environmental sustainability behavior	I use reusable plastic items like plastic bags, bottles, and cutlery.
		I avoid single-use plastic items.
		I go through the environmental information before visiting the destination.
		I use public or eco-friendly transportation.
		I prefer responsible waste disposal practices.
		I avoid visiting sites during peak tourist seasons.
		I participate in volunteer sustainable tourism programs.
		I adhere to rules in protected areas.
		I purchase local, eco-friendly products.
		I prefer staying in accommodations with a green certificate.
		I avoid overconsumption of resources.

Source: *Own*

To evaluate the content validity, items are developed from literature reviews (Adam, 2022; Jain & Sharma, 2021) and reviewed by experts to ensure relevance to sustainable metrics, demographics, and behavioral factors. Kaiser–Meyer–Olkin (KMO) test is used to measure sampling adequacy. Descriptive statistics provides a summary of the questionnaire items. Hypothesis (RH4) is tested using ANOVA to establish statistical significance between groups.

The reliability of the questionnaire is determined using Cronbach's Alpha (α) value (**Cronbach**, 1951), given by formula (12), where $k$is the number of items in the scale, σ_i^2 is the variance of each item, and σ_t^2 is the variance of the total scores. The questionnaire items are reliable if the α value > 0.7. Reliability analysis is done using SPSS.

Table 2. Description of SWOT factors

Strengths: ***The strengths of tourists can transform tourism from an extractive industry into a regenerative force, leading to responsible tourism.***	**Weaknesses:** ***Addressing weaknesses of tourists enhances visitor satisfaction and supports sustainable, long-term tourism growth.***
f_1. Age: Age groups allow for a diversified market. Baby Boomers appeal for steady, high-value income, and Gen Z rely on innovation, digital engagement, and long-term sustainable growth	f_{11}. Overconsumption of resources: Tourists often put immense pressure on local water, energy, and land resources, causing scarcities for residents.
f_2. Curiosity: Desire for novelty, knowledge, and emotional fulfilment through exploration by traveling to new destination f_3. Tech-savvy: Using digital platforms for planning, booking, and sharing experiences.	f_{12}. Infrastructure vandalism: Involves intentional destruction and disfigurement of facilities, historical monuments, and natural sites by tourists. f_{13}. Overtourism behaviors: Influx of tourists causes overcrowding and strains local infrastructure, resulting in a diminished experience for both visitors and residents.
f_4. Experience-driven tourism: Transforming travelers from passive observers into active participants, fostering visitor loyalty. f_5. Adaptability: Enable tourists to navigate unfamiliar cultural environments, manage unexpected disruption, and foster emotional resilience.	f_{14}. Generational gaps in technology: While smart technologies are desired, different generations have different weak points, which may enable finding issues with the reliability of apps and virtual experiences. f_{15}. Demand variability: Different demographic groups have highly diverse needs and expectations, making it difficult to create a single, efficient, and sustainable tourism management strategy.
f_6. Education: A significant portion of tourists are highly educated, which enables them to enhance their traveling experience through skill acquisition, personal growth, and cultural immersion.	f_{16}. Waste generation: Tourists generate excessive waste, which causes ecological damage through improper disposal, straining, and exceeding local infrastructure capacity.
Opportunities: *Opportunities can transform travel into a force for good and ensure that travel growth does not deplete natural resources.*	Threats: *Overcoming threats strengthens destination resilience, ensuring long-term sustainability, economic stability, and enhanced safety for tourists and residents.*
f_7. Travel education: Travel education, a *living textbook*, provides immersive experiential learning, fostering cultural empathy, and building global awareness. f_8. Personalized travel experience: Offering bespoke itineraries and integrated trip planning using AI based on individual user behaviors.	f_{17}. Cultural insensitivity: Includes irresponsible interaction, such as disrespecting sacred sites or disrupting local customs, which leads to the creation of inaccurate and stereotypical representations of host cultures. f_{18}. Overtourism impacts: High concentrations of visitors cause severe overtourism, leading to overcrowding, destruction of historical sites, pollution, and environmental degradation.
f_9. Informative activity-based travel: Focusing on the sequences of activities (e.g., work, shopping, leisure) rather than isolated trips, allowing specialized, high-demand, and local tourism development. f_{10}. Motivation-driven trips: Motivation-driven trips, including incentive travel and personalized experiences, boost employee performance, improve loyalty, and enhance overall well-being.	f_{19}.Resource depletion: High consumption of amenities and natural resources places a strain on local infrastructure and community stability. f_{20}. Vandalism: Degrades aesthetic appeal, harming cultural assets, and creating a sense of insecurity.

Source: *Own*

The pairwise comparison method is used to prioritize the SWOT groups and factors. The global weights are calculated using the principle of hierarchy (Saaty, 2008). The expert team designed 15 strategies (Ai, i=1,...,15) (Table 3) under four conceptually distinct strategic groups (SO, WO, ST, WT) using TOWS analysis (Singh & Singh, 2018).

Table 3. Designed Strategies.

S.No.	Strategies
A_1	Grow ethical awareness of responsible tourism.
A_2	Encourage to focus on slow travel.
A_3	Educate tourists to respectfully engage with locals.
A_4	Implement signboards for energy and water consumption.
A_5	Encourage informative travel.
A_6	Encourage tourists to visit lesser-known destinations.
A_7	Develop age-group-based strategies.
A_8	Create new tourist attractions.
A_9	Encourage following the leave no *trace* principles.
A_{10}	Avoid overcrowding at the tourist hotspots.
A_{11}	Organize pre-visit education campaigns at tourist accommodations.
A_{12}	Encourage eco-friendly alternatives.
A_{13}	Use social media for conservation awareness.
A_{14}	Balancing immediate needs with long-term scarcity through technology
A_{15}	Implement visitors dispersion model to reduce the overtourism impact

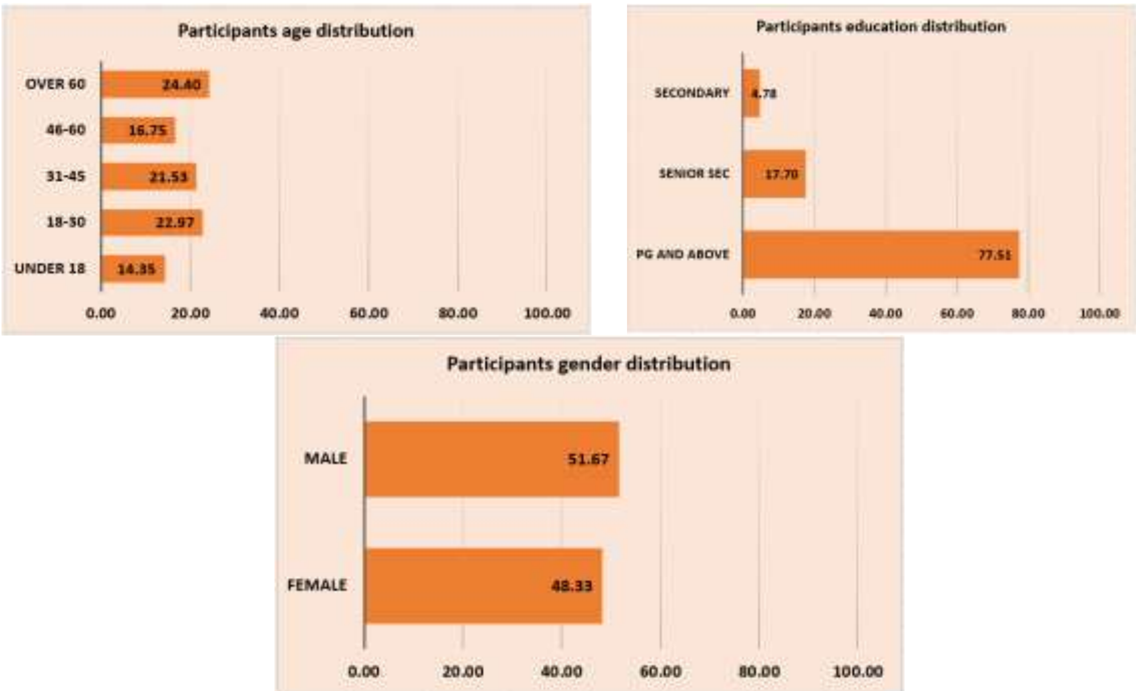
Source: *Own*

3. Results and Discussion

a. Demographic analysis of tourists

Survey responses were processed to obtain descriptive analysis. Figure 4 presents the demographic background of the tourist respondents.

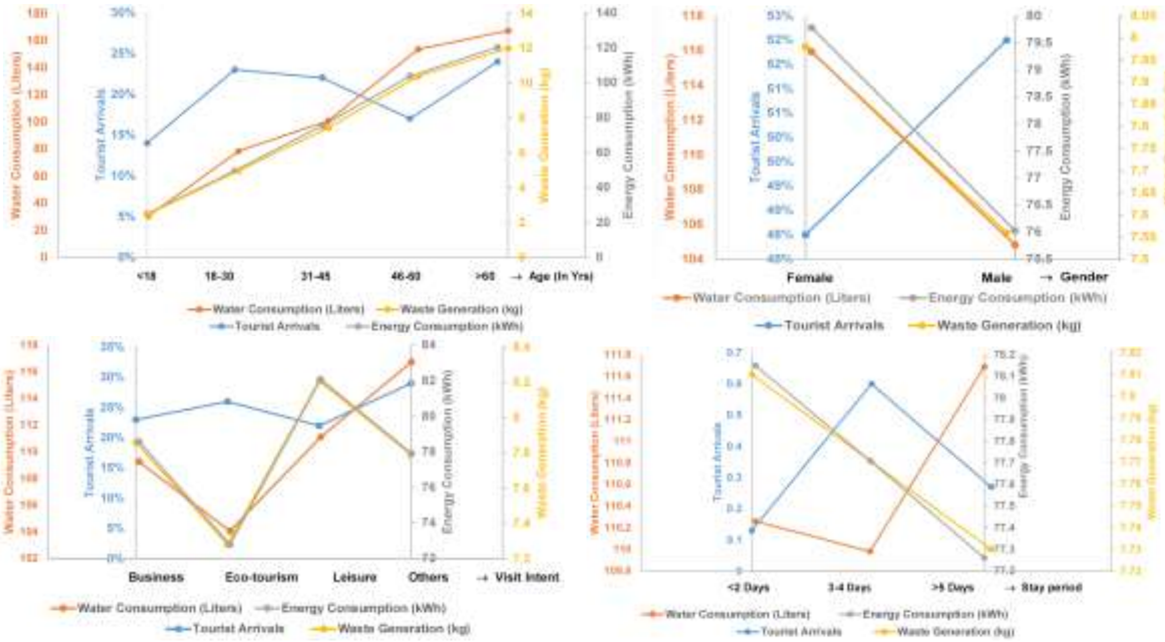
Figure 4. Demographics of respondents.



Source: *Own*

Analyzing this data, heterogeneity of tourist behavior and demographics was observed (Figure 5). For the factor visit intent, the largest share of tourists (29%) came for purposes of eco-tourism (26%), followed by business (23%), and leisure (22%), indicating a trend towards increased demand for eco-friendly travel. The per capita water and energy consumption and waste generation patterns of tourists preferring eco-tourism were lowest (1034.36 per liter, 72.91 per kWh, and 7.29 per kg, respectively), and the highest consumption and waste generation patterns were observed for tourists coming for business purposes (110.94 per liter) and for tourists coming for leisure purposes (82.67 per kWh and 8.27 per kg, respectively). This shows that the eco-tourism visitors understand their responsibility towards the environment.

Figure 5. Resource consumption and waste generation patterns of tourist's influxes



Source: *Own*

When it comes to the age group, the highest share was held by tourists aged 60 and above (24%), followed by tourists aged 18–30 (23%), with the lowest share being from the under-18 age group (14%), demonstrating a prevalence of older and young adult tourists. The water and energy consumption and waste generation patterns were highest for tourists aged 60 and above (165.47 per liter, 120.20 per kWh, and 12.02 per kg respectively) and quite low for tourists aged between 18-30 (77.44 per liter, 49.51 per kWh, and 4.95 per kg respectively). In terms of gender, the pattern is almost balanced, with 52% of males and 48% females. Females were consuming more water and energy and generating more waste (115.93 per liter, 79.78 per kWh, and 7.98 per kg, respectively) than males. For stay duration, most of the tourists (58%) spent 3–4 days, followed by 28% spending over 5 days, and a merely 14% spending less than 2 days, indicating a liking for moderate-duration stays, probably due to the number of places to visit and visit intent. Tourists staying for less than 2 days consumed more water and energy and generated more waste (112.97 per liter, 80.07 per kWh, and 8.01 per kg, respectively).

Table 4 shows the statistical breakdown of the demographics and behavior of tourists. The mean values signify that middle-aged tourists (MAge= 3.1388) have a moderate stay duration (MLS= 2.144) as they travel for leisure purposes (MPV= 2.565). The factors with the highest variability are age group (SD = 1.392) and visit intent (SD = 1.134), reflecting the necessity to accommodate the varying demands of a diverse range of tourists. Gender had the lowest variability (SD = 0.501 and var = 0.251), indicating a largely balanced distribution of male and female travelers.

Table 4. Summary Statistics of tourist data.

Statistics	Tourist demographic and behavioral factors				Water Consum (Liters)	Energy Consum (kWh)	Waste Generation (kg)
	Visit intent	Age Group	Gender	Stay duration			
Mean	2.5646	3.1388	1.5167	2.1435	110.1914	77.8421	7.7617
Std Error	0.0784	0.0963	0.0346	0.0439	4.4217	2.4391	0.2437
Median	3	3	2	2	103	80	8
Mode	4	5	2	2	78	105	5.6
SD	1.1338	1.3919	0.5009	0.6343	63.9242	35.2622	3.5238
Sample Var	1.2855	1.9374	0.2509	0.4024	4086.3093	1243.4221	12.4172
Count	209	209	209	209	209	209	209

Source: *Own*

b. Testing the hypothesis

Two-way ANOVA is performed to test the hypotheses (Table 5). Visit intent, age group, stay duration, and gender are extremely significant variables in terms of WEW. These are significantly influenced by any one factor (likely gender or stay duration, $F = 254.20$, $p \approx 0$), explaining most of the variation, while the other factor (likely age group or visit intent, $F = 24.83$, $p \approx 0$) shows a borderline effect, suggesting potential differences that warrant further investigation. The interaction between the two factors (e.g., age group and gender or visit intent and stay duration) shows a statistically significant effect on the WEW ($F = 5.95$, $p \approx 0$, $F > Fcrit = 2.29$), with an SS of 1,458.47 and MS of 243.08 across 6 degrees of freedom. This indicates that the impact of one factor on WEW depends on the level of the other, suggesting that specific combinations (e.g., young males or long-stay tourists) produce unique sustainability outcomes. Targeted interventions addressing these interactions, such as tailored campaigns for high-impact groups, are essential for improving environmental metrics. This reveals that different mixes of factors drive separate patterns of resource use. The analysis shows that the group of tourist demographic and behavioral factors increases the WEW. Hence, there is a directional difference in the mean resource consumption and mean waste generation as represented by directional hypotheses RH1, RH2, and RH3 (as also depicted in the column of p-value (= 0.00)).

Table 5. ANOVA outcomes.

Source of Variation	SS	Df	MS	F	P-value	Fcrit
Sample	3085.99	3	1028.67	24.83	0.00	2.80
Columns	959764.60	2	479882.29	254.20	0.00	3.01
Interaction	1458.47	6	243.08	5.95	0.00	2.29
Within	30071.85	540	51.404872			

Source: *Own*

c. Multivariate analysis

Multiple regression analysis is performed using formulas (1) - (3) shows the summary of these models in Table 6. The energy consumption and waste generation models exhibit high predictive accuracy ($R^2 > 0.91$), while the water consumption model shows moderate performance ($R^2 = 0.54$).

The generated YEC, YWC, and YWG models exhibit extreme effect sizes (Cohen, 1988), i.e., the independent variables (age-group, gender, visit intent, and stay duration) highly contribute to the dependent variables YEC and YWG (f^2 > 11). The large effect size (f^2=1.195) for YWC indicates water consumption may be influenced by additional factors (e.g., accommodation facilities, or tourist activities like bathing or laundry).

Table 6. Statistical model summary.

	Model Summary[b]											
Model*	R	R^2	Adj R change	MSE	RMSE	Std. error of the Est	Change statistics R^2change	F change	df1	df2	Cohen f^2 Effect Size	Sig. F change
Y_{EC}	0.9576	0.9170	0.9153	104.0562	10.2008	1.1216	0.9170	538.3136	4	203	11.042	0.000
Y_{WC}	0.7379	0.5445	0.5352	1898.481	43.5716	4.7908	0.5445	58.2756	4	203	1.195	0.000
Y_{WG}	0.9576	0.9111	0.9153	1.0406	1.0201	0.1122	0.9170	538.3136	4	203	11.043	0.000
DTRM	0.9195	0.8456	0.8061	164.9415	12.843	9.9933	0.8456	143.5667	4	203	10.321	0.000
RFRM	0.9327	0.8698	0.8366	139.0164	11.7905	9.9933	0.8698	143.5667	4	203	10.589	0.000

[*]DTRM: decision tree regression model, RFRM: random forest regression model (p threshold value <0.05)
[a] Predictors (Independent variable): age group, gender, visit intent, stay duration
[b]Dependent variable: energy consumption, water consumption, waste generation

Source: *Own*

The prediction capacity of the YEC model is highly accurate (R = 0.9576 and R^2 = 0.9170). This suggests that predictors account for 91.70% of the variance in energy consumption. Relatively low values of MSE and RMSE (104.05 and 10.20, respectively) prove the reliability of the model. The R (=0.7379) and R^2 (= 0.5445) values of the YWC model show that this model did not perform very strongly. It can be said that the predictors account for only for 54.45% of the variance in water consumption. The very low value of adjusted R^2 suggests that some predictors are not explanatory. Also, higher values of MSE and RMSE (1898.48 and 43.57, respectively) call for further improvement of the model. With R = 0.9576 and R^2 = 0.9111, the YWG model produces findings that are like those of the YEC model. The model shows outstanding predictive performance and is perfect for forecasting waste generation trends in tourism settings, as the MSE and RMSE values (1.0406 and 1.0201, respectively) show a good match with minimal error. The predictors collectively make a significant contribution to the models, as indicated by the p-value (<0.001).

Comparison between the results of the three models YEC, YWC, and YWG with the decision tree regression and random forest regression models (Table 6) shows that the generated YEC, YWC, and YWG models are more accurate than these two models. The increased MSE and RMSE values (164.94 and 12.84, respectively) also show high predictive power of YEC, YWC, and YWG models as compared to decision tree and random forest regression models.

Formula (10) is used to generate the coefficients table as shown in Table 7 to address the critique about whether regression coefficients are standardized. From Table 5 and Table 6, the significant F change statistics = 0.000 for all models indicate that at least one predictor significantly contributes to the explanatory power of each model. The unstandardized coefficients for the age group are significantly high (24.22 for energy consumption, 33.81 for water consumption, and 2.42 for waste generation), indicating that an increase in age group corresponds strongly with increased environmental impact. It emerges as the most significant factor influencing the irresponsible behavior of tourists. Therefore, tourism policies should adopt an age-targeted approach to sustainability.

Table 7. Coefficients table.

Dependent variable	Predictor	Unstd B	SE	Std Beta	t-Statistics	Sig
Energy Consumption	Const.	26.3190	2.1564	77.6450	12.2052	8.00E-26
	Age Group	24.2252	0.5236	33.8874	46.2652	**4.34E-107**
	Gender	0.8634	1.4694	0.4315	0.5876	5.57E-01
	Visit intent	0.2986	0.7341	0.3385	0.4068	6.85E-01
	Stay duration	-0.4999	0.7246	-0.5735	-0.6900	4.91E-01

Dependent variable	Predictor	Unstd B	SE	Std Beta	t-Statistics	Sig
Water Consumption	Const.	33.7679	9.2107	110.4800	3.6662	3.17E-04
	Age Group	33.8059	2.2366	47.2893	15.1151	**1.13E-34**
	Gender	5.9984	6.2763	2.9979	0.9557	3.40E-01
	Visit intent	2.4710	3.1356	2.8012	0.7880	4.32E-01
	Stay duration	-0.8781	3.0949	-1.0072	-0.2837	7.77E-01
Waste Generation	Const.	2.6319	0.2156	7.7645	12.2052	8.00E-26
	Age Group	2.4225	0.0524	3.3887	46.2652	**4.34E-107**
	Gender	0.0863	0.1469	0.0432	0.5876	5.57E-01
	Visit intent	0.0299	0.0734	0.0339	0.4068	6.85E-01
	Stay duration	-0.0500	0.0725	-0.0573	-0.6900	4.91E-01

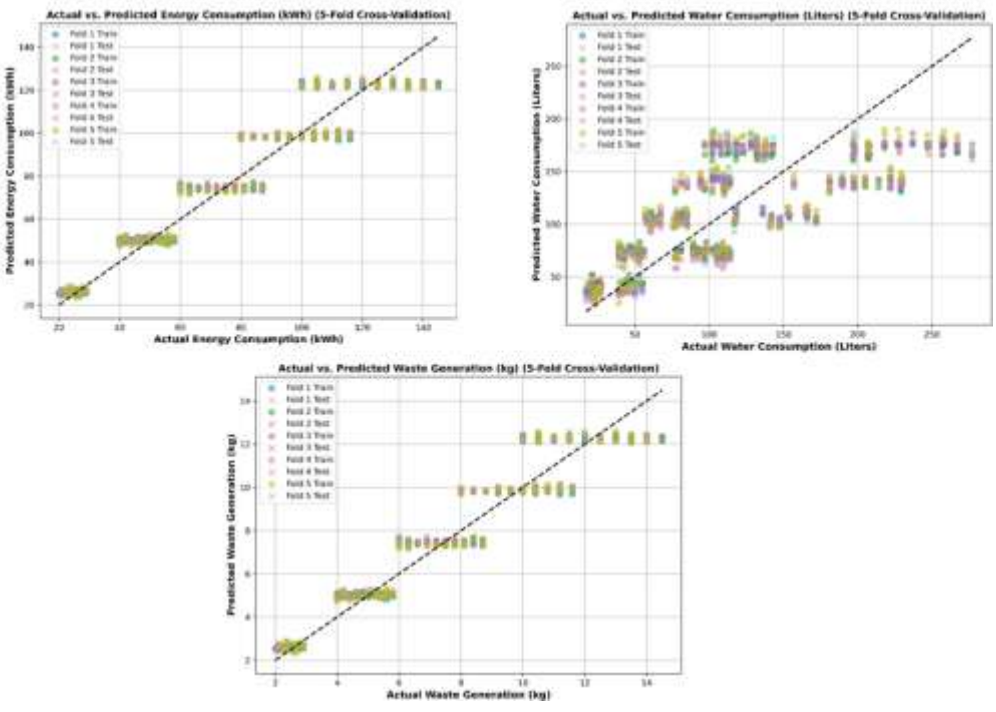
***Source**: Own*

The p-values (<0.05), shown in Table 7, also demonstrate that age group is the strongest predictor for WEW. On the other hand, gender, visit intent, and stay duration are statistically insignificant (p>0.05) across all three dependent variables. The negative coefficient of stay duration points to a possible decrease in per-day resource consumption for longer stays, but the effect is statistically weak. Similarly, the visit intent and gender exhibit slight differences that have little bearing on WEW.

Model validation

The 5-fold cross-validation scatter plots for validating the models are shown in Figure 6. The YEC and YWG models show strong predictive accuracy, with minimal error (1.1216 for YEC, 0.1122 for YWG) and consistent performance. This suggests that these models generalize well and capture underlying consumption patterns effectively. In contrast, the YWC model displays greater scatter and underprediction at higher values, indicating moderate accuracy and possible limitations in feature representation or model fit.

Figure 6. Comparison of Actual vs. Predicted values using 5-Fold Cross-Validation.



***Source:** Own*

The Variance Inflation Factor (VIF) analysis is done to detect multicollinearity in regression analysis. From Table 8 and Figures 7-9, VIF values for all the independent variables in YEC are below 2, confirming the absence of multicollinearity among independent variables. The Durbin-Watson statistics of 2.0134, close to the ideal value of 2, suggests no significant autocorrelation in residuals. The Shapiro-Wilk test (W = 0.9876, p = 0.0490) is borderline significant, implying that residuals are approximately normally distributed, although with slight deviation at the tails. Overall, the model is statistically significant and reliable for explaining variations in energy consumption. For YWC, the VIF values remain well below 2, confirming there is no multicollinearity among predictors. The Durbin-Watson statistics of 1.9616, close to 2, indicate no significant autocorrelation in residuals. However, the Shapiro-Wilk test result (W = 0.9605, p = 0.0000) strongly rejects the null hypothesis of normality, indicating that residuals are not normally distributed, which may affect the reliability of statistical inferences.

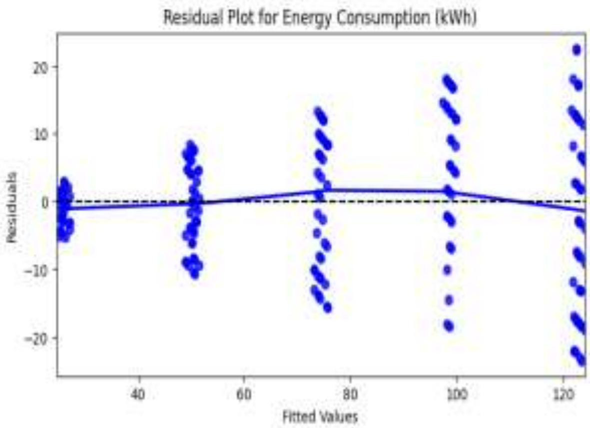
Table 8. Model validation results

Dependent variable	Feature	VIF	Durbin-Watson Statistic	Shapiro-Wilk Test	
				W	P
Energy Consumption	Age Group	0.945610	2.0134	0.9876	0.0490
	Gender	1.744086			
	Visit intent	0.889520			
	Stay duration	0.945401			
Water Consumption	Age Group	0.045691	1.9616	0.9605	0.0000
	Gender	1.744086			
	Visit intent	0.088952			
	Stay duration	0.835409			
Waste Generation	Age Group	0.945691	1.9569	0.9819	0.0110
	Gender	1.044086			
	Visit intent	0.788952			
	Stay duration	0.841427			

Source: *Own*

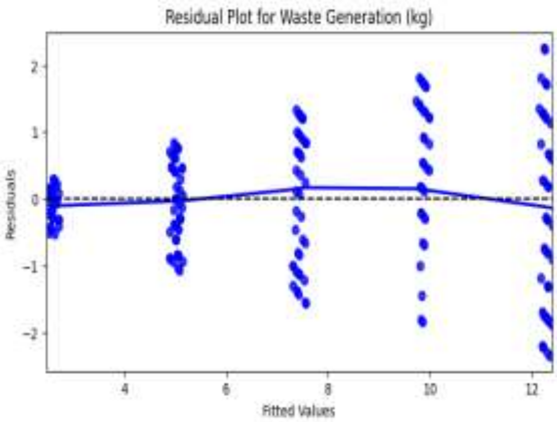
The VIF values of YWG for all predictors are below 2, confirming no multicollinearity issues. The Durbin-Watson statistic of 1.9569, which is close to the ideal value of 2, indicates that residuals are not autocorrelated. However, the Shapiro-Wilk test for normality (W = 0.9819, p = 0.0110) shows a statistically significant deviation from normality, suggesting a slight violation of the normality assumption of residuals. Despite this, given the high explanatory power and overall diagnostics, the waste generation model is statistically strong and reliable, with only minor concerns regarding the normality of residuals.

Figure 7. Residual Plot for energy consumption.



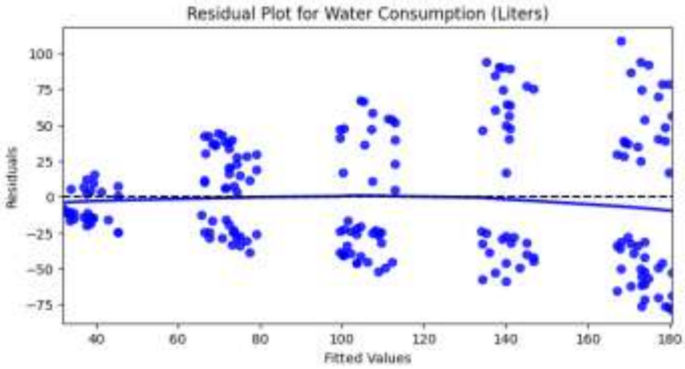
Source:

Figure 8. Residual Plot for waste generation.



Source:

Figure 9. Residual Plot for water consumption.



Source: *Own*

Based on the above analysis, it can be concluded that the developed WEW models demonstrate excellent fit and strong predictive performance as shown by the large effect size and R^2 values, low standard errors, and 5-fold cross-validation. The models performed well in predicting water and energy consumption and waste generation and can serve as efficient tools for sustainability planning.

The results of regression analysis showed that the age group is a strong predictor of water and energy consumption and waste generation. The rest of the predictors (gender, visit intent, and stay duration) also affect water and energy consumption and waste generation. Overall, the impact of the visitors' demographics and behavior on environmental metrics is very high, resulting in resource depletion that, in turn, affects the sustainability of the destination.

The results are in line with the findings of various researchers. For example, Rodríguez, Jacob & Florido (2020) showed that senior tourists had a higher pro-environmental attitude in hotel establishments than younger ones. Forleo & Bredice (2025) showed that the environmental behavior of Gen Z tourists was mainly related with the litter and single-use plastics issues. Torres-Bagur, Ribas & Vila-Subirós (2020) analyzed water-saving practices among guests at various destinations and demonstrated that differences in practices were impacted by the type of accommodation, reason for stay, and geographic origin. Gabarda-Mallorquí, Garcia, Fraguell & Ribas (2021) showed that stay duration significantly and positively influenced water conservation habits. Torabi, Hall, Azarniou & Borzu (2025) showed that environmental concerns, and situational responsibility positively impact water conservation behaviors.

d. Analyzing the attitude of tourists

The ESA questionnaire is analyzed to assess the sustainable awareness of tourists visiting Agra. The KMO measure (=0.827) exceeds the acceptable threshold (Kaiser, 1974). This supports the appropriateness of exploratory factor analysis for assessing data reliability. Computed Cronbach's alpha value (Table 9) for the questionnaire items reveals a high degree of reliability in all the constructs (as α values > 0.7).

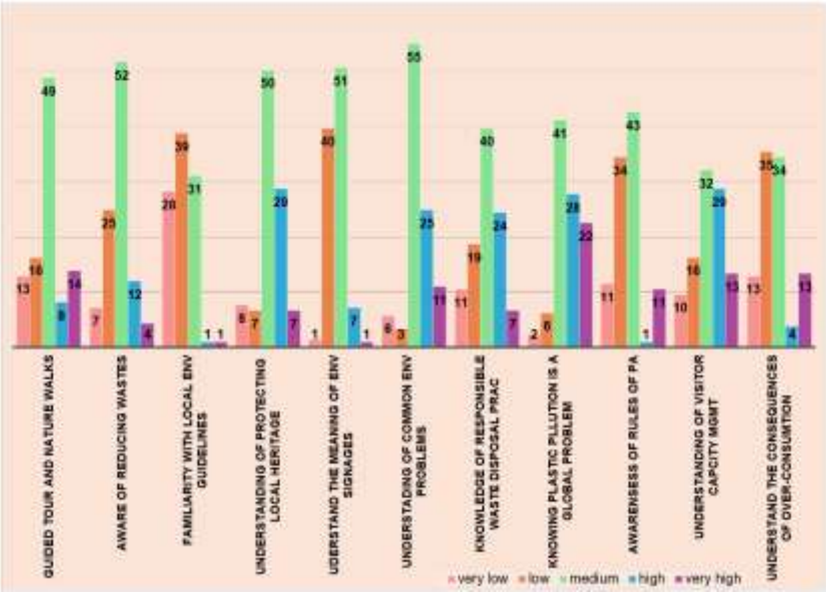
Table 9. Reliability analysis of ESA questionnaire.

Questionnaire Item	Cronbach's Alpha
Environmental sustainability knowledge	0.7332
Environmental sustainability behavior	0.8035

Source: *Own*

As observed from Figure 10, 35.40 % of the tourist respondents understood protecting the local heritage, 35.88% of the respondents had an understanding of common environmental problems, 50.23% respondents knew that plastic waste is a global problem, and 42.10% of the respondents understood visitor capacity management. For the rest of the factors, the knowledge level of the tourist respondent was poor. Therefore, only 44.97% of the respondents avoided visiting during peak season, 48.80% of respondents participated in sustainability tourism programs, and 59.33% of respondents adhered to the rules of the protected areas (Figure 10).

Figure 10. Environmental sustainability knowledge distribution among tourists.

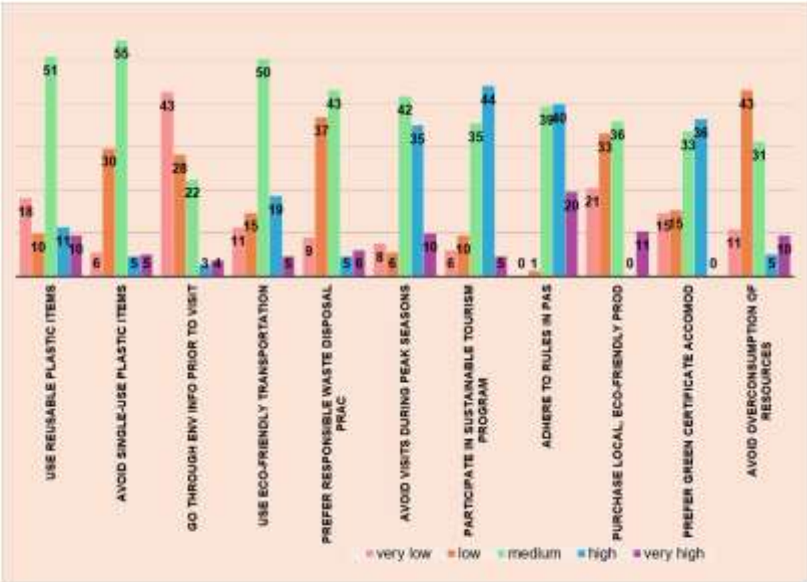


Source: *Own*

Overall, 74.60% of tourist respondents rated their sustainability awareness as medium to low. This demonstrates that 73.90% and 75.29% of tourist respondents, respectively, had medium to low levels of sustainability behavior and sustainability knowledge, which have a substantial impact on WEW, all of which have an impact on environmental sustainability. It was observed that from the arrived tourist respondents, only 24.71% had sustainable knowledge, and therefore, the behavior of 73.90% was medium to low. These results suggest a clear alignment between sustainable knowledge and sustainable behavior: lower levels of knowledge directly impact the behavior of arrival of tourists, resulting in lower levels of environmental sustainability awareness.

The results of correlation analysis are shown in Tables 10-12. The correlation between demographic features (age-group, gender, and education level) and knowledge-related variables (QK1, …, QK11) indicated very ineffective correlations (correlation coefficients mostly <0.1). Out of the 33 combinations, only 10 (gender-QK1, gender-QK6, gender-QK7, gender-QK8, gender-QK9, gender-QK11, ageGp-QK2, ageGp-QK10, ageGp-QK11, and educ-QK10) were only marginally favorable. This suggests that tourist respondents' understanding of environmental sustainability is mostly unaffected by demographic features.

Figure 11. Environmental sustainability behavior distribution of tourists.



Source: *Own*

Table 10. Correlation between demographics and tourist knowledge

	Q_{K1}	Q_{K2}	Q_{K3}	Q_{K4}	Q_{K5}	Q_{K6}	Q_{K7}	Q_{K8}	Q_{K9}	Q_{K10}	Q_{K11}
GEN	0.0394	-0.0306	-0.0598	-0.0071	-0.0118	0.0455	0.0097	0.0720	0.1658	-0.0058	0.0335
AGEGP	-0.0668	0.0055	-0.0499	-0.0762	-0.0578	-0.0086	-0.0698	-0.1831	-0.0188	0.0035	0.1034
EDUC	-0.0119	-0.0757	-0.0799	-0.0613	-0.1193	-0.1027	-0.1592	-0.0435	-0.0015	0.0877	-0.1097

Source: *Own*

Similarly, correlation between demographic features (age-group, gender, and education level) and behavior-related variables (QB1, …, QB11) showed very weak connections (correlation coefficients mostly < 0.1). 18 out of 33 combinations (gender- QB1, gender-QB5, gender-QB6, gender-QB7, gender-QB9, gender-QB11, ageGp-QB1, ageGp-QB2, ageGp-QB5, educ-QB1, educ-QB2, educ-QB3, educ-QB5, educ-QB6, educ-QB7, educ-QB8, educ-QB9, and educ-QB10) were only marginally positive. This suggests that tourist respondents' behavioral elements related to environmental sustainability are not significantly influenced by demographic factors.

Table 11. Correlation between demographics and tourist knowledge

	Q_{B1}	Q_{B2}	Q_{B3}	Q_{B4}	Q_{B5}	Q_{B6}	Q_{B7}	Q_{B8}	Q_{B9}	Q_{B10}	Q_{B11}
GEN	0.0004	-0.0689	-0.0082	-0.0064	0.0898	0.0221	0.0705	-0.0213	0.0030	-0.0428	0.0262
AGEGP	0.0592	0.0467	-0.0529	-0.0287	0.0182	-0.0443	-0.0963	-0.0647	-0.0473	-0.0968	-0.0845
EDUC	0.0542	0.0341	0.0366	0.0138	0.0230	0.0209	0.0566	0.1736	0.0600	0.1352	-0.0345

Source: *Own*

Table 12. Correlation between tourist behavior and tourist knowledge level

	Q_{K1}	Q_{K2}	Q_{K3}	Q_{K4}	Q_{K5}	Q_{K6}	Q_{K7}	Q_{K8}	Q_{K9}	Q_{K10}	Q_{K11}
Q_{B1}	0.0181	0.1076	-0.0372	-0.0105	-0.0627	0.1028	-0.0104	0.0918	-0.0027	0.1152	-0.0581
Q_{B2}	-0.1102	-0.0322	-0.1129	-0.0968	-0.0763	-0.1697	0.0212	-0.0559	-0.1240	-0.0595	-0.0512
Q_{B3}	-0.0530	0.0300	0.0832	-0.0424	0.0202	-0.0792	-0.0091	-0.1409	0.0383	0.0008	-0.0697
Q_{B4}	0.0370	-0.0203	0.0030	-0.0564	0.0454	-0.0504	-0.0063	-0.0280	0.0502	-0.0167	-0.0880
Q_{B5}	0.0093	0.1385	-0.0901	-0.0169	-0.0791	0.0239	-0.0217	0.0456	0.0194	0.0524	-0.0664
Q_{B6}	-0.0275	0.0443	0.0089	-0.0064	0.0554	-0.0091	-0.0300	0.1087	-0.0266	0.0944	-0.0999
Q_{B7}	-0.0218	0.0879	-0.0124	-0.0611	-0.0372	0.0047	0.0109	0.1270	0.0406	0.0831	-0.1530
Q_{B8}	0.0979	-0.0611	0.0705	0.0029	0.0946	0.0005	0.0885	0.0318	0.1375	0.0347	-0.0234
Q_{B9}	0.0261	-0.0317	0.0374	-0.0478	-0.0887	0.0209	-0.0522	0.1401	0.0707	0.1618	-0.1376
Q_{B10}	0.0194	0.0493	0.0614	-0.0212	0.1285	-0.0160	0.0933	0.0052	0.0633	0.0538	-0.0765
Q_{B11}	-0.0246	-0.0345	0.0239	-0.0376	0.0368	-0.0037	0.0397	0.1260	0.0336	0.0936	-0.0926

Source: *Own*

No significant association was found between the behavior and knowledge level of tourists, indicating that tourist respondents' attitudes towards environmental sustainability awareness are poor, because of the large gap between the demographic characteristics and behavioral factors, and knowledge level. This analysis also shows a knowledge-behavior gap, suggesting that tourist respondents possess environmental knowledge but do not act accordingly.

ANOVA results are illustrated in Table 13, showing that all predictors significantly influence WEW. With the p-value (< 0.05) and the F-value ($= 182.07$), it is confirmed that these factors contribute meaningfully to WEW. The RH4 hypothesis reveals that tourists with low environmental awareness show higher waste generation.

Thus, the need is to design awareness-raising targeted strategies to encourage more responsible tourist behavior.

Table 13. Model summary

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5637.21	22	256.23	182.07	0.00	1.54
Within Groups	6732.75	4784.00	1.40			
Total	12369.97	4806.00				

Source: *Own*

e. Designing strategies

The computed weights of the SWOT groups and their factors are shown in Table 14. The strengths group had the highest priority, followed by opportunities, weaknesses, and threats.

Table 14. Priority weights of S, W, O, T.

Strengths (g_1:0.4191)	**Weights**	**Weaknesses (g_2:0.1894)**	**Weights**
Age	0.0968	Overconsumption of resources	0.0665
Curiosity	0.0629	Infrastructure vandalism	0.0481
Tech-savvy	0.0679	Overtourism behaviors	0.0333
Experience-driven tourism	0.0256	Generational gaps in technology	0.0106
Adaptability	0.0226	Demand variability	0.0121
Education	0.1438	Waste generation	0.0170
Opportunities (g_3:0.2731)	**Weights**	**Threats (g_4:0.1181)**	**Weights**
Travel education	0.1161	Cultural insensitivity	0.0557
Personalization	0.0806	Overtourism impacts	0.0281
Informative activity-based travel	0.0576	Resource depletion	0.0228
Motivation-driven trips	0.0188	Vandalism	0.0115

Source: *Own*

The weights of SWOT factors (Table 14) indicate that the factors *f*6, *f*1, *f*3, and *f*2 of the Strength group and *f*7, *f*8, and *f*9 of the Opportunity group are more important than factors in other groups. The involvement of these higher-weighted factors in the Strength and Opportunity groups testifies to the rank of SO as 'maxi-maxi' strategy turned out to be the best one, hence the consistency of the proposed approach.

TWOS Analysis is performed to design strategies to increase awareness among tourists. In this method, strategies are designed for using strengths to capitalize on opportunities (SO) and minimize threats (ST), while overcoming weaknesses through opportunities (WO) or avoiding threats (WT). The TOWS matrix is shown in Table 15.

The following measures must be taken to successfully execute the strategies:

- *A_1. Grow ethical awareness of responsible tourism*: Awareness campaigns should be launched at tourist accommodations to educate tourists about how to avoid wildlife exploitation, reduce waste, and buy locally.
- *A_2. Encourage to focus on slow travel*: Booklets or pamphlets should be prepared containing information about all the tourist spots and cultural heritage, so that tourists are encouraged to stay longer in one location.
- *A_3. Educate tourists to respectfully engage with locals*: While making online bookings, tourists must be shown short films to perform pre-trip research on cultural norms, promoting local language basics (hello, thank you), and encouraging respectful photography by asking permission.
- *A_4. Implement signboards for minimizing energy and water consumption*: Tourist accommodation should place signboards designed attractively to show the consequences of overconsumption of energy and water. Signs must be placed in prominent and well-lit locations where individuals can read them clearly.

Table 15. TOWS Matrix

	Opportunities	**Threats**
	f_7. Travel education	f_{17}. Cultural insensitivity
	f_8. Personalized travel experience	f_{18}. Overtourism impacts
	f_9. Informative activity-based travel	f_{19}.Resource depletion
	f_{10}. Motivation-driven trips.	f_{20}. Vandalism
Strengths	**SO**	**ST**
f_1. Age	A_1: Grow ethical awareness of responsible tourism (f_1, f_2, f_7)	A_3: Educate tourists to respectfully engage with locals (f_1, f_6, f_{17})
f_2. Curiosity	A_2: Focus on slow travel (f_2, f_3, f_8, f_{10})	A_4: Implementing signboards for minimizing energy and water consumption (f_6, f_{19})
f_3. Tech-savvy	A_5: Encourage informative travel (f_3, f_6, f_7)	A_6: Encourage tourists to visit lesser-known destinations (f_2, f_4, f_{18}, f_{19})
f_4. Experience-driven tourism	A_7: Develop age-group based strategies (f_1, f_2, f_3, f_7, f_8)	A_{12}: Encourage eco-friendly alternatives (f_1, f_5, f_{18}, f_{19})
f_5. Adaptability	A_{11}: Organize pre-visit education campaigns at tourist accommodations (f_3, f_5, f_6, f_7, f_9)	

***f*$_6$. Education**	A$_{13}$: Use social media for conservation awareness (*f*$_1$, *f*$_3$*f*$_6$, *f*$_7$)	
Weaknesses	**WO**	**WT**
***f*$_{11}$. Overconsumption of resources**	A$_8$: Create new tourist attractions (*f*$_{15}$, *f*$_8$, *f*$_9$, *f*$_{10}$)	A$_{10}$: Avoid overcrowding at the tourist hotspots (*f*$_{13}$, *f*$_{18}$)
***f*$_{12}$. Infrastructure vandalism**	A$_9$: Encourage to follow *leave no trace* principles (*f*$_{11}$, *f*$_{12}$, *f*$_{16}$, *f*$_8$,*f*$_9$)	A$_{14}$: Balance immediate needs with long-term scarcity through technology (*f*$_{14}$, *f*$_{15}$, *f*$_{19}$)
***f*$_{13}$. Overtourism behaviors**		A$_{15}$: Implement visitor dispersion model to reduce overtourism impact (*f*$_{13}$, *f*$_{16}$, *f*$_{19}$)
***f*$_{14}$. Generational gaps in technology**		
***f*$_{15}$. Demand variability**		
***f*$_{16}$. Waste generation**		

Source: *Own*

- A5. Encourage informative travel: Tourists must be guided by displaying the relevant information through digital signage, interactive kiosks, and large-screen displays at every tourist spot and tourist accommodation. They must be informed about the government initiatives, and rules must be made to ensure these are followed strictly.

- A6. Encourage tourists to visit lesser-known destinations: Tourists must be informed about off-beat locations via blogs and local forums, and must be encouraged to travel during the off-season. Focus should be placed on visiting smaller towns, national parks, and regions overshadowed by popular spots. Promoting slow travel can also reveal unique, non-touristy experiences.

- A7. Develop age-group-based strategies: Develop an online campaign to raise awareness about responsible tourism practices. Integrating age-specific sustainability materials into tourist welcome kits, digital guides, and hotel messaging. For Gen Z, suggest eco-friendly Instagrammable hotspots. For Gen Y and X, suggest eco-labelled responsible travel options combining leisure with ethical consumerism. For senior tourists, provide sustainable behavior training to promote eco-friendly habits such as minimizing energy and water consumption and reducing waste, provide social tourism packages that offer cultural engagement catering to comfort needs, and promote slow travel options.

- A8. Create new tourist attractions: Tourists should be encouraged to develop unique, authentic, and sustainable experiences, such as focusing on local culture, nature-based activities (cycling, trekking).

- A9. Encourage to follow leave no trace principles: Prepare a brief documentary to give them the knowledge of the regulations and special concerns for the area they will visit, prepare them for extreme weather and emergencies before tourists reach the destination. The accommodation destination manager may suggest another schedule for the trip to avoid times of high use. The manager should impose strict rules to reduce vandalism and preserve the past, should be told about disposing of waste properly, and should respect wildlife.

- A10. Avoid overcrowding at the tourist hotspots: To avoid overcrowding, tourist accommodations must provide facilities for advance online bookings of the tourist spots. The destination manager should restrict the number of tickets sold at a particular time. Virtual tours of the tourist spots can also be provided.

- A11. Organize pre-visit education campaigns at tourist accommodations: Tourists must be provided with early, accurate information, documentation, and application timelines via hotel digital platforms.

- A12. Encourage eco-friendly alternatives: Tourists should be given knowledge of biodegradable materials to minimize single-use plastics at tourist spots/accommodations, choose energy efficient accommodation, use environmentally friendly transportation modes, visit destinations that prioritize sustainability, and provide resources to educate visitors about eco-conscious choices, and should be encouraged to use the same.

- A13. Use social media for conservation awareness: Engaging educational content (videos/ infographics) must be created, collaborate with influencers, live streaming must be used for Q&As, and hashtag-driven activism to drive tangible action may be launched.

- A14: Balance immediate needs with long-term scarcity through technology: The destination manager should use AI and IoT based real-time resource tracking to implement the circular economy and invest in renewable, decentralized infrastructure.

- A15. Implement visitor dispersion model to reduce overtourism impact: Destination managers should use IoT devices to track visitor density in real-time, and implement apps to suggest less-crowded areas. Alternative sites, hidden gems or rural tourism can be suggested to relieve pressure on central hotspots.

This targeted approach can help bridge the sustainability gap across age demographics and support more responsible tourism practices.

CONCLUSION

The goal of this study was to analyze the environmental impact of tourist influxes at Agra and to generate strategies for increasing environmental sustainability awareness among tourists to minimize the consequences of tourist influxes. 8 years of data were collected, and explanatory analysis was performed to achieve the research study goal and answer the research questions. Three regression models, YWC, YEC, and YWG, were developed to find the dominant pattern of resource consumption and waste generation. Descriptive analysis and the regression models helped in relating these patterns to the demographics and behavior of tourists. This answers RQ1. A tourist environmental sustainability awareness questionnaire was developed and analyzed to assess the environmental awareness of tourists and it was found that very few tourists arriving in Agra had environmental awareness. This answers RQ2. Finally, strategies are designed using TWOS analysis to increase awareness among tourists and make them environmentally friendly. This answers RQ3.

This study has certain limitations. An in-depth analysis of different dimensions of sustainable metrics (carbon footprint, water pollution, and soil erosion) is not discussed, as the intensity and enforcement of tourist arrival factors may also have a significant impact on these metrics. Another limitation is not considering qualitative elements which could offer more profound insights. Future studies can include analyzing the impact of tourist influxes on sustainability metrics. Generating insight from the perspective of stakeholders could bring in understanding of which shortfalls are likely in the perceptions regarding sustainability and strategies for improvement. Including socio-economic factors for such analysis and used of ensemble methods can enhance accuracy of the analysis.

The purpose is added at page 2, paragraph 1; and page 3, paragraph 2.

Literature review and results already reflect the intended design, scope, and theoretical framework of the study. Therefore, these sections are not revised.

DATA AVAILABILITY

The data presented in this study are available on request from the corresponding author.

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