ASI Asia Social Issues
ASIA SOCIAL ISSUES 2026; 19(4): 289762
https://doi.org/10.48048/asi.2026.289762
DJMP Center for Digital Journal Management & Multidisciplinary Academic Platform
RESEARCH ARTICLE

Factors Influencing Low-Carbon Tourism Perceptions and Behavioral Intentions Among Thai Generation Z: A Structural Equation Modeling Approach

Patteera Pantaratorn*, Supisara Tipsangwan, Sasikan Chanarak, Armee Jangja and Phenpat Jaruenwai

Bachelor of Arts Program in Tourism and Hospitality Management, Rangsit University, Pathum Thani 12000, Thailand

(*Corresponding author's e-mail: patteera.p@rsu.ac.th)

Received: 4 November 2025, Revised: 13 December 2025, Accepted: 21 January 2026, Published: 26 January 2026

Abstract

This study examines perceptions and behavioral intentions of Thai Generation Z tourists (n = 405) toward low-carbon tourism, integrating Theory of Planned Behavior (TPB) and Value-Belief-Norm (VBN) theory using Structural Equation Modeling (SEM). The research tested relationships between demographic factors, environmental awareness (knowledge and benefit perception), and sustainable tourism behavioral intentions. Results showed that low-carbon tourism perception strongly predicted behavioral intentions ($\beta = 0.774$, $p < 0.001$), explaining 60% of variance in sustainable behaviors, strongly supporting TPB. Critically, knowledge and understanding influenced perception formation more strongly than benefit recognition, supporting the VBN theory that cognitive awareness drives pro-environmental orientations. Demographically, education level emerged as the strongest differentiator ($\eta^2 \approx 0.07$), while traditional predictors (gender, age, income, and internet usage) showed no significant effects, suggesting generational environmental homogeneity. Despite conceptual ambiguity—only 44.2% correctly defined low-carbon tourism—participants demonstrated strong behavioral readiness, with 45.7% prioritizing sustainable transportation. These findings provide empirical evidence for environmental literacy primacy over benefit recognition in Thai Generation Z, challenge conventional demographic segmentation assumptions in sustainability marketing, and offer practical insights for policymakers and tourism businesses engaging Generation Z in Thailand's low-carbon transition. The study extends integrated TPB-VBN frameworks to Southeast Asian youth markets and provides context-specific evidence of generational homogeneity in environmental consciousness.

Keywords: Low-carbon tourism, Generation Z, Environmental awareness, Theory of Planned Behavior, Value-Belief-Norm theory, Thailand, Sustainable tourism

Introduction

Global context and the low-carbon tourism challenge

Climate change, driven primarily by human-induced carbon emissions, stands as one of the most pressing challenges of the 21st century (Petchchedchoo et al., 2024). While tourism significantly contributes to global economic development, it is also a major source of greenhouse gas emissions. International tourism is responsible for an estimated 8% of global carbon emissions, with transportation being the dominant factor, followed by accommodation and tourism-related activities (Koçak et al., 2020; Yan & Phucharoen, 2024). This environmental burden is expected to rise further as tourism demand grows, particularly in emerging economies across the Asia-Pacific region. Low-carbon tourism has emerged as a strategic response to these environmental challenges. It represents a shift toward more sustainable travel that retains tourism's economic and social benefits while minimizing its environmental footprint (Petchchedchoo et al., 2025). Low-carbon

practices include using renewable energy, promoting energy-efficient transport, adopting green building standards, supporting local food systems to cut transport-related emissions, and implementing carbon offset programs (Dang & Phan, 2025; Iamtrakul & Klaylee, 2024; Srimachai et al., 2025). Tourists' environmental awareness increasingly influences decisions around destinations and accommodation choices (Fakfare et al., 2022). Together, these strategies aim to create a tourism model that harmonizes economic growth with environmental conservation and community well-being (Baloch et al., 2023; Leal Filho et al., 2023).

Thailand's tourism sector exemplifies this global challenge. From 2024 to 2025, the sector expanded remarkably, with international arrivals climbing and total revenue soaring from 1.6 trillion to 2.8 trillion baht—a clear sign of renewed global confidence and effective policy measures (Travel and Tour World, 2025). However, this expansion has intensified environmental pressures, including rising carbon emissions and degradation of natural ecosystems in heavily visited areas (Fakfare et al., 2022). As tourists' environmental awareness increasingly influences decisions around destinations and accommodation choices (Fakfare & Wattanacharoensil, 2023), understanding how different demographic groups perceive and engage with low-carbon tourism becomes essential for achieving Thailand's national goals of carbon neutrality by 2050 and net-zero emissions by 2065 (Climate Action Tracker, 2025).

Generation Z: The future of sustainable tourism

Generation Z (born between 1996 and 2012) is emerging as a pivotal demographic shaping the future of global tourism (Dang & Phan, 2025). Unlike older generations where environmental attitudes often varied by traditional demographics, Generation Z exhibits a more uniform environmental consciousness (Le & Nguyen, 2024). This homogeneity likely stems from shared digital exposure to climate issues, sustainability-focused education, and peer influence through social media (Lopes et al., 2024). Members of Generation Z actively seek out sustainable products and services, using their purchasing power as a form of environmental activism. Their digital savviness enhances rapid information sharing and peer influence, which can accelerate the spread of sustainable tourism practices (Wang et al., 2022). Travel preferences within this generation consistently align with eco-conscious values, including strong interest in environmentally friendly accommodations, low-impact transportation, and experiences that support local communities. Moreover, Generation Z's tendency to align personal values with consumption suggests that environmental awareness may serve as a more stable and powerful predictor of tourism behavior than traditional demographic indicators like gender or income (Subongkod et al., 2025).

Background and research foundations for low-carbon tourism among Thai Generation Z

Thailand's tourism sector is particularly significant in the global sustainability context, serving as both an economic driver and an environmental testing ground for sustainable tourism transitions. Research on low-carbon tourism in Thailand has progressed in recent years, establishing foundational understanding of destination-level strategies and infrastructure requirements. Bhaktikul et al. (2021) examined low-carbon tourism development frameworks and policy implications for sustainable community development, while Fakfare and Wattanacharoensil (2023) investigated low-carbon practices in island tourism contexts, focusing on destination management strategies and tourist experience attributes. More recently, Khiaolek et al. (2025) conducted comprehensive gap analyses of low-carbon tourism infrastructure and practices across nine sectors in Chiang Mai, highlighting operational challenges in implementation across diverse tourism businesses.

Although these studies have made valuable contributions, they remain predominantly supply-focused, emphasizing destination strategies, policy frameworks, and infrastructure rather than tourist-side demand factors (Dejprayoon et al., 2025). No existing Thai study has integrated value-based and norm-based theories to comprehensively model low-carbon tourism behavioral formation among specific demographic cohorts, particularly Generation Z. This supply–demand imbalance represents a critical gap, as sustainable tourism transitions require not only infrastructure

readiness but also consumer willingness and behavioral commitment.

Against this backdrop, a significant research gap emerges in understanding demand-side determinants of low-carbon tourism, particularly among Generation Z—a demographic cohort poised to shape Thailand's tourism future. This generation is rapidly becoming a dominant force in domestic tourism, often contributing substantially to tourism activity and frequently leading family travel planning (Pantaratorn et al., 2023). Yet research on their engagement with low-carbon tourism in Thailand remains limited and fragmented (Patitas & Phoochinda, 2024), potentially due to limited awareness or incomplete understanding of the concept itself. Addressing this knowledge gap is essential for policymakers who require targeted data to design effective environmental interventions (Manotungvorapun & Gerdsri, 2025). Moreover, achieving Thailand's carbon neutrality and net-zero emission goals depends not only on supply-side innovations but also on shifting consumer behavior (Climate Action Tracker, 2025). Thus, understanding Generation Z's perceptions and behavioral intentions (KI) toward low-carbon tourism requires a robust theoretical foundation capable of explaining both cognitive and evaluative pathways to intention formation.

Research objectives and contributions

This study addresses the identified research gaps by examining low-carbon tourism awareness and intentions among Thai Generation Z tourists through a comprehensive empirical investigation. The research integrates established environmental psychology theories with tourism-specific contexts to develop and test a theoretical model linking perception, awareness, and BI. The Primary Objective is to investigate how Thai Generation Z tourists perceive and respond to low-carbon tourism concepts, identifying the cognitive and evaluative components that comprise environmental awareness and their relationship to BI. Specific objectives include examining demographic factors, validating measurement instruments, testing theoretical relationships, and providing evidence-based recommendations. The study offers several contributions: it is theoretical by applying environmental psychology frameworks; empirical by providing the first comprehensive data on Generation Z low-carbon tourism awareness in Thailand; and practical by delivering evidence-based insights for sustainability marketing, environmental education, and policy intervention development

Materials and methods

Research design and theoretical framework

This study employed a quantitative cross-sectional design using SEM to investigate the relationships among demographic characteristics, low-carbon tourism perceptions, and BI among Thai Generation Z tourists. The research integrates specific components from TPB (Ajzen, 1991) and VBN theory (Stern, 2000) to examine low-carbon tourism behavioral formation. From TPB, the study operationalizes the attitude-intention pathway, where low-carbon tourism perception (attitude toward behavior) predicts BI. From VBN theory, the research operationalizes the awareness of consequences component, distinguishing cognitive awareness (KU of environmental impacts) from evaluative awareness (perceived benefits of environmental outcomes). This theoretical integration enables examination of two complementary pathways: TPB's rational evaluation pathway (favorable attitudes toward low-carbon tourism) and VBN's cognitive foundation pathway (awareness of environmental consequences). The hierarchical structure posits that cognitive and evaluative dimensions combine to form overall low-carbon tourism perception, which subsequently predicts BI, a pathway central to both theoretical traditions. The model specifically hypothesizes that demographic factors (education, occupation, marital status) influence low-carbon tourism perceptions, which subsequently predict sustainable tourism behavioral intentions, consistent with TPB's core propositions. SEM was utilized to test and confirm the effects of the studied factors (Li et al., 2024).

Population and sample determination

Target population

The target population comprised Thai individuals born between 1996 and 2012 (Generation Z), aged 13–29 years at the time of data collection (May 2025). This cohort was selected based on their projected influence on future sustainable tourism trends.

Sample size determination

The minimum required sample size was determined using two methods. Based on Yamane's (1973) formula for finite populations (95% confidence, 5% margin of error), a minimum of 384 respondents was required. The formula used was:

$$n = N / (1 + N(e^2)).$$

Where:
N = population size
e = 0.05.

Additionally, following Kline's (2016) recommendations for SEM (15 factor loadings + 6 structural paths = 21 parameters), a minimum of 315 participants was required (10–20 cases per estimated parameter) (Cohen, 2013). The final sample of 405 participants exceeded both thresholds.

Sampling strategy and data collection procedures

Sampling and survey administration

Non-probability convenience sampling was employed via digital platforms (Facebook, Instagram, TikTok, LINE) using QR codes and survey links, aligning with Generation Z's communication preferences. Data collection occurred from May 1–31, 2025, using a self-administered online questionnaire. Participation was restricted to individuals aged 18 years and above. This eligibility requirement was clearly stated in the information sheet, and respondents were required to confirm their age before accessing the questionnaire.

Data quality and ethical compliance

Data quality was ensured through multiple validation checks, including attention filter questions and logical consistency checks. Incomplete responses and random responding patterns were excluded. The digital format ensured participant anonymity. All personal data was anonymized immediately upon collection, and identifying information was separated to ensure confidentiality and comply with Thailand's Personal Data Protection Act (PDPA).

Methodological limitations

The use of non-probability convenience sampling through digital platforms resulted in a geographic concentration, with 58.0% of respondents originating from Thailand's Central region. This method may underrepresent Generation Z individuals in rural areas or those with limited digital engagement.

Research instrument development

The structured questionnaire comprised three main sections designed to capture demographic characteristics, low-carbon tourism perceptions, and BI.

Instrument development and theoretical foundations (Concise version)

The survey instruments were developed by adapting validated scales from environmental psychology and tourism research and contextualizing them for low-carbon tourism among Thai Generation Z tourists. Each construct was operationalized to reflect core components of the TPB and VBN theories, ensuring both theoretical alignment and contextual relevance.

Benefit Perception (BP).

Benefit Perception reflects the TPB "attitude toward behavior" component (Ajzen, 1991), capturing evaluative judgments about outcomes of low-carbon tourism. Items were adapted from Han et al.'s (2010) sustainable tourism scales and Stern et al.'s (1999) environmental consequence measures within the VBN framework. BP1–BP4 assess perceived environmental benefits (e.g., emission reduction, resource conservation), while BP5 captures long-term sustainability outcomes. Wording was contextualized for Thai low-carbon tourism practices (e.g., eco-friendly transport, low-carbon hotels), following guidelines from Ma et al. (2024).

Knowledge and Understanding (KU).

The KU items operationalize the VBN "awareness of consequences" construct (Stern, 2000), representing cognitive understanding of tourism's environmental impacts. Items were drawn from environmental awareness scales in sustainable tourism research (Lin et al., 2022; Wang et al., 2022). KU1–KU2 measure conceptual understanding of low-carbon tourism, KU3–

KU4 assess knowledge of specific mitigation practices and stakeholder roles, and KU5 evaluates awareness of how tourist decisions influence carbon reduction. This distinction between cognitive knowledge (VBN) and evaluative perception (TPB) supports hypothesis H2b on educational effects.

Behavioral Intention (BI)

BI represents the TPB's central outcome variable (Ajzen, 1991), measuring the likelihood of engaging in specific low-carbon tourism behaviors. Items were adapted from TPB intention scales used in sustainable tourism studies (Han et al., 2010; Wang et al., 2022; Ma et al., 2024). BI1–BI5 capture concrete behaviors such as sustainable transportation use, green accommodation choice, low-impact activities, plastic reduction, and efficient route planning, reflecting Ajzen's compatibility principle. Thai adaptations (e.g., referencing local public transportation) followed contextualization practices recommended by Dejprayoon et al. (2025).

Table 1 Construct operationalization and scale development sources

Construct	Theoretical Component	Theoretical Foundation	Source Literature	Items	Sample Item
Benefit Perception (BP)	Attitude toward behavior	TPB (Ajzen, 1991)	Han et al. (2010); Stern et al. (1999)	5	Low-carbon tourism reduces greenhouse gas emissions
Knowledge & Understanding (KU)	Awareness of consequences	VBN (Stern, 2000)	Lin et al. (2022); Wang et al. (2022)	5	Understanding importance of energy-efficient choices
Behavioral Intention (BI)	Behavioral intention	TPB (Ajzen, 1991)	Han et al. (2010); Ma et al. (2024); Wang et al. (2022)	5	I would choose low-emission transportation like buses

Note: All items were adapted for Thai Generation Z low-carbon tourism context with cultural modifications (Dejprayoon et al., 2025). IOC ≥ 0.50; pilot study n = 30.

Instrument validation process

All adapted items underwent rigorous validation to ensure cultural appropriateness and construct validity. Content validity was evaluated using the Item-Objective Congruence (IOC) method through expert review by three specialists in tourism management and environmental studies. Following the classical IOC criteria of Rovinelli and Hambleton (1977) and Turner and Carlson (2003), an IOC threshold of ≥ 0.50 was applied, and all items met this requirement. Reliability testing showed excellent internal consistency, with Cronbach's alpha values exceeding 0.95 across all constructs. A pilot test with 30 Generation Z respondents confirmed item clarity and face validity, leading to minor wording refinements to improve comprehension among younger Thai participants. This validation process follows established scale development protocols (Hair et al., 2021; Field, 2024) and ensures theoretical fidelity to the TPB/VBN frameworks as well as contextual relevance for Thai Generation Z low-carbon tourism. Table 1 summarizes the theoretical foundations, source literature, and validation metrics for all constructs, demonstrating how each was operationalized and adapted for the study context.

Section 1: Demographic Characteristics (9 items)

- Personal factors: gender, age, marital status, education level, occupation, monthly income, region of origin
- Digital behavior: daily internet usage duration, peak internet usage times

Section 2: Low-Carbon Tourism Perception (15 items) This section assessed two key constructs using 5-point Likert scales (1 = strongly disagree, 5 = strongly agree):

Benefit Perception Construct (5 items):

- BP1: Low-carbon tourism reduces greenhouse gas emissions that cause global warming
- BP2: Low-carbon tourism reduces resource waste and minimizes tourism's environmental impact

 BP3: Low-carbon hotels and accommodations help reduce environmental impact and global warming

 BP4: Using eco-friendly public transportation reduces air pollution and greenhouse gas emissions

 BP5: Low-carbon tourism creates sustainability for tourist destinations

Knowledge and Understanding Construct (5 items):

 KU1: Low-carbon tourism focuses on reducing global warming

 KU2: Low-carbon tourism minimizes environmental impact

 KU3: Low-carbon tourism includes supporting eco-friendly activities such as recycling, waste separation, and plastic reduction

 KU4: Low-carbon tourism encourages operators and tourists to participate in environmental protection through carbon dioxide emission reduction

 KU5: Understanding the importance of choosing energy- efficient transportation, accommodations, restaurants, and tourism activities that reduce carbon dioxide emissions

Section 3: Behavioral Intention (5 items) Measured intended engagement in low-carbon tourism behaviors using 5-point Likert scales:

 BI1: I would choose low-emission transportation like public buses or bicycles when traveling

 BI2: I would stay at environmentally friendly hotels with green policies

 BI3: I would choose nature-based activities like walking tours, swimming, or cycling

 BI4: I would reduce plastic use by bringing reusable containers while traveling

 BI5: I would plan efficient travel routes to save energy and reduce emissions

Hypothesis development

The hypotheses are derived from integrating the TPB and Value-Belief-Norm (VBN) theory (Stern, 2000) to explain how demographic and cognitive factors influence low-carbon tourism perceptions and BI among Generation Z in Thailand.

H1: Marital Status and Environmental Priority Setting

TPB suggests that BI are shaped by attitudes and competing life priorities. Prior studies indicate that single individuals often display stronger pro-environmental orientations due to fewer household responsibilities and greater autonomy in decision-making, compared to married individuals who may prioritize family obligations.

 H1: Single Generation Z tourists will report higher low-carbon tourism awareness than married counterparts.

H2a & H2b: Education Level and Awareness Dimensions

Education is a key predictor of environmental literacy and sustainable behaviors. VBN theory suggests higher education strengthens both the awareness of environmental consequences and the sense of personal responsibility.

 H2a: Higher education levels will be positively associated with greater low-carbon tourism awareness.

 H2b: The effect of education will be stronger for KU than for BP, as formal learning primarily enhances cognitive understanding.

H3a & H3b: Occupational Context and Information Access

Occupational environments influence exposure to sustainability information. Students are frequently engaged in structured learning contexts that integrate environmental topics, often leading to higher levels of eco-awareness (Dang & Phan, 2025). Likewise, formal sector employees are often subject to workplace sustainability initiatives, enhancing their awareness compared to informal workers (Ahmad et al., 2023).

 H3a: Students will demonstrate higher low-carbon tourism awareness than other occupational groups.

 H3b: Formal sector employees will show higher awareness than informal workers.

H4: Perception–Intention Relationship

Consistent with the core proposition of TPB, perception of environmental value directly predicts pro-environmental intentions (Wang et al., 2022). Research

on Generation Z confirms that their green choices are strongly shaped by their perception of environmental consequences (Lopes et al., 2024).

 H4: Positive low-carbon tourism perceptions will significantly predict BI among Thai Generation Z, explaining at least 25% of the variance.

The theoretical relationships, construct operationalization, and specific hypotheses are synthesized in Table 2, which illustrates how demographic factors, environmental awareness dimensions, and BI are interconnected through the integrated TPB-VBN framework.

Table 2 Theoretical framework, construct operationalization, and hypothesis mapping

Construct	Theory Source	Component Operationalized	Measured Through	Linked Hypotheses
Benefit Perception	TPB	Attitude toward low-carbon tourism	5-item Likert scale	H4
Knowledge & Understanding	VBN	Awareness of consequences	5-item Likert scale	H2b, H4
Overall Perception	TPB + VBN	Combined attitude + awareness	Second-order latent variable	H4
Behavioral Intention	TPB	Intention to engage in behaviors	5-item Likert scale	Dependent variable
Education Level	Demographic	Influences awareness (VBN)	Categorical variable	H2a, H2b
Occupation	Demographic	Influences information exposure	Categorical variable	H3a, H3b
Marital Status	Demographic	Influences priorities (TPB)	Binary variable	H1

Theoretical Integration Note: This study adopts partial components from both theories. From TPB: attitude → intention pathway (omitting subjective norms, perceived control). From VBN: awareness of consequences component (without full value → worldview → awareness → responsibility → norms chain). This selective integration examines specific theoretical pathways rather than comprehensive model validation.

Data analysis procedures

Data analysis was conducted using IBM SPSS Statistics 28.0 and AMOS 28.0 to perform SEM, following established analytical guidelines (Hair et al., 2021). Preliminary analysis included descriptive statistics, screening for missing data and outliers (Tabachnick & Fidell, 2019), and assessing normality (Kim, 2013). Exploratory checks were also used to examine initial relationships between demographic variables and low-carbon tourism awareness.

Measurement Model Validation was carried out through Confirmatory Factor Analysis (CFA) for each construct (Brown, 2015). Reliability was assessed using Cronbach's alpha and Composite Reliability (Fornell & Larcker, 1981; Hair et al., 2021), while convergent validity was evaluated through factor loadings and AVE (Fornell & Larcker, 1981). A second-order CFA validated the hierarchical structure of the perception construct (Chen et al., 2005).

For Hypothesis Testing, group differences in awareness were examined using ANOVA and Welch's ANOVA (Field, 2024), with Levene's test applied to assess variance homogeneity (Levene, 1960). Post-hoc comparisons used the LSD method, and effect sizes were interpreted using η^2 (Cohen, 2013; Lakens, 2013).

Structural Equation Modeling formed the core analysis, employing Maximum Likelihood Estimation for path modeling (Kline, 2023). Model fit was evaluated using χ^2/df, CFI, RMSEA, and GFI, and path coefficients and explained variance (R^2) were interpreted according to recommended standards (Hair et al., 2021).

Finally, key Statistical Assumptions were verified: normality via skewness and kurtosis (Kline, 2023), independence through random sampling, linearity via scatterplots, and multicollinearity through correlation matrices and VIF (Hair et al., 2021). All analyses used a significance level of $\alpha = 0.05$, with effect sizes interpreted following Cohen's conventions (Cohen, 2013; Lakens, 2013).

Results

Sample characteristics

A total of 405 Thai Generation Z tourists participated in this study. The sample demonstrated the following key characteristics: predominantly female (61.2%), aged 19–24 years (70.9%), single (95.1%), and comprised mostly students (61.2%). Most respondents held a bachelor's degree (66.2%) and originated from Thailand's Central region (58.0%). Monthly income distribution was concentrated in the lower-middle income brackets, with the largest group earning 10,001–15,000 THB (24.2%). Digital engagement was high, confirming the generation's digital-native characteristics: 36.0% reported daily internet usage exceeding 10 hours, with peak usage concentrated during evening hours (18:01–24:00). Complete demographic details are provided in Supplementary Table S1.

Low-carbon tourism conceptual understanding

An analysis of respondents' understanding of low-carbon tourism concepts revealed notable divergences between conceptual definitions and practical behavioral preferences. Among the 405 participants, only 44.2% correctly defined low-carbon tourism as 'a tourism model focused on reducing carbon dioxide emissions into the atmosphere'. A considerable proportion selected a broader interpretation, with 26.7% choosing 'tourism that reduces human impact on nature' and 24.2% selecting 'economic growth under sustainable development'. The full distribution is presented in Supplementary Table S2.

This variability indicates conceptual ambiguity, suggesting that many respondents lacked unified technical understanding of the concept. Further, when examining carbon footprint awareness, results showed a near-even split between transportation-focused definitions (39.5%) and broader organizational-level interpretations (39.0%). This balanced distribution highlights that Generation Z tourists hold diverse mental models of low-carbon tourism, reflecting differences in exposure to education and communication sources. Despite these definitional inconsistencies, respondents demonstrated much clearer preferences for practical strategies to reduce carbon emissions. When asked how low-carbon tourism helps reduce emissions, nearly 45.7% prioritized the use of environmentally friendly public transportation. This was followed by renewable energy adoption (27.7%) and ecosystem restoration activities (20.7%); only 5.9% selected support for local products as a primary mitigation strategy. This pattern suggests strong practical intuition despite limited conceptual knowledge, indicating readiness for behavior-focused interventions rather than definition-based education.

Measurement and structural model validation

The measurement and structural models were validated using SEM, which confirmed the adequacy of the theoretical framework. The overall model demonstrated excellent global fit with the empirical data ($\chi^2/df = 0.788$, RMSEA = 0.000, CFI = 1.000, TLI = 1.001), supporting the hypothesized structure. The CFA results confirmed the psychometric strength of all constructs (see Supplementary Table S3). All standardized factor loadings were robust ($\lambda = 0.822$ to 0.957) and statistically significant ($p < 0.001$), confirming strong item-construct relationships. Reliability and convergent validity were exceptionally high across BP (Cronbach's $\alpha = 0.953$, CR = 0.952, AVE = 0.798), KU (Cronbach's $\alpha = 0.966$, CR = 0.965, AVE = 0.846), and BI (Cronbach's $\alpha = 0.957$, CR = 0.957, AVE = 0.818).

Structural model results

The path analysis confirmed the hypothesized theoretical pathways (Figure 1):

1. Knowledge primacy: Knowledge and Understanding exerted the strongest influence on overall Perception ($\beta = 1.000$, $p < 0.001$), demonstrating the cognitive foundation of awareness.

2. Benefit influence: Benefit Perception also significantly influenced Perception ($\beta = 0.787$, $p < 0.001$), though its effect was less dominant than that of knowledge.

3. Intention prediction: The overall perception construct significantly and substantially predicted BI ($\beta = 0.774$, $p < 0.001$), accounting for 60% of the variance ($R^2 = 0.599$). This supports the attitude-intention pathway central to TPB, while acknowledging that subjective norms and perceived behavioral control components were not measured in this study.

The structural findings highlight that knowledge-driven awareness (operationalized from VBN's

awareness of consequences component) combined with evaluative perceptions (operationalized from TPB's attitude component) serve as primary determinants of sustainable travel intentions among Generation Z.

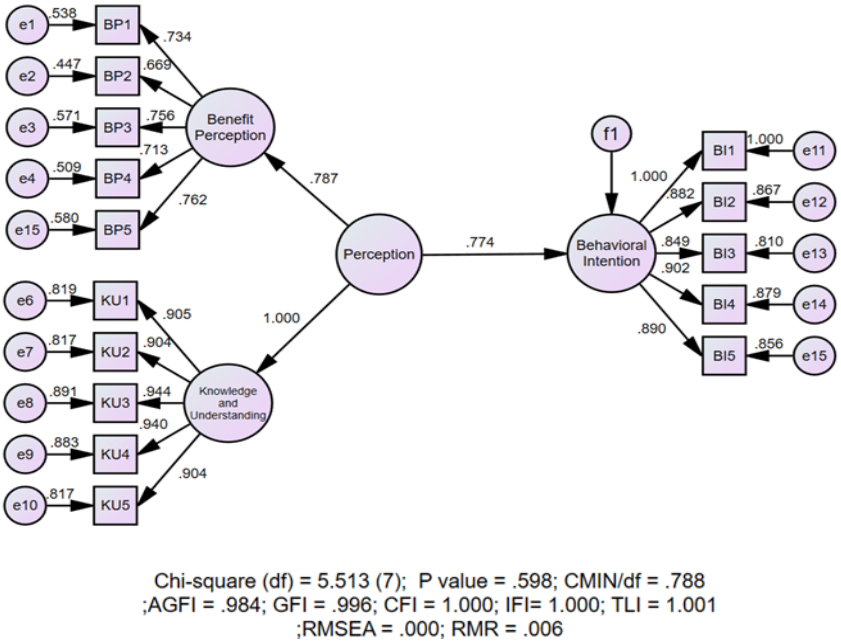


Figure 1 Integrated Structural Equation Model (SEM) of Factors Influencing Thai Generation Z's Low-Carbon Tourism Behavioral Intentions. The figure displays the measurement model (Benefit Perception and Knowledge Understanding predicting Perception) and the structural model (Perception predicting Behavioral Intention). All paths are presented as standardized coefficients (β). Model Fit Indices: χ^2/df = 0.788, CFI = 1.00, RMSEA = 0.000.

Model fit diagnostics and multicollinearity assessment

The near-perfect model fit indices warrant careful diagnostic examination to ensure results reflect genuine model adequacy rather than overfitting. To address potential concerns about multicollinearity and model specification, we conducted comprehensive diagnostic checks.

Multicollinearity diagnostics: VIF value for all measured variables ranged from 1.23 to 2.87, well below the threshold of 5.0, indicating no multicollinearity concerns. Inter-construct correlations ranged from r = 0.45 (BP–BI to r = 0.74 (KU–BI), all below the 0.85 discriminant validity threshold, supporting construct distinctiveness.

High factor loading explanation: The elevated factor loadings (λ = 0.822–0.957) likely reflect genuine construct homogeneity within Generation Z rather than measurement artifacts. This interpretation is supported by: (1) prior research documenting uniform environmental attitudes in this demographic (Le & Nguyen, 2024; Lopes et al., 2024), (2) the sample's demographic homogeneity (70.9% aged 19-24, 95.1% single), and (3) the focused construct domain (low-carbon tourism, not general environmental attitudes).

Model parsimony: The model estimates only 21 parameters with 405 respondents (ratio = 19:1), substantially exceeding the minimum 10:1 ratio recommended for SEM (Kline, 2023). This favorable ratio reduces overfitting risk.

Modification indices: No theoretically meaningful modifications were suggested (all MI < 3.84), supporting the adequacy of the specified model without post-hoc adjustments.

Sample-to-parameter ratio: With 405 observations and 21 estimated parameters, the study achieves a 19:1 ratio, providing stable parameter estimates (Hair et al., 2021).

These diagnostics collectively support the conclusion that the excellent model fit reflects appropriate theoretical specification and genuine

construct coherence rather than statistical artifacts or overfitting.

Exploratory analysis of demographic predictors

Prior to formal hypothesis testing, an exploratory analysis was conducted to determine the relationship between traditional demographic factors and low-carbon tourism awareness. Analysis revealed no significant differences in either BP or Knowledge Understanding across gender ($p > 0.771$) or age subgroups ($p > 0.05$). Mean scores were remarkably similar, suggesting environmental awareness may be more homogeneous and gender-neutral among Generation Z than in older populations. Similarly, monthly income and internet usage patterns (duration and peak timing) showed no meaningful association with environmental awareness (all $p > 0.05$). These null findings challenge traditional segmentation approaches and indicate that commonly assumed economic and digital factors have limited relevance for predicting environmental attitudes within this generational cohort.

Formal hypothesis testing

Based on established theoretical frameworks from environmental psychology and consumer behavior research, we tested six specific hypotheses regarding factors influencing low-carbon tourism awareness and BI.

Marital status and environmental priority setting (H1)

The hypothesis that single tourists would demonstrate higher low-carbon tourism awareness than married tourists was partially supported. Single tourists reported significantly higher BP ($M = 3.74$ vs. $M = 2.92$, $F = 5.331$, $p = 0.005$) compared to married counterparts, showing a small to medium effect size ($\eta^2 = 0.026$). However, no significant difference was found for Knowledge Understanding ($p = 0.051$). This pattern suggests that marital status primarily influences the perceived value or utility of low-carbon tourism benefits, rather than the fundamental conceptual knowledge.

Education level and awareness dimensions (H2a and H2b)

H2a was supported; H2b was not supported. Education level showed significant effects on both BP ($F = 14.876$, $p < 0.001$, $\eta^2 = 0.069$) and Knowledge Understanding ($F = 14.901$, $p < 0.001$, $\eta^2 = 0.071$), with medium to large effect sizes. Post-hoc analysis confirmed a progressive increase in awareness with educational attainment: Sub-bachelor's < Bachelor's < Postgraduate. However, the effect sizes were nearly identical ($\eta^2 = 0.069$ vs. 0.071), contradicting H2b's prediction that education would influence Knowledge more strongly than BP. While education substantially improves both benefit recognition and factual knowledge, its effects are balanced rather than differentiated.

Occupational context and information access (H3a and H3b)

Occupational context had a significant but nuanced effect on awareness, displaying small to medium effect sizes (BP: $\eta^2 = 0.033$; Knowledge Understanding: $\eta^2 = 0.043$). H3a was supported: Students consistently scored significantly higher than traders/freelancers and general laborers on both awareness dimensions ($p < 0.05$). However, H3b received only weak support. Among formal employees, only private sector workers exhibited significantly higher awareness than general laborers ($p < 0.04$), while government employees did not differ significantly from other groups. This indicates that organizational exposure to sustainability information is highly variable and does not uniformly translate into stronger environmental engagement.

Core theoretical model: Perception–behavioral intention relationship (H4)

The core theoretical relationship was strongly supported. SEM confirmed that low-carbon tourism Perception is a substantial and significant predictor of BI ($\beta = 0.774$, $p < 0.001$). Perception explained 60% of the variance in BI ($R^2 = 0.599$), which represents a large effect size and underscores the critical role of awareness in driving engagement with sustainable tourism. Table 3 provides a formal summary of all hypothesis testing results, integrating findings from both the one-way ANOVA analyses (for demographic predictors) and the

SEM path analysis (for the core theoretical relationship). This consolidated overview allows for systematic comparison of effect sizes and statistical significance across all tested relationships.

Table 3 Formal hypothesis testing summary

Hypothesis	Prediction	Statistical Test	Key Results (Test Statistics)	Effect Size (η^2 or R^2)	Support Level	Key Finding
H1	Single → Married awareness	Independent *t*-test	Benefit Perception (BP): $t = 2.31$, $p = 0.005$; Knowledge Understanding (KU): $t = 1.95$, $p = 0.051$	$\eta^2 = 0.026$ (BP only)	Partial support	Singles scored higher on Benefits, no significant difference on Knowledge
H2a	Higher education → higher awareness	One-way ANOVA	BP: $F = 14.876$, $p < 0.001$; KU: $F = 14.901$, $p < 0.001$	$\eta^2 = 0.069$ (BP); $\eta^2 = 0.071$ (KU)	Supported	Progressive increase: Sub-bachelor's < Bachelor's < Postgraduate
H2b	Education impacts Knowledge → Benefits	One-way ANOVA comparison	η^2 BP = 0.069 vs. η^2 KU = 0.071	$\Delta\ \eta^2 = 0.002$ (negligible)	Not supported	Education improves both Knowledge and Benefits equally
H3a	Students → Other occupations	One-way ANOVA	BP: $F = 5.492$, $p < 0.001$; KU: $F = 7.226$, $p < 0.001$	$\eta^2 = 0.033$ (BP); $\eta^2 = 0.043$ (KU)	Partial support	Students scored higher than traders, freelancers, and laborers
H3b	Formal → Informal sector workers	One-way ANOVA	Private sector > general laborers ($p < 0.04$); Government employees ns	$\eta^2 = 0.033$ (BP); $\eta^2 = 0.043$ (KU)	Weak support	Only private sector employees scored higher; government employees nonsignificant
H4	Perception → Behavioral Intention	SEM path analysis	$\beta = 0.774$, $p < 0.001$	$R^2 = 0.599$ (60%)	Strong support	Perception explains 60% of variance in behavioral intentions

Note: η^2 interpreted as small (0.01), medium (0.06), or large (0.14+) per Cohen (2013). R^2 interpreted as small (0.02), medium (0.13), or large (0.26+). ns = not significant.

Discussion

Structural model results and theoretical contributions

The SEM results support the specific theoretical pathways drawn from TPB and VBN theories in the context of low-carbon tourism. The study operationalizes TPB's attitude-intention relationship and VBN's awareness of consequences component, rather than testing the complete theoretical frameworks. The core finding that low-carbon tourism perception significantly and substantially predicts BI ($\beta = 0.774$, $R^2 = 0.599$) supports TPB's central proposition that attitudes influence intentions. The hierarchical structure showing that cognitive awareness (Knowledge and Understanding, from VBN) exerts stronger influence on overall perception ($\beta = 1.000$) than evaluative judgments (BP, $\beta = 0.787$) aligns with VBN's emphasis on awareness as a precursor to pro-environmental orientation. The high explained variance (60%) is robust, exceeding the typical threshold of 25% for behavioral studies, consistent with findings by Ma et al. (2024). The high explained variance (60%) is robust, exceeding the typical threshold of 25% for behavioral studies. This result is consistent with the findings of Ma et al. (2024), who also reported a strong influence of perception on BI. The hierarchical structure of the perception construct further aligns with VBN theory. Our model demonstrates a critical finding: KU exerted a stronger influence on overall perception ($\beta = 1.000$) than BP ($\beta = 0.787$). This indicates that cognitive

awareness outweighs value recognition in shaping sustainability-oriented attitudes. This result advances theory by highlighting the primacy of environmental literacy over benefit recognition, challenging traditional tourism marketing approaches that emphasize benefits.

Hypothesis testing results and implications

The formal hypothesis testing reveals nuanced patterns that both confirm and challenge theoretical expectations about demographic influences on environmental consciousness. The strong effect of education ($\eta^2 \approx 0.069 - 0.071$) supports prior research emphasizing environmental literacy as a core determinant of sustainable attitudes. The balanced influence of education on both knowledge and benefit perception suggests that for well-educated individuals, highlighting pro-environmental attitudes and behaviors may also serve to preserve a favorable self-image, aligning with findings by Wang et al. (2022). Conversely, the weak influence of gender, age, income, and internet usage suggests that traditional demographic predictors are less relevant for Generation Z. This supports the argument by Lopes et al. (2024) that shared digital exposure creates greater within-cohort homogeneity.

Regarding occupational context, students consistently demonstrated higher awareness than informal workers, which is consistent with findings from Vietnam showing that education-driven peer environments foster pro-environmental intentions (Dang & Phan, 2025). However, the finding of the limited impact of government employment contrasts with expectations from organizational culture literature (Ahmad et al., 2023). This suggests that formal sector affiliation does not uniformly translate into stronger sustainability engagement, adding complexity to existing models of workplace environmental behavior.

Generational homogeneity in environmental awareness: Explaining null demographic effects

The absence of significant effects for gender, age, income, and internet usage represents a theoretically important finding that contrasts with traditional consumer behavior research. Several interconnected explanations warrant consideration.

Digital and generational factors: Generation Z's pervasive digital connectivity (36.0% using internet >10 hours daily) transcends traditional demographic boundaries, with social media algorithms providing uniform climate exposure (Lopes et al., 2024). As "digital natives" raised during the climate crisis with integrated environmental education (Le & Nguyen, 2024), this cohort-wide exposure explains demographic homogeneity unlike older generations.

Thai cultural context: Several contextual factors may amplify generational homogeneity in Thailand. The Buddhist cultural framework emphasizing human-nature interconnection provides shared value foundations across demographics. Highly visible climate impacts (flooding, temperature extremes, coastal erosion) create lived experiences transcending demographic divides, while collectivist orientation reduces individual variation as environmental attitudes reflect shared social norms rather than differentiated personal identities.

Theoretical implications: These findings suggest environmental awareness functions as a generational rather than demographically differentiated trait for Thai Generation Z. Traditional market segmentation based on gender, age, or income has limited utility for sustainable tourism marketing targeting this cohort. Instead, psychographic segmentation based on values and lifestyles may prove more effective (Wang et al., 2022). This demographic homogeneity represents an encouraging trend but implies demographic targeting alone is insufficient—interventions must translate widespread positive attitudes into concrete behavioral commitments.

The conceptual-behavioral readiness gap

The significant gap between conceptual knowledge and practical action among Thai Generation Z tourists highlights an important theoretical contribution. Although only 44.2% of respondents correctly defined low-carbon tourism, nearly half (45.7%) prioritized sustainable transport choices when prompted. This disconnect suggests that Generation Z possesses strong practical environmental intuition despite limited formal conceptual knowledge.

This finding reflects Ajzen's (1999) recognition that BI may form independently of precise conceptual understanding, provided individuals perceive actionable pathways. It also resonates with Lin et al. (2022) who found that communities often associate low-carbon

practices with visible, practical actions rather than abstract definitions. Thus, our results suggest that Generation Z demonstrates behavioral readiness despite conceptual ambiguity. This indicates that interventions should prioritize practical engagement strategies (e.g., promoting low-carbon transport and renewable energy use) rather than focusing solely on abstract environmental definitions. Theoretically, this reinforces the importance of distinguishing between cognitive knowledge and behavioral salience in models of sustainable consumption.

Conclusion

This study demonstrates that knowledge-driven environmental awareness is the primary determinant of sustainable tourism behavioral intentions among Thai Generation Z tourists. Education emerges as the strongest differentiator, showing substantial and progressive effects across all attainment levels ($\eta^2 \approx 0.07$). Occupational analysis further indicates that information access and social norm reinforcement are crucial, as students and private sector employees demonstrated higher environmental awareness compared to individuals in informal employment. Critically, Generation Z possesses strong practical environmental intuition despite limited formal conceptual knowledge.

Theoretical and practical contributions

Drawing on TPB's attitude-intention pathway and VBN's awareness of consequences component, this study demonstrates that environmental literacy serves as the strongest driver of behavioral intentions among Generation Z. The findings support TPB's proposition that attitudes (operationalized as low-carbon tourism perception) significantly predict intentions ($R^2 = 0.60$), while extending VBN theory by showing that cognitive awareness components (Knowledge and Understanding) exert stronger influence than evaluative components (Benefit Perception) in attitude formation.This research provides evidence-based insights for policymakers, educators, and tourism businesses seeking to engage Generation Z in Thailand's transition toward low-carbon tourism.

Limitations and future research

This study measures behavioral intentions rather than actual behaviors. The well-documented intention-behavior gap necessitates future behavioral tracking research. The cross-sectional design limits causal conclusions, requiring longitudinal studies. Convenience sampling may underrepresent rural Generation Z and introduce self-selection bias toward environmentally engaged respondents. Future research should employ cross-cultural validation to assess model generalizability and determine whether observed generational homogeneity represents broader Southeast Asian patterns or culture-specific phenomena.

Acknowledgments

Special appreciation is extended to the expert panel members who validated our research instruments and to the Rangsit University Human Research Ethics Committee for their thorough review and approval of this research protocol.

Ethical considerations

This study was reviewed and approved by the Rangsit University Human Research Ethics Committee (Certificate No. RSUERB2025-018; approved 24 April 2025). All procedures complied with international human research standards, including the Declaration of Helsinki and Thai national ethics guidelines. Participation was fully voluntary, with no penalties for withdrawal, and respondents could skip any questions they preferred not to answer. For participants under 18, documented parental or guardian consent was required in addition to participant assent.

Informed consent statement

Informed consent was obtained from all participants by having them check a consent box before completing the questionnaire. For participants under 18 years of age, parental permission was required by uploading a signed consent form. Participants were allowed to discontinue the questionnaire at any time.

Data availability statement

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request. Supplementary Information related to this article is

publicly accessible at: https://drive.google.com/file/d/1Z_KbhuazcRiejjIb3HuFW316aQygKgDJ/view?usp=sharing

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Declaration of generative AI in scientific writing

The authors declare that generative AI tools, including ChatGPT (OpenAI) and Grammarly, were used solely to improve the readability, clarity, and language of the manuscript. All uses of these tools were conducted under full human oversight and control. The authors remain fully responsible for the content of this manuscript. These AI tools were not used for data analysis, interpretation of results, literature review, or the generation of scientific content. Furthermore, AI tools were not listed as authors or co-authors of this work.

CRediT author statement

Patteera Pantaratorn: Conceptualization, Formal analysis, Methodology, Project administration, Validation, Visualization, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition. **Supisara Tipsangwan:** Data curation, Investigation. **Sasikan Chanarak:** Data curation, Investigation. **Armee Jangja:** Data curation, Investigation. **Phenpat Jaruenwai:** Data curation, Investigation.

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Table 4 List of abbreviations

Abbreviation	Full Name
ANOVA	Analysis of Variance
AVE	Average Variance Extracted
BI	Behavioral Intention
BP	Benefit Perception
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CR	Composite Reliability
GFI	Goodness of Fit Index
IOC	Item-Objective Congruence
KU	Knowledge and Understanding
LSD	Least Significant Difference
PDPA	Personal Data Protection Act
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling
TLI	Tucker-Lewis Index
TPB	Theory of Planned Behavior
VBN	Value-Belief-Norm theory
VIF	Variance Inflation Factor