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# TRANSFORMING URBAN TOURISM: ESSENTIAL CONDITIONS AND LOW-CARBON ATTRIBUTES FOR SUSTAINABLE TOURIST BEHAVIORS

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## Abstract

This study examines the role of low-carbon tourism attributes in shaping sustainable tourist behaviors (STB) within urban destinations. Drawing on Stimulus-Response (S-R) theory and necessity logic, the research identifies six critical attributes, including eco-friendly accommodation (ECA), sustainable service providers (SSP), efficient transportation (ET), low-carbon activities (LA), sustainable dining (SD), and responsible waste management (WM). Using Integrated Generalized Structured Component Analysis (IGSCA) and Necessary Condition Analysis (NCA), data from 440 urban tourists in Thailand was analyzed to determine the sufficiency and necessity of these attributes in influencing STB. The findings indicate that ECA, SSP, and ET are the most influential determinants, while LA, SD, and WM serve as necessary but less impactful conditions. The study provides empirical validation of necessity logic, demonstrating that without the presence of key low-carbon enablers, tourists' sustainable behaviors do not reach high levels. The results offer theoretical insights into STB formation and inform policy recommendations for urban planners and tourism stakeholders to enhance sustainability strategies. By integrating low-carbon tourism attributes into urban policies, cities can foster environmentally responsible travel behaviors and contribute to global climate action initiatives.

**Keywords:** Low-carbon tourism, sustainable tourist behavior, urban tourism, Stimulus-Response theory, necessity logic

## 1. INTRODUCTION

The rapid expansion of urban tourism has produced significant economic benefits for cities worldwide (Leruksa et al., 2025) but has also exacerbated environmental degradation, particularly through carbon emissions (Pinthong et al., 2024). As urban centers become key destinations for global travel, the urgency for sustainable tourism practices aimed at mitigating carbon footprints has never been more pronounced (Fakfare & Wattanacharoensil, 2023a). The tourism sector, responsible for approximately 8% of global carbon emissions, is increasingly scrutinized for its environmental impact, necessitating the adoption of low-carbon strategies aligned with global climate action goals (Fakfare & Wattanacharoensil, 2024). Urban tourism, characterized by dense populations, extensive transportation networks, and energy-intensive hospitality services, represents a major contributor to these emissions (Kumsura et al., 2024). Thus, fostering sustainable tourism behaviors (STBs) among tourists is crucial for transitioning toward low-carbon urban tourism.

Sustainable tourism behaviors (STBs) encompass environmentally responsible actions undertaken by tourists, including reducing energy consumption, utilizing public transportation,

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supporting local sustainable businesses, and minimizing waste generation (Fakfare et al., 2024a; Han et al., 2024). These behaviors are significantly influenced by low-carbon tourism attributes, such as eco-friendly accommodation, sustainable service providers, efficient transportation, low-carbon activities, responsible dining, and waste management practices (Fakfare et al., 2023b). The presence and accessibility of these attributes shape tourists' actions, yet the transition from awareness to behavioral change remains a challenge.

To understand this behavioral transition, Stimulus-Response (S-R) Theory provides a useful framework for explaining how tourists react to low-carbon tourism attributes in urban settings. According to S-R Theory, behavior is a direct response to external stimuli, wherein environmental cues influence individual actions through conditioning (Treisman, 1960). In the context of urban tourism, low-carbon tourism attributes function as external stimuli that elicit sustainable behaviors from tourists (Fakfare & Wattanacharoensil, 2023a). For instance, the presence of efficient public transportation (stimulus) encourages tourists to choose eco-friendly travel options (response), while the availability of green accommodations conditions tourists to prefer sustainable lodging options. Reinforcement mechanisms, such as incentives for sustainable choices or penalties for unsustainable behaviors, further shape the likelihood of behavioral adoption (Treisman, 1960). By leveraging S-R Theory, this study examines how the strategic implementation of low-carbon tourism attributes can effectively condition tourists toward sustainable behavioral patterns.

Despite advancements in sustainable urban tourism, several research gaps persist. First, there is a lack of comprehensive models integrating multiple low-carbon tourism attributes within urban tourism contexts. While studies have explored specific aspects such as transportation and accommodation (Becken, 2017), a holistic framework incorporating various low-carbon attributes remains absent. Second, although prior research acknowledges the importance of low-carbon tourism attributes, empirical validation of their influence on tourist behavior in urban destinations remains limited (Fakfare et al., 2023a; 2023b). Additionally, little is known about how these attributes interact to shape tourists' decision-making processes and behavioral outcomes, warranting further investigation into their practical implementation and effectiveness.

Considering the abovementioned research gaps, this study aims to 1) identify the key low-carbon tourism attributes that influence STB and 2) determine the critical conditions required for these sustainable behaviors to manifest. By analyzing the role of eco-friendly accommodation, sustainable service providers, efficient transportation, low-carbon activities, responsible dining, and waste management, this research offers insights into how these attributes function as stimuli within the S-R framework to drive sustainable behaviors. The findings will inform policymakers, tourism practitioners, and urban planners on how to design and implement interventions that reinforce tourists' transition toward low-carbon lifestyles while enhancing their overall travel experience. Applying S-R Theory will enable a deeper understanding of the mechanisms through which environmental stimuli condition tourists' responses, thereby contributing to more effective and impactful sustainability initiatives in urban tourism.

## 2. LITERATURE REVIEW

### 2.1 Low-carbon Tourism and Urban Cities

Low-carbon tourism (LCT) has gained significant attention as a strategy for mitigating the environmental impact of urban tourism (Fakfare & Wattanacharoensil., 2024). As cities continue to experience increasing tourist arrivals, concerns about carbon emissions and resource consumption have intensified (Kumsara et al., 2024). LCT focuses on reducing the

carbon footprint associated with travel, accommodation, and activities by promoting environmentally sustainable practices. It encompasses various components, including eco-friendly accommodation, sustainable service providers, low-emission transportation, and responsible waste management (Becken, 2017; Fakfare & Wattanacharoensil, 2023b). For urban tourism to transition toward a low-carbon model, it is essential to encourage sustainable tourist behaviors (Pinthong et al., 2024), which include environmentally responsible actions such as reducing energy consumption, choosing low-carbon transportation, and supporting green businesses (Han et al., 2024). However, despite increasing awareness of sustainability issues, low-carbon tourism attributes have not been empirically verified or tested for their predictive power on tourists' sustainable behaviors.

### 2.2 Underlying Low-carbon Tourism Attributes in Urban Destinations

Existing research highlights that STBs are directly influenced by the availability, accessibility, and affordability of low-carbon tourism attributes within urban destinations (Fakfare et al., 2023a). These attributes encompass multiple dimensions of tourism. This study reviews the following attributes and dimensions, which potentially influence tourists' sustainable behaviors. These attributes include eco-friendly accommodation, sustainable service providers, low-emission transportation, low-carbon activities and attractions, sustainable dining, and waste management.

Eco-friendly accommodations play a crucial role in reducing the environmental footprint of urban tourism. These establishments incorporate sustainable practices such as energy-efficient infrastructure, renewable energy sources, water conservation systems, and eco-certified amenities (Becken, 2017; Fakfare et al., 2024b). Many green hotels implement waste reduction initiatives, including recycling programs and eliminating single-use plastics, to minimize their environmental impact. Additionally, eco-friendly accommodations often seek green certifications, such as LEED (Leadership in Energy and Environmental Design) or EarthCheck, to ensure compliance with sustainability standards (Fakfare & Wattanacharoensil, 2023b). Research suggests that the presence of eco-friendly lodging options can influence tourists' decision-making, as environmentally conscious travelers prefer accommodations that align with their sustainability values (Han et al., 2024). However, empirical studies assessing the direct impact of eco-friendly accommodations on tourists' sustainable behaviors remain limited, necessitating further investigation.

Sustainable service providers, including tour operators, travel agencies, and hospitality businesses, contribute to the promotion of low-carbon tourism by integrating environmentally responsible practices into their operations. These businesses adopt sustainability policies such as reducing carbon emissions, offering carbon offset programs, and providing tourists with eco-friendly travel options (Fakfare et al., 2023a). For instance, tour operators that promote cycling tours, walking excursions, and electric vehicle rentals encourage travelers to engage in low-impact tourism experiences (Pinthong et al., 2024). Moreover, educational programs and responsible tourism campaigns led by service providers play a vital role in raising awareness about sustainable practices among tourists (Sathatip et al., 2025). Despite these efforts, further empirical research is needed to assess how sustainable service providers influence tourist behavior, beyond intention-based studies.

Transportation is one of the largest contributors to carbon emissions in urban tourism (Fakfare, 2023; Kumsura et al., 2024). Encouraging tourists to adopt low-carbon transportation options, such as electric buses, metro systems, shared bicycles, and pedestrian-friendly pathways, is essential for reducing the environmental impact of urban travel (Fakfare & Wattanacharoensil, 2024). Cities which invest in sustainable transportation infrastructure, such as high-speed rail networks and extensive public transit systems, provide tourists with viable alternatives to carbon-intensive private vehicles (Gössling & Higham, 2021). Studies suggest

that convenience, affordability, and accessibility are key determinants in tourists' willingness to choose low-emission transportation (e.g., Han et al., 2024). However, challenges such as limited infrastructure, lack of awareness, and perceived inconvenience can deter tourists from adopting these options, highlighting the need for further policy interventions and behavioral incentives.

Tourist activities and attractions significantly impact the sustainability of urban destinations. Low-carbon activities, such as eco-tours, heritage site conservation programs, and carbon-neutral experiences, encourage tourists to engage in responsible travel behaviors (Becken, 2017). Some cities have introduced green tourism zones, where electric transport, sustainable shopping, and eco-friendly dining options are prioritized (Fakfare et al., 2023b). Attractions which integrate environmental education components, such as botanical gardens, wildlife sanctuaries, and green architectural sites, further enhance tourists' awareness of sustainability issues (Pinthong et al., 2024). However, despite the growing availability of low-carbon attractions, empirical research assessing their effectiveness in promoting long-term behavior change among tourists, is still lacking.

Food consumption is another critical aspect of low-carbon tourism (Yong et al., 2024). Sustainable dining practices, such as organic food sourcing, reduced food waste policies, plant-based meal options, and sustainable seafood choices, help lower the carbon footprint of the food industry in urban tourism (Agmapisarn & Fakfare, 2025). Restaurants and bars which adopt farm-to-table practices, composting initiatives, and eco-friendly packaging contribute to the overall sustainability of tourism destinations (Issariyakulkarn et al., 2024; Suwannakul et al., 2025). Research indicates that tourist preferences for sustainable dining options are influenced by factors such as affordability, availability, and cultural appeal (Sathatip, 2024). While some studies suggest that tourists are willing to pay a premium for sustainable food choices (Yong et al., 2024), barriers such as lack of awareness and limited accessibility remain key challenges to widespread adoption.

Effective waste management systems are essential for minimizing the environmental impact of urban tourism (Koh et al., 2022). Many destinations have introduced recycling programs, zero-waste initiatives, and sustainable packaging regulations to address the growing issue of tourism-related waste (Cheng et al., 2013). Additionally, environmental awareness campaigns which educate tourists on proper waste disposal, plastic reduction, and sustainable consumption patterns play a crucial role in fostering responsible behaviors (Gössling & Higham, 2021). However, inconsistent waste management policies, lack of enforcement, and limited tourist compliance pose significant challenges (Fakfare & Wattanacharoensil, 2023b). Further research is required to explore effective communication strategies and incentive-based interventions which encourage tourists to participate in waste reduction initiatives.

Low-carbon tourism attributes play a vital role in shaping sustainable tourist behaviors. Attributes such as eco-friendly accommodation, sustainable service providers, low-emission transportation, low-carbon activities, sustainable dining, and waste management, are essential components of LCT. However, despite increasing awareness of sustainability issues, empirical validation of these attributes remains limited, particularly in urban tourism contexts. Further research is necessary to explore how these attributes interact, their predictive power on sustainable tourist behaviors, and the necessary conditions required for their successful adoption. Understanding these factors will contribute to the development of effective policies, infrastructure improvements, and behavioral interventions aimed at promoting low-carbon urban tourism. Given this, the following hypothesis are proposed:

> H1: Low carbon tourism attributes, including eco-friendly accommodation, sustainable service providers, low-emission transportation, low-carbon activities, and responsible waste management, positively affect tourists' sustainable behavior in the context of urban destinations.

## 2.3 The Adoption of Necessity Logic

In business research, particularly within hospitality and tourism studies, scholars frequently investigate causal relationships between various predictors and outcomes. This often involves employing path analysis techniques, such as regression analysis and sufficient condition analysis. Structural Equation Modeling (SEM) is widely utilized to examine these relationships, assessing how specific predictors (X) influence particular outcomes (Y). Conventionally, SEM findings are interpreted using sufficiency logic (Dul, 2024), which leads to conclusions such as "X contributes to Y" or similar assertions. However, interpreting results solely through this lens does not necessarily imply that a predictor is essential for an outcome to materialize.

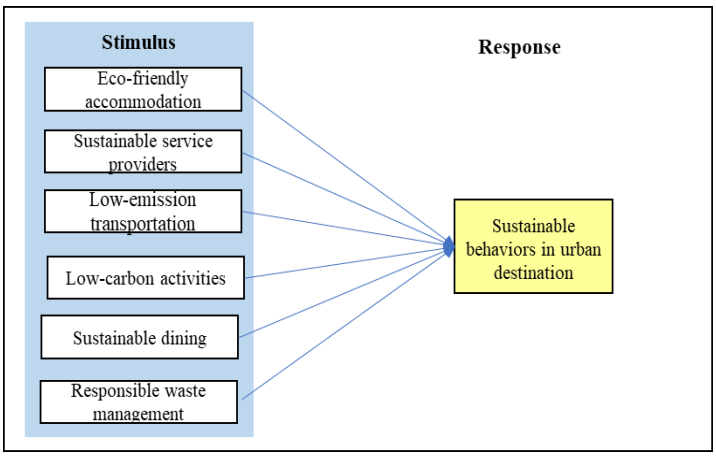
As Richter et al. (2020) highlighted, necessity logic provides a distinct perspective by suggesting that a particular level of an outcome can only be achieved if a necessary condition exists in a certain form or magnitude. For instance, while the availability of low-carbon tourism attributes, such as eco-friendly accommodation, sustainable service providers, low-emission transportation, and responsible waste management may enhance tourists' sustainable behavior, necessity logic posits that these attributes may be required for such behavior to occur at higher levels. In other words, tourists may only engage in substantial sustainable practices if key low-carbon tourism attributes are adequately present. However, merely ensuring these attributes exist may not be sufficient to drive sustainable behavior unless additional facilitating conditions, such as affordability, accessibility, and convenience, are also met. This contrasts with sufficiency logic, which allows for alternative compensatory mechanisms when specific factors are absent (Meeprom et al., 2023).

Prior research has conceptualized necessity logic using Necessary Condition Analysis (NCA), formulating hypotheses such as "if not X, then probably not Y" (Dul, 2024). Under this approach, the absence of a necessary factor renders the desired outcome unattainable. However, in the present study, where variables are measured on a Likert scale, the notion of complete absence is not applicable. Instead, varying levels of low-carbon tourism attributes and sustainable behavior are considered. Based on necessity logic, the following hypothesis is proposed.

> H2: If the levels of low carbon tourism attributes (e.g., eco-friendly accommodation, sustainable service providers, low-emission transportation, low-carbon activities, sustainable dining, and responsible waste management) are low, tourists' sustainable behavior will not reach high levels.

Figure 1 shows the research framework.

**Figure 1** Research Framework



## 3. METHODS

### 3.1 Measurement and Data Collection Process

The measurement of research constructs in this study was based on the adaptation of dimensions and indicators associated with low-carbon tourism attributes from established literature on sustainable tourism and environmentally responsible travel behavior. Specifically, measurement items were drawn from multiple scholarly sources, including Cheng et al. (2013); Cho et al. (2016); and Fakfare and Wattanacharoensil (2023a; 2023b; 2024), which provided a robust foundation for evaluating key aspects of low-carbon tourism offerings and their influence on tourists' sustainable behaviors. For example, items assessing eco-friendly accommodation were adapted from (Cho et al., 2016), while indicators related to the availability of sustainable service providers were developed based on Fakfare and Wattanacharoensil (2024). To measure sustainable travel behaviors, items were derived from previous studies on pro-environmental tourism practices (Cho et al., 2016; Hsiao et al., 2021). To ensure content validity and practical relevance, all measurement items were reviewed by a panel comprising two academic experts specializing in sustainable tourism and urban environmental management, along with two industry professionals with extensive experience in eco-friendly hospitality services. A multi-item approach was employed for all constructs, using a six-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). This approach ensured a comprehensive and reliable assessment of the study's key variables.

Data collection took place between November 15 and December 14, 2024. The survey was hosted on Google Forms and targeted tourists with prior experience or interest in low-carbon (LC) tourism in urban destinations in Thailand. To facilitate data distribution, seven research students assisted in sharing the survey link across various platforms. Screening questions were incorporated to ensure that participants met the study criteria. These questions included statements such as "I have previously visited a low-carbon tourism destination" and "I am interested in engaging in low-carbon tourism activities in an urban destination". Additionally, respondents were asked to identify a specific urban destination in Thailand where they had recently experienced LC tourist offerings.

A total of 450 responses were gathered, with 10 cases removed due to incomplete data, resulting in a final dataset of 440 valid responses. In terms of demographic distribution, female participants comprised 63.4% of the sample. Regarding educational background, the majority held a bachelor's degree (67.3%), followed by those with an associate degree (13.4), a high school diploma (11.6%), or a postgraduate degree (7.7%). The largest age group was 20–30 years (44.7%), followed by 31-50 (31.3%), and finally 51 and above (14.0%).

## 4. RESULTS

### 4.1 Measurement and Structural Model Evaluation

The structural model analysis was conducted using the IGSCA approach (Hwang et al., 2021a), with data processing performed via GSCA Pro, an advanced software specifically designed for Generalized Structured Component Analysis (GSCA) (Hwang et al., 2021b). The full dataset (n = 440) was utilized for both measurement and structural model evaluations. The composite model included estimated weight scores for the identified low-carbon urban tourism components, including as eco-friendly accommodation, sustainable service providers, efficient transportation, low-carbon activities, responsible dining, and waste management practices. Additionally, the 95% confidence interval did not include zero (see Table 1), indicating that all items meaningfully contributed to the composite models. To assess the convergent validity of

a common factor (i.e., sustainable behaviors), the standardized loadings and average variance extracted (AVE) were examined, with both meeting the recommended threshold of 0.5. Construct reliability was evaluated using Dijkstra–Henseler's rho (ρa), which exceeded the acceptable level of 0.6 (Hair et al., 2020). Furthermore, discriminant validity was confirmed, as the Heterotrait-Monotrait Ratio (HTMT) remained below 1, aligning with established criteria (Henseler et al., 2015).

**Table 1** Estimates of Weights, Loadings, and their 95% CI Obtained from the Structural Model Analysis (n = 440)

| **Construct** | **Type** | **Indicator** | $\widehat{w}_i$ | $CI_{\widehat{w}_i}$ | | $\widehat{\lambda}_i$ | $CI_{\widehat{\lambda}_i}$ | |
|---|---|---|---|---|---|---|---|---|
| Eco-friendly accommodation (ECA) | Composite | ECA1: Accommodation facilities in urban destinations use environmentally friendly building materials. | 0.400 | 0.376 | 0.419 | 0.874 | 0.839 | 0.899 |
| | | ECA2: Urban accommodation providers hold national or international eco-certifications (e.g., Green Hotel, ASEAN Green Hotel). | 0.381 | 0.368 | 0.403 | 0.832 | 0.783 | 0.881 |
| | | ECA3: Urban hotels and accommodations provide reusable amenities and supplies to minimize waste. | 0.384 | 0.363 | 0.403 | 0.868 | 0.839 | 0.892 |
| Sustainable service providers (SSP) | Composite | SSP1: Service providers offer alternative travel experiences, such as guided slow-travel tours within the city. | 0.373 | 0.355 | 0.386 | 0.808 | 0.744 | 0.863 |
| | | SSP2: Service providers actively share updates and initiatives on urban environmental conservation efforts. | 0.405 | 0.380 | 0.427 | 0.872 | 0.834 | 0.901 |
| | | SSP3: Service providers educate tourists about low-carbon tourism practices in urban destinations. | 0.396 | 0.374 | 0.423 | 0.872 | 0.837 | 0.903 |
| Efficient transportation (ET) | Composite | ET1: Urban land transport systems comply with local and national environmental policies (e.g., e.g., limitations on private vehicle usage in tourist areas). | 0.383 | 0.373 | 0.396 | 0.871 | 0.834 | 0.906 |
| | | ET2: Low-energy consumption vehicles, such as electric buses or shared electric scooters, are available for tourists. | 0.388 | 0.373 | 0.414 | 0.882 | 0.858 | 0.906 |
| | | ET3: There are accessible and well-maintained bicycle rental services for tourists in the city. | 0.372 | 0.352 | 0.385 | 0.872 | 0.840 | 0.900 |
| Low-carbon activities (LA) | Composite | LA1: This destination offers low-carbon activities that encourage tourists to engage with local residents (e.g., community-based workshops or cultural experiences). | 0.546 | 0.532 | 0.557 | 0.917 | 0.895 | 0.938 |
| | | LA2: This destination has well-developed eco-friendly touring trails for sustainable exploration. | 0.545 | 0.532 | 0.559 | 0.917 | 0.896 | 0.936 |
| Sustainable dining (SD) | Composite | SD1: This destination offers locally sourced and home-grown food options to support the community. | 0.547 | 0.536 | 0.562 | 0.916 | 0.895 | 0.935 |
| | | SD2: This destination promotes low-carbon menu options to reduce environmental impact. | 0.545 | 0.531 | 0.559 | 0.915 | 0.894 | 0.935 |
| Responsible waste management (WM) | Composite | WM1: This destination has an efficient waste management and recycling system in place. | 0.397 | 0.376 | 0.419 | 0.852 | 0.801 | 0.887 |
| | | WM2: This destination promotes proper garbage sorting practices in public and commercial areas. | 0.399 | 0.381 | 0.416 | 0.856 | 0.819 | 0.883 |
| | | WM3: This destination implements wastewater recycling and reuse systems to minimize negative environmental impacts. | 0.386 | 0.368 | 0.407 | 0.830 | 0.785 | 0.869 |
| Sustainable behavior (STB) | Common factor | STB1: I choose environmentally friendly transportation options in urban areas (e.g., public transit instead of private cars). | 0.266 | 0.241 | 0.305 | 0.550 | 0.478 | 0.623 |
| | | STB2: I prefer eco-certified hotels over conventional accommodations in urban destinations. | 0.345 | 0.314 | 0.382 | 0.730 | 0.669 | 0.778 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *AVE: 0.50* | STB3: I prioritize consuming locally sourced | | | | | | |
| *rho: 0.785* | food while traveling in the city. | 0.293 | 0.267 | 0.321 | 0.602 | 0.515 | 0.673 |
| | STB4: I opt for low-emission urban transport options (e.g., cycling or walking instead of | | | | | | |
| | motorized vehicles). | 0.330 | 0.301 | 0.362 | 0.700 | 0.628 | 0.749 |
| *GFI: 0.995* | STB5: I avoid the use of single-use plastics and | | | | | | |
| *SRMR: 0.035* | non-biodegradable materials during travel. | 0.307 | 0.283 | 0.330 | 0.633 | 0.562 | 0.704 |

Note: $\widehat{w}_i$ = estimated weights, $CI_{\widehat{w}_i}$ = 95% Confidence interval of estimated weights, $\widehat{\lambda_i}$ = estimated loadings, $CI_{\widehat{\lambda_i}}$ = 95% Confidence interval of estimated loadings with 1,000 bootstrap samples.

The structural model was assessed using GSCA Pro 1.2.1 (Hwang et al., 2021b), confirming the hypothesized relationships. When evaluating composite-based structural models, it is crucial to assess the relevance of path coefficients and examine potential multicollinearity issues. A commonly used conservative threshold for identifying multicollinearity is a Variance Inflation Factor (VIF) of 3.3 (Diamantopoulos & Siguaw, 2006). In this study, VIF values ranged between 2.62 and 3.4, suggesting that multicollinearity was not a significant concern. To further validate the model, a bootstrapping procedure with 1,000 resamples was applied, utilizing a bias-corrected and accelerated confidence interval to ensure accurate estimation of path coefficients. The model fit was evaluated using standard criteria, with results indicating an acceptable model fit (SRMR = 0.035, GFI = 0.995), reinforcing the robustness of the structural model.

**Table 2** Estimates of Path Coefficients, their 95% CI, and Fit Indices Obtained from the Structural Model Analysis (n = 440)

| **Relationship** | $\hat{\beta}_i$ | **SE** | $CI_{\hat{\beta}_i}$ | | **$R^2$** |
|---|---|---|---|---|---|
| ECA->STB | 0.319 | 0.068 | 0.178 | 0.443 | |
| SSP->STB | 0.260 | 0.082 | 0.083 | 0.404 | |
| ET->STB | 0.236 | 0.066 | 0.109 | 0.343 | 0.65 |
| LA->STB | 0.124 | 0.076 | 0.010 | 0.264 | |
| SD->STB | -0.112 | 0.070 | -0.240 | 0.016 | |
| WM->STB | 0.073 | 0.060 | -0.034 | 0.229 | |
| SRMR | 0.035 | | | | |

Note: $\widehat{\beta_i}$ = estimated path coefficients, $CI_{\widehat{\beta_i}}$ = 95% Confidence interval of estimated path coefficients, $R^2$= coefficient of determination, ECA = eco-friendly accommodation, SSP = sustainable service provider, ET = efficient transportation, SD = sustainable dining, WM = responsible waste management, STB = sustainable behavior

The structural model analysis, based on a sample of 440 respondents, provides valuable insights into the factors influencing tourists' sustainable behavior (STB) in urban destinations (Table 2). The model explains 65% of the variance ($R^2$ = 0.65) in sustainable behavior, demonstrating strong predictive validity. Among the key predictors, eco-friendly accommodation (ECA, β = 0.319, CI: 0.178–0.443, p < 0.05) had the most substantial positive effect, indicating that tourists who stay in environmentally certified or sustainable hotels are more likely to engage in pro-environmental behaviors. Similarly, sustainable service providers (SSP, β = 0.260, CI: 0.083–0.404, p < 0.05) significantly influenced STB, suggesting that businesses offering eco-conscious tourism services play a crucial role in shaping tourists' sustainability choices.

Another significant predictor was efficient transportation (TF, β = 0.236, CI: 0.109–0.343, p < 0.05), suggesting that the availability of low-carbon mobility options (e.g., electric public transit, bike-sharing) encourages tourists to behave more sustainably. Low-carbon activities (LA, β = 0.124, CI: 0.010–0.264, p < 0.05) also contributed positively, though with

a smaller effect size, indicating that tourists who engage in eco-tours, nature trails, or sustainable workshops tend to adopt more environmentally responsible behaviors. In contrast, sustainable dining (SD, $\beta = -0.112$, CI: -0.240–0.016, $p > 0.05$) showed a negative but non-significant relationship with STB. This suggests that while sustainable food choices are promoted, they may not necessarily translate into overall sustainable behavior, possibly due to cost considerations or accessibility. Similarly, responsible waste management (WM, $\beta = 0.073$, CI: -0.034–0.229, $p > 0.05$) had a weak and non-significant effect, implying that tourists may not perceive destination-level waste management efforts as directly impacting their own sustainable actions. Overall, the model fit indices (SRMR = 0.035) indicate a well-fitting model, validating the structural relationships. These findings highlight that eco-friendly accommodation, sustainable service providers, and efficient transportation, are the most influential factors in promoting sustainable behavior among urban tourists. This highlights the need for hospitality businesses to adopt green certification and sustainability practices, for service providers to actively communicate their eco-friendly initiatives, and for urban destinations to prioritize low-carbon transport systems to enhance overall sustainability. Overall, H1 was partially supported.

### 4.2 Necessary Condition Analysis Results

In the Necessary Condition Analysis (NCA) model, composite factor scores derived from IGSCA-SEM were utilized following the methodological guidelines recommended by Dul (2016). This approach has been widely applied in tourism and sustainability research (Wattanacharoensil et al., 2024), reinforcing its relevance and robustness. The NCA procedures used in this study, aimed to provide deeper insights into tourists' sustainable behavior (STB), particularly in the context of low-carbon tourism practices in urban destinations. Specifically, the analysis examined the conditions influencing sustainable behavior, including eco-friendly accommodation (ECA), sustainable service providers (SSP), efficient transportation (ET), low-carbon activities (LA), sustainable dining (SD), and responsible waste management (WM).

Table 3 presents a summary of ceiling lines, depicting the upper bounds of necessity for each identified relationship. NCA plots are also illustrated in Figure 2. The results indicate that all six determinants had a significant necessity effect size ($d > 0.1$, $p < 0.01$), confirming their essential roles in fostering sustainable behavior in urban tourism settings. Among the key predictors, sustainable service providers (SSP, $d = 0.512$, $p < 0.01$) exhibited the highest necessity effect size, indicating that a well-established network of eco-conscious tourism businesses is critical for encouraging sustainable actions. Similarly, efficient transportation (ET, $d = 0.469$, $p < 0.01$) and eco-friendly accommodation (ECA, $d = 0.394$, $p < 0.01$) were found to be indispensable factors, highlighting the importance of low-carbon mobility options and sustainable lodging in urban destinations.

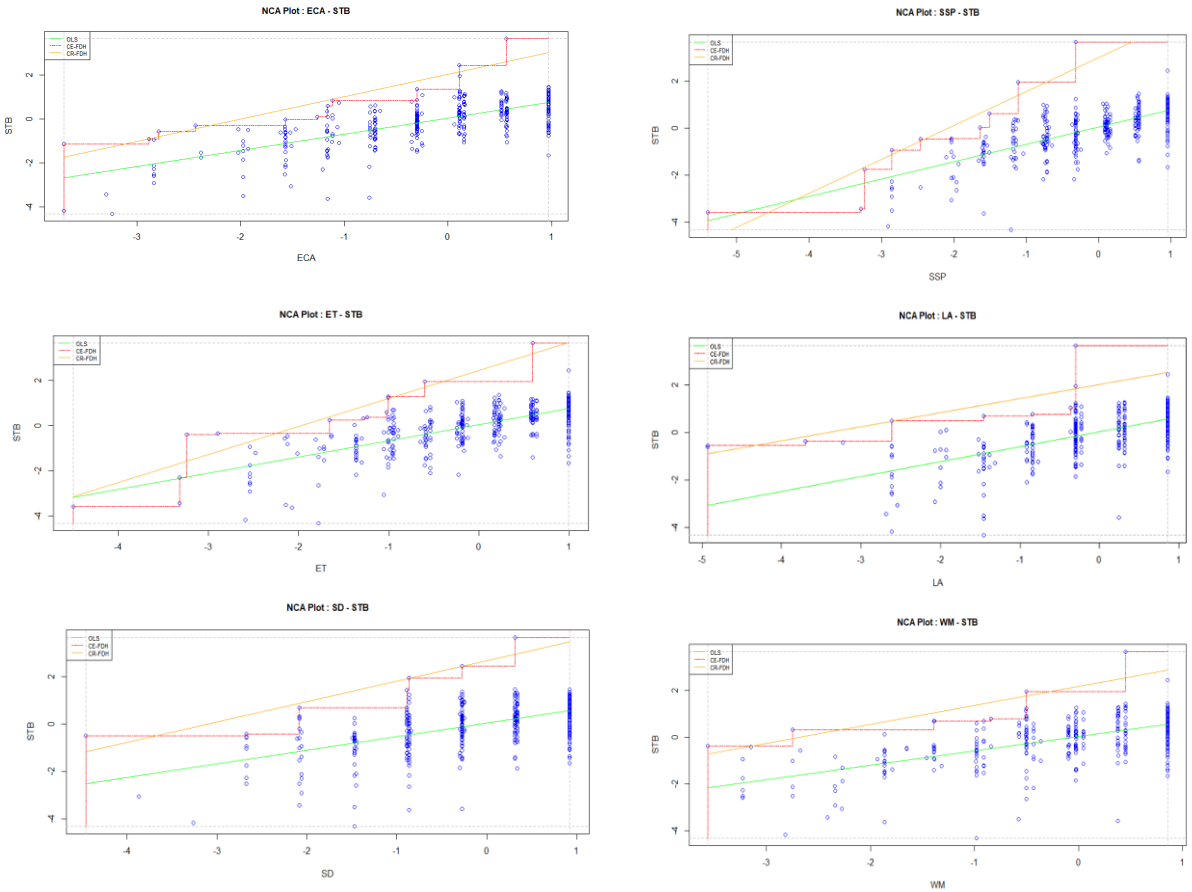
Moreover, low-carbon activities (LA, $d = 0.359$, $p < 0.01$) and sustainable dining (SD, $d = 0.352$, $p < 0.01$) also emerged as necessary conditions, suggesting that experiential sustainability initiatives and eco-friendly food choices contribute significantly to shaping tourists' sustainable behaviors. Although responsible waste management (WM, $d = 0.341$, $p < 0.01$) had the lowest necessity effect size, its presence remains a fundamental requirement for achieving higher levels of sustainable behavior. Overall, these findings affirm H2, demonstrating that all six identified determinants are necessary conditions for fostering sustainable behavior (STB) in urban low-carbon tourism. Figure 2 visually illustrates the NCA plots, providing a clear representation of the relationships between key constructs in the model. This analysis reinforces the idea that while these factors alone may not be sufficient to guarantee sustainable behavior, their presence is essential for achieving higher levels of sustainability in urban tourism destinations.

**Table 3** Single Necessary Condition Analysis

| Outcome STB | CE-FDH (d) | p-value | Triggered level 50% Outcome | Necessary? |
|---|---|---|---|---|
| ECA | 0.394 | 0.00 | 27.2% | In kind |
| SSP | 0.512 | 0.00 | 59.2% | In kind |
| ET | 0.469 | 0.00 | 51.7% | In kind |
| LA | 0.359 | 0.00 | 40.0% | In kind |
| SD | 0.352 | 0.00 | 44.1% | In kind |
| WM | 0.341 | 0.00 | 18.4% | In kind |

Note: CE-FDH = Ceiling Envelopment with Free Disposal Hull, CR-FDH = Ceiling Regression with Free Disposal Hull, ECA = eco-friendly accommodation, SSP = sustainable service provider, ET = efficient transportation, SD = sustainable dining, WM = responsible waste management, STB = sustainable behavior

**Figure 2** NCA Plots




## 5. DISCUSSION AND IMPLICATIONS

### 5.1 Theoretical Implications

This study advances the understanding of low-carbon tourism in urban destinations by integrating stimulus-response (S-R) theory and necessity logic to examine the essential conditions shaping sustainable tourist behavior (STB). The findings provide empirical validation of how low-carbon tourism attributes, including eco-friendly accommodation

(ECA), sustainable service providers (SSP), efficient transportation (ET), low-carbon activities (LA), sustainable dining (SD), and responsible waste management (WM)—influence tourists' engagement in sustainability practices.

By applying structural model analysis, the study demonstrates that ECA, SSP, and ET have the most substantial influence on STB, reinforcing the S-R framework where external environmental cues (Treisman, 1960), such as green hotels or low-emission transport options, condition tourists to engage in sustainable actions. The results align with previous research emphasizing the importance of infrastructure and service-oriented sustainability initiatives in encouraging pro-environmental behaviors among tourists (Becken, 2017; Cho et al., 2016; Han et al., 2024). The non-significant impact of SD and WM on STB suggests that while sustainable dining and waste management are important components of low-carbon tourism, they may not directly drive tourists' sustainable behaviors unless supported by complementary enablers, such as accessibility, affordability, and social norms (Fakfare & Wattanacharoensil., 2023a; Yong et al., 2024).

Furthermore, the Necessary Condition Analysis (NCA) provides a deeper causal perspective by identifying SSP, ET, and ECA as the most critical determinants. The necessity effect sizes ($d > 0.1$, $p < 0.01$) confirm that these elements are not just contributory but essential conditions for fostering sustainable behavior (STB). This supports necessity logic, which suggests that while sufficiency models can demonstrate how predictors enhance an outcome, they do not determine whether those factors are required for the outcome to occur (Dul, 2016). The results indicate that without the presence of essential low-carbon enablers, tourists' sustainable behaviors may not reach high levels, even if other sustainability initiatives exist.

In addition to SSP, ET, and ECA, the findings also highlight that sustainable dining (SD), low-carbon activities (LA), and responsible waste management (WM) are necessary conditions for STB, albeit with smaller necessity effects. While their necessity effect sizes ($SD = 0.352$, $LA = 0.359$, $WM = 0.341$, $p < 0.01$) are lower compared to SSP, ET, and ECA, they remain essential components of the low-carbon tourism framework. This suggests that without access to sustainable food options, low-carbon experiences, and effective waste management strategies, achieving high levels of sustainable behavior may be difficult.

A notable theoretical contribution is the empirical validation of necessity logic in urban tourism sustainability research. Previous studies have primarily examined sufficiency-based models (Fakfare & Wattanacharoensil, 2023a), yet this study highlights that certain low-carbon tourism attributes must be present to achieve high levels of sustainable behavior. This insight advances the S-R theory application in tourism (Treisman, 1960), emphasizing that conditioning effects are not uniform but rather dependent on the presence of essential sustainability enablers. By integrating necessity logic with the S-R framework, this study offers a more comprehensive understanding of how urban tourism destinations can strategically structure their low-carbon tourism initiatives to maximize sustainable behavioral outcomes among tourists.

## 5.2 Practical and Policy Implications

The findings of this study offer valuable insights for urban tourism stakeholders, including policymakers, tourism businesses, urban planners, and sustainability advocates. By identifying the essential conditions for fostering sustainable tourist behavior (STB), this study provides strategic guidance on designing and implementing effective low-carbon tourism policies and interventions that encourage environmentally responsible tourism in urban destinations.

From a practical standpoint, the results highlight the necessity of eco-friendly accommodation (ECA), which significantly influences tourists' sustainable behaviors. Hotels

and lodging facilities should integrate sustainable practices, such as renewable energy sources, water conservation systems, and waste reduction initiatives, to reinforce their low-carbon credentials. Obtaining eco-certifications (e.g., LEED, ASEAN Green Hotel) can further encourage environmentally conscious tourists to prioritize green accommodations. Additionally, hotels should actively promote their sustainability efforts through marketing campaigns, as tourists are more likely to choose accommodations which align with their environmental values.

The role of sustainable service providers (SSP) as a critical enabler of STB is also evident in the findings, with SSP exhibiting the highest necessity effect size ($d = 0.512$, $p < 0.01$). Tourism businesses, including tour operators, travel agencies, and hospitality service providers, should emphasize sustainability in their operations. Offering low-carbon tour packages, carbon-offset programs, and eco-friendly travel options can significantly influence tourists' choices and reinforce sustainable behaviors. Additionally, businesses should engage in sustainability education efforts, such as digital campaigns, eco-tourism workshops, and community-led conservation programs, to raise awareness and encourage responsible tourism practices.

Efficient transportation infrastructure is another fundamental requirement for fostering sustainable behavior, with efficient transportation (ET, $d = 0.469$, $p < 0.01$) emerging as a key necessity condition. Urban tourism planners should prioritize low-carbon transport solutions, such as electric buses, metro systems, bike-sharing programs, and pedestrian-friendly pathways, to facilitate tourists' access to sustainable mobility options. Implementing public incentives, such as free transit passes for tourists or reduced fares on low-emission vehicles, can encourage the adoption of environmentally friendly transport choices. Additionally, cities should integrate smart mobility solutions, such as app-based ride-sharing services and real-time public transport information, to enhance the accessibility and convenience of low-carbon travel.

While low-carbon activities (LA), sustainable dining (SD), and responsible waste management (WM) were also identified as necessary conditions, their necessity effects were relatively small compared to ECA, SSP, and ET. This suggests that while these factors contribute to sustainability, they require complementary structural enablers to maximize their impact. Tourism businesses should enhance low-carbon activities by incorporating interactive and educational experiences, such as eco-trails, guided sustainability tours, and carbon-neutral attractions, to reinforce pro-environmental behaviors. Sustainable dining should be made more accessible and affordable, with local restaurants offering eco-friendly food options, reduced food waste programs, and plant-based meal alternatives. Responsible waste management initiatives should focus on improving waste separation, promoting reusable packaging, and incentivizing tourists to minimize single-use plastics while traveling.

From a policy perspective, governments and city authorities must play a proactive role in establishing regulations and incentives that reinforce low-carbon tourism behaviors. Implementing mandatory green certification programs for accommodation providers, restaurants, and tourism service providers, can ensure compliance with sustainability standards while also providing financial incentives, tax reductions, or operational benefits to businesses which adopt green practices. Policies that promote low-carbon transportation networks, such as urban congestion charges, car-free tourism zones, and investment in public transit expansion, can further reduce the environmental impact of tourism in urban settings.

Collaboration between public and private stakeholders is crucial for the success of these sustainability initiatives. Tourism authorities, urban planners, and environmental organizations should work together to develop integrated sustainability strategies that align with international climate action goals. Governments should also support public-private partnerships to fund

research and innovation in low-carbon tourism technologies, such as smart energy solutions for hotels, sustainable aviation fuel alternatives, and AI-driven waste management systems.

## 6. LIMITATIONS AND FUTURE RESEARCH

This study has certain limitations to be addressed. First, the study primarily applies Stimulus-Response (S-R) theory and necessity logic to assess the impact of low-carbon tourism attributes on STB. While these theoretical frameworks offer valuable explanatory power, additional psychological and behavioral theories, such as planned behavior theory, norm activation theory, or protection motivation theory, could further enrich the understanding of how personal motivations, emotions, and perceived barriers influence tourists' decision-making processes. Second, while the study identifies eco-friendly accommodation (ECA), sustainable service providers (SSP), and efficient transportation (ET) as the most influential attributes, it does not deeply explore the interplay between these attributes and broader urban policies. Future research should investigate how regulatory frameworks, economic incentives, and digital technologies (e.g., smart city infrastructure, AI-driven sustainability apps) could enhance the effectiveness of low-carbon tourism initiatives in urban settings. Lastly, this study employs Integrated Generalized Structured Component Analysis (IGSCA) and Necessary Condition Analysis (NCA), which provide robust insights into sufficiency and necessity conditions. However, alternative data analysis techniques, such as fsQCA (Fuzzy-Set Qualitative Comparative Analysis) or agent-based modeling, could further explore complex causal relationships and interactions among multiple sustainability factors. Future research could integrate hybrid methodologies to develop more holistic sustainability models for urban tourism.

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