

Enhancing Carbon Footprint Awareness among Consumers: A Developmental Approach in Pathum Thani, Thailand

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Date Received: 15 November 2025 Revised: 5 March 2026 Accepted: 11 March 2026

Paper Type: Original Research

Abstract

Aim/Purpose: This study provides important policy and development implications by identifying carbon footprint awareness as the central mechanism driving low-carbon consumption behaviors across transportation, electricity use, and waste management domains. Rather than relying on broad environmental campaigns, the findings suggest that policymakers should embed awareness-building strategies directly into everyday consumption systems. The strong mediating role of awareness within the integrated Theory of Planned Behavior and Value-Belief-Norm framework offers an evidence-based foundation for designing interventions that activate attitudes, perceived behavioral control, and personal moral norms simultaneously. From a development perspective, enhancing carbon footprint awareness supports not only environmental sustainability, but also responsible citizenship and long-term behavioral change, particularly in rapidly urbanizing peri-urban areas such as Pathum Thani. Accordingly, integrated low-carbon strategies that coordinate energy, transportation, and waste policies under an awareness-centered framework are recommended to strengthen both policy coherence and sustainable social development outcomes.

Introduction/Background: Climate change is a critical global challenge driven by emissions from energy use, transportation, and industry. Beyond technological innovation, achieving long-term climate targets requires changes in consumer behavior, particularly in daily decisions about energy and mobility. In Thailand, the commitment to net-zero emissions by 2050 underscores the importance of consumer participation, making carbon footprint awareness a key mechanism for promoting sustainable consumption at household and community levels. Beyond environmental outcomes, carbon footprint awareness carries significant policy and social development implications. Integrating awareness into transportation, energy, and waste policies can strengthen civic responsibility, stimulate demand for low-carbon goods and services, and support green economic transformation. Focusing on Pathum Thani Province, this study applied behavioral theories to examine how carbon footprint awareness influences pro-environmental behavior and regional socio-economic outcomes. The findings highlight the importance of awareness-centered policies in advancing sustainable regional development and inclusive climate transition.

Methodology: A quantitative, cross-sectional survey design was employed to examine the relationships among transportation, electricity consumption, waste management, carbon footprint awareness, and consumer consumption behavior in Pathum Thani Province, Thailand. A structured questionnaire using a five-point Likert scale measured five latent constructs, with a sample of 360 residents aged 18 years or older selected through simple random sampling. Content validity was confirmed by expert review, and reliability testing showed strong internal consistency (Cronbach's alpha scores = .84–.91). Data were analyzed using Confirmatory Factor Analysis and Structural Equation Modeling to test direct and indirect relationships, with model fit assessed using standard goodness-of-fit indices according to established criteria.

Finding: The measurement model demonstrated strong convergent and discriminant validity across five constructs—Transportation, Electricity Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption with factor loadings above .70, AVE values exceeding .50, composite reliability above .70, and Cronbach’s alpha ranging from .84 to .91, confirming internal consistency and construct distinctiveness. Confirmatory Factor Analysis indicated acceptable model fit, supporting the adequacy of the measurement structure for structural analysis. The Structural Equation Model further revealed that Transportation ($\beta = .42$), Electricity Consumption ($\beta = .55$), and Waste Management ($\beta = .48$) had significant positive effects on Carbon Footprint Awareness, with electricity consumption exerting the strongest influence. In turn, Carbon Footprint Awareness significantly affected Consumer Consumption ($\beta = .69$), confirming its mediating role. Hypothesis testing supported all proposed relationships ($p < .001$), indicating that routine consumption-related behaviors enhance environmental awareness, which subsequently translates into sustainable consumption decisions.

Contribution/Impact on Society: This study contributes theoretically by empirically establishing carbon footprint awareness as a key psychological mechanism linking consumption-related behaviors to sustainable consumption. Practically, the findings provide evidence-based insights for policymakers and local authorities in Pathum Thani to design targeted interventions focused on energy use, mobility, and waste management. The validated analytical framework also offers applicability for examining sustainable consumption behavior in other regional contexts.

Recommendations: Accordingly, policy interventions in Pathum Thani Province should prioritize energy-related measures, such as real-time electricity feedback systems, carbon labeling of appliances, and tiered tariffs based on energy efficiency, as these are likely to generate the greatest downstream impact on sustainable consumption through enhanced awareness. Waste management programs should integrate explicit carbon-impact communication and community-level emission reporting to strengthen the awareness mechanism identified in the mediation analysis, while transportation policies should combine infrastructure improvements with visible carbon-emission information and digital emission calculators to reinforce cognitive associations between commuting behavior and environmental impact. Overall, an integrated low-carbon strategy centered on systematically enhancing carbon footprint awareness—particularly through energy-focused interventions—offers the most empirically grounded pathway for promoting sustainable consumption in peri-urban contexts similar to Pathum Thani Province.

Research Limitation: This study was subject to several limitations. The focus on a single province may limit generalizability, and the use of self-reported data may have introduced response bias. In addition, the cross-sectional design restricts causal interpretation of the observed relationships, and the model does not incorporate broader social or policy-related factors.

Future Research: Future research should extend the framework to multiple regions and adopt longitudinal designs to better capture changes in awareness and behavior over time. Incorporating additional variables such as social norms, policy interventions, and technological accessibility, as well as mixed-method approaches, would provide a more comprehensive understanding of sustainable consumer behavior.

Keywords: Carbon footprint, waste management, transportation, electricity consumption

Introduction

Climate change constitutes one of the most pressing global challenges of the 21st century, primarily driven by anthropogenic greenhouse gas emissions arising from energy consumption, transportation, and industrial activities (IPCC, 2023). Although technological innovation remains central to emission reduction strategies, growing evidence suggests that meaningful progress toward climate targets also depends on changes in human behavior, particularly consumer decision-making related to

consumption, energy use, and mobility (Rajbhandari et al., 2024). In Thailand, the national commitment to achieve net-zero emissions by 2050, alongside an interim target of a 40% reduction in greenhouse gas emissions by 2030 under the Paris Agreement, underscores the importance of consumer participation in climate mitigation efforts (World Bank Group, 2024). Within this context, consumer carbon footprint awareness emerges as a critical behavioral mechanism shaping sustainable consumption practices at both household and community levels.

Beyond its environmental significance, carbon footprint awareness holds substantial policy and social development implications. Embedding awareness-building mechanisms into transportation, energy, and waste management policies can strengthen civic responsibility, encourage collective action, and support inclusive local governance. When consumers understand the carbon consequences of their daily choices, they are more likely to demand low-carbon goods and services, thereby stimulating green markets and reinforcing structural shifts toward sustainable production systems. Consequently, awareness functions not only as a behavioral variable, but it also is a developmental lever capable of influencing employment structures, innovation pathways, and long-term regional resilience (Nielsen et al., 2021).

In this study, an interdisciplinary perspective by integrating behavioral science, environmental economics, and regional development analysis was adopted to examine how consumer behavior contributes to broader social and economic outcomes. The research was theoretically grounded in an integrated framework combining the Theory of Planned Behavior (TPB) and the Value–Belief–Norm (VBN) theory, which together formed the study’s core analytical foundation. TPB explains how attitudes, subjective norms, and perceived behavioral control influence consumers’ intentions and behaviors related to carbon-intensive consumption; VBN complements this approach by capturing the role of environmental values, beliefs about the consequences of climate change, and personal moral norms in motivating pro-environmental action. Integration of these theories enables a comprehensive explanation of both rational and normative dimensions of consumer behavior, thus advancing understanding of human behavior and social change in the context of sustainability transitions.

Empirically, the study focused on Pathum Thani Province, a key industrial and residential region that contributes approximately 3% of Thailand’s industrial output and hosts more than 10,000 SMEs employing over 120,000 workers (Tachaphan et al., 2024). By situating consumer carbon footprint awareness within this regional economic context, the study demonstrates how behavioral awareness can influence demand for low-carbon products and sustainable services, with implications for employment creation, household income, and regional economic performance. For example, sustainable transportation initiatives such as electric bus deployment are projected to reduce CO₂ emissions in the transportation sector by up to 15% while simultaneously generating new employment opportunities in green technology and maintenance sectors (Tachaphan et al., 2024; World Bank Group, 2024). These dynamics illustrate how changes in consumer behavior can generate broader societal impacts through economic spillover effects and structural shifts toward sustainable industries.

Despite increasing policy attention to climate mitigation, existing research in Thailand has largely focused on industrial emissions and macro-level policy frameworks, with limited empirical attention to consumer-level behavioral determinants such as environmental knowledge, attitudes, social norms, and perceived consumer effectiveness (Canlas & Karpudewan, 2023). Moreover, provincial-level analyses remain scarce, constraining the development of context-specific interventions that account for regional economic structures and social dynamics. Addressing these gaps is essential, as behavioral factors mediate the effectiveness of climate policies and market mechanisms by shaping household consumption patterns, income allocation, and, ultimately, regional economic outcomes. Without incorporating behavioral awareness into policy design, technological and regulatory interventions may yield suboptimal results due to limited public engagement and compliance.

Accordingly, the central problem addressed by this study is the absence of an empirically validated, awareness-centered behavioral framework that explains how routine consumption behaviors influence sustainable consumption and regional socio-economic development. By integrating TPB and VBN theories and testing a mediation-based structural equation model, this research sought to fill this

theoretical and empirical gap. The study aimed to clarify whether carbon footprint awareness functions as a key psychological transmission mechanism linking everyday behaviors to low-carbon consumption decisions, and in turn to broader social and economic development outcomes.

By investigating consumer carbon footprint awareness in Pathum Thani using structural equation modeling, this study contributes to the sustainable consumption literature by empirically linking behavioral awareness to socio-economic indicators such as employment, income, and regional economic output. The findings offer clear policy and development implications. Specifically, they support the formulation of integrated low-carbon consumption strategies that align transportation, electricity, and waste policies under a unified awareness-centered framework. Such an approach can enhance policy coherence, strengthen public participation, and improve long-term policy effectiveness. Furthermore, continuous monitoring of awareness indicators alongside economic and environmental performance metrics can facilitate adaptive governance and evidence-based policy refinement. In doing so, the article reinforces its relevance to interdisciplinary research on human behavior and social development, demonstrating that consumer carbon footprint awareness represents a foundational mechanism for achieving sustainable regional development and socially inclusive climate transitions.

Study Objectives

1. To assess the adequacy of the measurement model by examining the reliability and validity of the latent constructs, including transportation, electronic consumption, waste management, carbon footprint awareness, and consumer consumption
2. To analyze the structural relationships among transportation behavior, electronic consumption, waste management, carbon footprint awareness, and consumer consumption, with particular emphasis on the mediating role of carbon footprint awareness

Literature Review

This study is grounded in the Theory of Planned Behavior (TPB) (Ajzen, 1991) and the Value–Belief–Norm (VBN) theory (Stern et al., 1999), and advances both frameworks by integrating them through carbon footprint awareness as a central explanatory mechanism. Rather than positioning TPB and VBN as parallel models, its findings demonstrate that cognitive–intentional and moral–normative processes operate interactively through everyday consumption-related behaviors. This addresses recent scholarly calls for integrated behavioral frameworks capable of explaining pro-environmental action beyond single-theory applications (Nielsen et al., 2021; Steg & De Groot, 2019).

From a TPB perspective, it refines the traditional intention-driven structure by demonstrating a feedback-oriented mechanism. Transportation behavior, electricity consumption, and waste management are not treated as outcomes of attitudes, subjective norms, and perceived behavioral control; they function as experiential antecedents that construct carbon footprint awareness. This awareness subsequently strengthens sustainable consumption behavior, suggesting a recursive reinforcement process between action and cognition rather than a strictly linear intention–behavior pathway. Such findings align with contemporary behavioral research emphasizing dynamic belief–behavior feedback loops in environmental contexts (Lange & Dewitte, 2019; Nielsen et al., 2021).

From a VBN perspective, the study extends the classical value–belief–norm chain by empirically positioning carbon footprint awareness as a measurable mediating cognitive mechanism. While traditional VBN theory conceptualizes values influencing beliefs, which in turn activate personal norms and behavior, these results indicate that routine domain-specific behaviors—particularly energy-related practices—intensify awareness of environmental consequences, thereby strengthening pro-environmental consumption. Thus, norm activation may be reinforced through habitual behavioral engagement, offering a more dynamic interpretation of VBN processes (Steg & De Groot, 2019).

Methodologically, this study's novelty lies in the application of Structural Equation Modeling (SEM) to validate carbon footprint awareness as a statistically significant mediating variable between routine consumption behaviors and sustainable consumption outcomes. The significant indirect effects and

strong model fit indices provide empirical confirmation that awareness operates as a central psychological transmission mechanism, rather than a peripheral attitudinal construct. By integrating TPB and VBN within a mediation-based SEM framework and testing it in a regional developing-country context, the study refines both theories and offers a dynamic, empirically grounded model for explaining sustainable consumption behavior.

Relationship between Transportation and Carbon Footprint Awareness

Prior research grounded in the Theory of Planned Behavior (TPB) explains transportation choices primarily in terms of attitudes, subjective norms, and perceived behavioral control. In this perspective, awareness of environmental consequences is often embedded within attitudinal evaluation rather than treated as a distinct outcome. By contrast, the Value–Belief–Norm (VBN) theory explicitly conceptualizes awareness of consequences as a cognitive trigger that activates personal norms and environmentally responsible behavior. Empirical findings reveal an inconsistency in directionality. Wang et al. (2023) and Asiamah et al. (2025) reported that exposure to sustainable transportation systems enhances environmental awareness, implying that behavior or infrastructural engagement may shape cognition. However, other TPB- and VBN-based studies typically model awareness as an antecedent of sustainable transport adoption, rather than a consequence of routine travel practices. This asymmetry suggests a theoretical gap: transportation behavior may not only be predicted by awareness, but it may also contribute to its formation through repeated experiential engagement. Evidence examining this reverse pathway remains limited, particularly in subnational contexts. Based on the literature review, the hypothesis is:

H₁: Transportation has positively influenced carbon footprint awareness

Relationship between Electricity Consumption and Carbon Footprint Awareness

Within TPB-oriented energy research, electricity-saving behavior is largely explained by intention formation, while awareness is positioned as a cognitive antecedent that influences attitudes. VBN theory similarly emphasizes awareness of environmental consequences as a precursor to moral obligation. Empirical studies such as Goldstein et al.'s (2020) and Üstgörül et al.'s (2024) have consistently shown that higher environmental awareness is associated with lower electricity consumption. Nevertheless, comparatively few studies investigate whether electricity consumption behavior itself contributes to awareness formation. This is notable given that repeated interaction with energy use—particularly when supported by informational feedback—may increase cognitive salience of carbon emissions. The dominant assumption of a one-directional relationship (awareness → behavior) thus overlooks a potentially reciprocal dynamic. Empirical validation of behavior-to-awareness pathways in household electricity contexts remains limited, particularly in provincial settings. Drawing from the literature, the study proposed the following hypothesis:

H₂: Electricity consumption has a positive influence on carbon footprint awareness

Relationship between Waste Management and Carbon Footprint Awareness

Waste management research under TPB emphasizes perceived social norms and behavioral control as determinants of recycling and waste separation. In contrast, VBN theory frames awareness of environmental harm as a necessary cognitive condition for activating personal norms. Ustgorul et al. (2024) demonstrated that environmental knowledge significantly predicted pro-environmental waste behavior, reinforcing the awareness-to-behavior assumption. However, as in the transportation and electricity domains, most empirical models have treated awareness as exogenous. Limited research has examined whether participation in routine waste management practices strengthens individuals' carbon-related awareness through experiential learning. The absence of studies testing this reverse relationship restricts theoretical understanding of how awareness evolves in everyday contexts (Chummee, 2025; Jing et al., 2022). This gap is particularly relevant in rapidly developing provincial regions where waste generation patterns are changing. Drawing on the literature, it is proposed that:

H₃: Waste management has a positive influence on carbon footprint awareness

Relationship between Carbon Footprint Awareness and Consumer Consumption

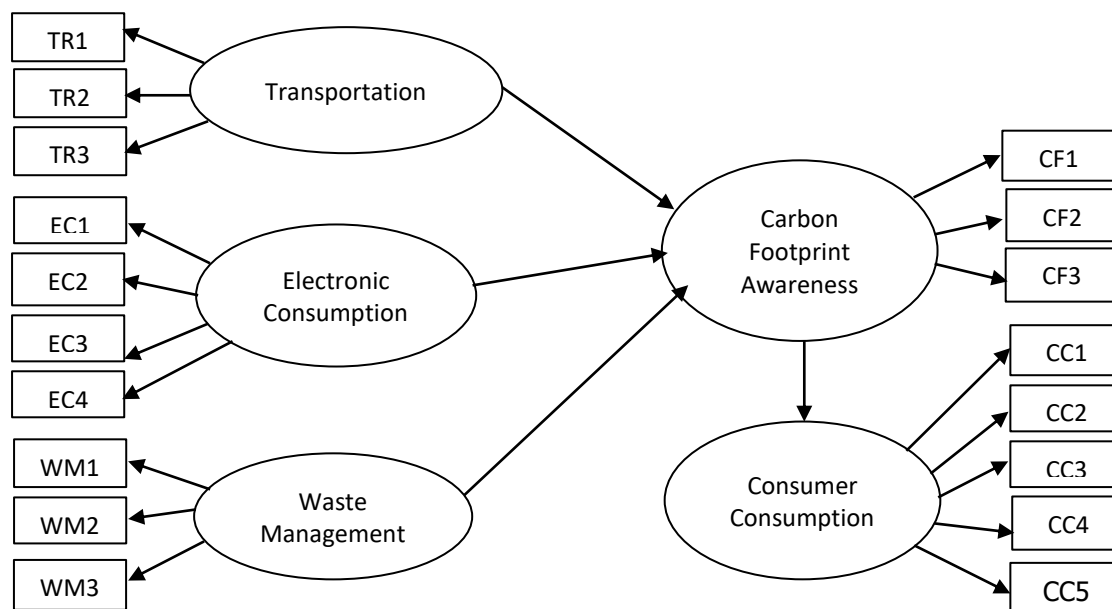
Both the TPB and VBN frameworks recognize awareness as an important determinant of pro-environmental action, but they conceptualize its function differently. TPB integrates awareness within attitudinal evaluation influencing intention, whereas VBN positions awareness of consequences as a mediating mechanism between values and personal norms. Empirical evidence supports a positive association between environmental awareness and specific low-carbon behaviors (Fosgaard et al., 2024). However, findings vary in magnitude, and many studies focus on isolated behaviors rather than on broader consumption patterns. Furthermore, awareness is often modeled independently of the behavioral domains that may shape it, limiting understanding of its role within a more integrated behavioral system. Research examining awareness in relation to overall consumer consumption within Thai provincial contexts remains limited (Wongsaichia et al., 2025). The hypothesis is proposed as follows:

H₄: Carbon footprint has a positive influence on consumer consumption.

Conceptual Model

Based on a thorough review of recent literature, including studies by Fosgaard et al. (2024), Goldstein et al. (2020), and Vázquez-Paja et al. (2024), etc., a conceptual framework has been developed to guide this research. This framework synthesizes the key variables and empirical evidence regarding transportation, electricity consumption, waste management, carbon footprint awareness, and consumer consumption. By integrating these findings, the framework provides a structured representation of the key constructs and their interrelations, offering a clear basis for understanding how awareness of carbon emissions can influence consumer behavior. The conceptual framework, illustrated in Figure 1, serves as a foundation for developing research hypotheses and designing the study's methodology.

Figure 1 *Conceptual Model*

**Research Method**

In this study, a quantitative research methodology was adopted to examine structural relationships among transportation, electricity consumption, waste management, carbon footprint awareness, and consumer consumption behavior in Pathum Thani Province, Thailand. Quantitative analysis was selected to enable systematic hypothesis testing and theory-driven model validation using Structural Equation Modeling. The unit of analysis was individual consumers residing in Pathum Thani Province.

Research Design

The study was classified as applied research with the objective of generating empirical evidence to support consumer-level carbon emission reduction strategies. A cross-sectional research design was employed, with data collected at a single point in time to capture prevailing behaviors and awareness levels. Descriptive statistics were used to summarize respondent characteristics, while inferential statistics and SEM were applied to test hypothesized relationships among latent constructs.

Target Population and Sample Group

The target population consisted of residents of Pathum Thani Province, which has an estimated population of approximately 1.19 million (National Statistical Office, 2023). Pathum Thani was selected due to its rapid urbanization, mixed residential–industrial structure, and increasing household energy use, making it an appropriate context for examining carbon-related consumer behavior beyond major metropolitan areas.

Following SEM sample size recommendations of 5–20 observations per observed variable (Hair et al., 2019), a minimum sample size of 360 respondents was determined based on 18 observed variables. Simple random sampling was employed to enhance representativeness and reduce systematic selection bias. Eligibility screening ensured that respondents were residents of Pathum Thani and aged 18 years or older. Contextual access constraints may have limited full population coverage; therefore, generalization of findings should be restricted to populations with similar socioeconomic and urban characteristics.

Questionnaire Development

The questionnaire was developed based on validated constructs from prior research grounded in the Theory of Planned Behavior (TPB) and the Value–Belief–Norm (VBN) theory. The measurement instrument was comprised of latent constructs with a total of 18 observed indicators.

Transportation behavior was measured using three items (TR1–TR3) adapted from TPB-based transportation behavior studies that examined travel mode choice and environmentally relevant mobility decisions (Bamberg & Möser, 2007; Wang et al., 2023). Electricity consumption behavior was measured using four items (EC1–EC4) adapted from established household energy use and conservation scales (Goldstein et al., 2020), which assess routine electricity consumption practices and conservation tendencies. Waste management behavior was assessed using three items (WM1–WM3) derived from recycling and waste separation measures commonly employed in TPB and VBN research (Shafiei-Alavijeh et al., 2025). Carbon footprint awareness was measured using three items (CF1–CF3) adapted from awareness-of-consequences constructs within the VBN framework and carbon literacy research (Fosgaard et al., 2024). Finally, consumer consumption behavior was measured using five items (CC1–CC5) adapted from sustainable consumption and green purchasing behavior scales (Wongsaichia et al., 2025).

All items were measured using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Minor wording modifications were made to ensure contextual relevance to the study setting. The questionnaire was translated using a back-translation procedure to ensure semantic equivalence, and a pilot test was conducted prior to the main data collection to confirm clarity, reliability, and content validity.

Validity and Reliability of Instruments

The research instrument underwent content validity and reliability testing to ensure accuracy and internal consistency. Content validity was assessed through the Index of Item-Objective Congruence (IOC) evaluated by five experts, with IOC values ranging from .80 to 1.00, confirming alignment with the research objectives. Reliability was examined using Cronbach's alpha, yielding acceptable coefficients for all constructs: Transportation (.84), Electricity Consumption (.86), Waste Management (.88), Carbon Footprint Awareness (.90), and Consumer Consumption (.91). All values exceeded the recommended threshold of .70 (Nunnally & Bernstein, 1994), indicating strong internal consistency.

Data Analysis

The data analysis employed Confirmatory Factor Analysis (CFA) to validate the measurement model and Structural Equation Modeling to examine relationships among the five latent variables: Transportation, Electricity Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption. CFA confirmed that the observed variables appropriately represented their constructs, while SEM tested the hypothesized causal relationships within the conceptual framework, including direct and indirect effects. Model adequacy was assessed using standard goodness of fit indices, including χ^2/df , GFI, AGFI, CFI, NFI, IFI, TLI, RMSEA, and SRMR. Thresholds for acceptable fit followed established guidelines: χ^2/df less than 3.00, GFI, AGFI, CFI, NFI, IFI, and TLI above .90, and RMSEA and SRMR below .08 (Hair et al., 2019; Hancock et al., 2010).

Common Method Bias and Multicollinearity

To ensure the structural model's robustness, both common method bias and multicollinearity were assessed using variance inflation factor (VIF) and tolerance statistics. Since data were collected using a single self-reported questionnaire, the possibility that common method variance inflated the observed relationships was carefully evaluated (Podsakoff et al., 2003). Following the full collinearity assessment approach proposed by Kock (2015), VIF values below 3.3 indicated that common method bias is unlikely to be a serious concern in PLS-SEM models. As shown in Table 1, the VIF values for all constructs ranged from 1.92 to 2.68. Specifically, Transportation (VIF = 2.05), Electronic Consumption (VIF = 2.41), Waste Management (VIF = 1.92), Carbon Footprint Awareness (VIF = 2.68), and Consumer Consumption (VIF = 2.27) all fell well below the conservative threshold of 3.3. These results suggest that common method bias did not pose a significant threat to the validity of the findings.

In addition, multicollinearity among constructs was examined. Excessive multicollinearity can distort path coefficients and inflate standard errors, thus weakening the interpretability and reliability of structural relationships (Hair et al., 2019). According to established guidelines, VIF values should be below 5.0 and tolerance values should exceed .20 to indicate acceptable levels of multicollinearity (Hair et al., 2019). The tolerance values reported in the table ranged from .373 to .521, all above the minimum threshold of .20. Correspondingly, all VIF values remained substantially below 5.0.

Research Results

Convergent and Discriminant Validity

Table 1 summarizes the convergent and discriminant validity of the measurement model for the five latent variables: Transportation, Electricity Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption. Convergent validity was confirmed through factor loadings above .60, AVE values exceeding .50, and composite reliability above .70; Transportation showed an AVE of .62 and CR of .88, while Carbon Footprint Awareness reported an AVE of .64 and CR of .90, indicating strong internal consistency and sufficient variance explanation. Mean scores ranged from 3.95 to 4.28, with standard deviations between .63 and .71, reflecting moderately high agreement and moderate response variability. Discriminant validity, assessed using Fornell and Larcker's (1981) criterion, showed that the square root of each construct's AVE exceeded its correlations with other constructs, confirming distinctiveness among the variables. R^2 values further indicated moderate explanatory power, with Carbon Footprint Awareness at .61 and Consumer Consumption at .54.

Table 1 Convergent and Discriminant Validity

Construct	Mean	SD	CR	AVE	R^2	VIF	Tolerance	TR	EC	WM	CF	CC
Transportation (TR)	4.12	.67	.88	.62	.56	2.05	.488	.79				
Electricity Consumption (EC)	3.95	.71	.86	.59	.48	2.41	.415	.42	.77			
Waste Management (WM)	4.05	.65	.87	.61	.52	1.92	.521	.35	.33	.78		
Carbon Footprint Awareness (CF)	4.28	.63	.90	.64	.61	2.68	.373	.40	.37	.36	.80	
Consumer Consumption (CC)	4.01	.69	.88	.60	.54	2.27	.441	.38	.35	.34	.41	.78

Demographic Information

A total of 360 consumers residing in Pathum Thani Province were surveyed for this study; the respondents' demographic characteristics are presented in Table 2. The information includes gender, age, education level, occupation, and monthly income, which provides a comprehensive overview of the sample profile. The majority of respondents were female (58.3%, $n = 210$), while male respondents accounted for 41.7% ($n = 150$). In terms of age distribution, the largest group was aged 26–35 years (33.3%, $n = 120$), followed by those aged 18–25 years (25.0%, $n = 90$). Respondents aged 36–45 years represented 23.6% ($n = 85$), and those aged 46 years and above accounted for 18.1% ($n = 65$). Regarding educational attainment, more than half of the respondents held a bachelor's degree (55.6%, $n = 200$). Master's degree holders comprised 22.2% ($n = 80$), while 16.7% ($n = 60$) had completed high school or below. A smaller proportion of respondents held a doctoral degree (5.5%, $n = 20$). With respect to occupation, private-sector employees constituted the largest proportion of the sample (40.3%, $n = 145$). Students accounted for 19.4% ($n = 70$), followed by government officers at 18.1% ($n = 65$). Business owners represented 13.9% ($n = 50$), and respondents in other occupations accounted for 8.3% ($n = 30$). In terms of monthly income, the largest group of respondents reported earning between 15,001–30,000 Thai Baht (THB) (38.9%, $n = 140$). Those earning 30,001–50,000 THB accounted for 26.4% ($n = 95$), while 22.2% ($n = 80$) earned below 15,000 THB. The smallest group consisted of respondents earning above 50,000 THB (12.5%, $n = 45$).

Table 2 Demographic Characteristics of Respondents ($n = 360$)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	150	41.7
	Female	210	58.3
Age	18–25 years	90	25.0
	26–35 years	120	33.3
	36–45 years	85	23.6
	46 years and above	65	18.1
Education Level	High School or below	60	16.7
	Bachelor's Degree	200	55.6
	Master's Degree	80	22.2
	Doctoral Degree	20	5.5
Occupation	Student	70	19.4
	Government Officer	65	18.1
	Private Employee	145	40.3
	Business Owner	50	13.9
	Other	30	8.3
Monthly Income (Thai Baht)	Below 15,000	80	22.2
	15,001–30,000	140	38.9
	30,001–50,000	95	26.4
	Above 50,000	45	12.5

Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) was conducted to evaluate the adequacy of the measurement model comprising five latent constructs: Transportation, Electricity Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption. As reported in Table 3, the model demonstrated an acceptable overall fit, indicating that the specified factor structure was consistent with the empirical data and appropriate for subsequent structural analysis.

All observed indicators loaded strongly on their respective latent constructs, with standardized factor loadings exceeding the recommended threshold of .70. This provided evidence of satisfactory convergent validity and confirmed that the measurement items reliably captured the underlying behavioral and awareness dimensions. The results suggested that daily practices related to transportation, electricity use, and waste management were meaningfully operationalized as distinct yet theoretically related constructs, consistent with prior environmental behavior research grounded in the Theory of Planned Behavior and Value–Belief–Norm frameworks.

Moreover, the clear differentiation among constructs supported the conceptual assumption that carbon footprint awareness functions as a cognitive mechanism distinct from, but influenced by, routine consumption-related behaviors. The Consumer Consumption construct's reliability further indicated that environmentally conscious purchasing and low-carbon consumption preferences represent a coherent behavioral outcome rather than isolated actions.

Table 3 *Confirmatory Factor Analysis*

Latent Variable	χ^2/df	CFI	TLI	RMSEA	SRMR	Item	Factor Loading
Transportation	1.94	.95	.94	.053	.044	TR1	.75
						TR2	.78
						TR3	.81
Electricity Consumption	1.97	.95	.94	.055	.045	EC1	.72
						EC2	.74
						EC3	.77
						EC4	.79
Waste Management	1.92	.96	.95	.052	.043	WM1	.76
						WM2	.79
						WM3	.82
Carbon Footprint Awareness	2.01	.95	.94	.057	.046	CF1	.78
						CF2	.81
						CF3	.84
Consumer Consumption	1.96	.95	.94	.054	.045	CC1	.73
						CC2	.75
						CC3	.77
						CC4	.78
						CC5	.80

Note. χ^2/df : Chi-squared divided by degrees of freedom; CFI: Comparative Fit Index; TLI: Tucker-Lewis Index; RMSEA: Root Mean Square Error of Approximation; SRMR: Standardized Root Mean Square Residual

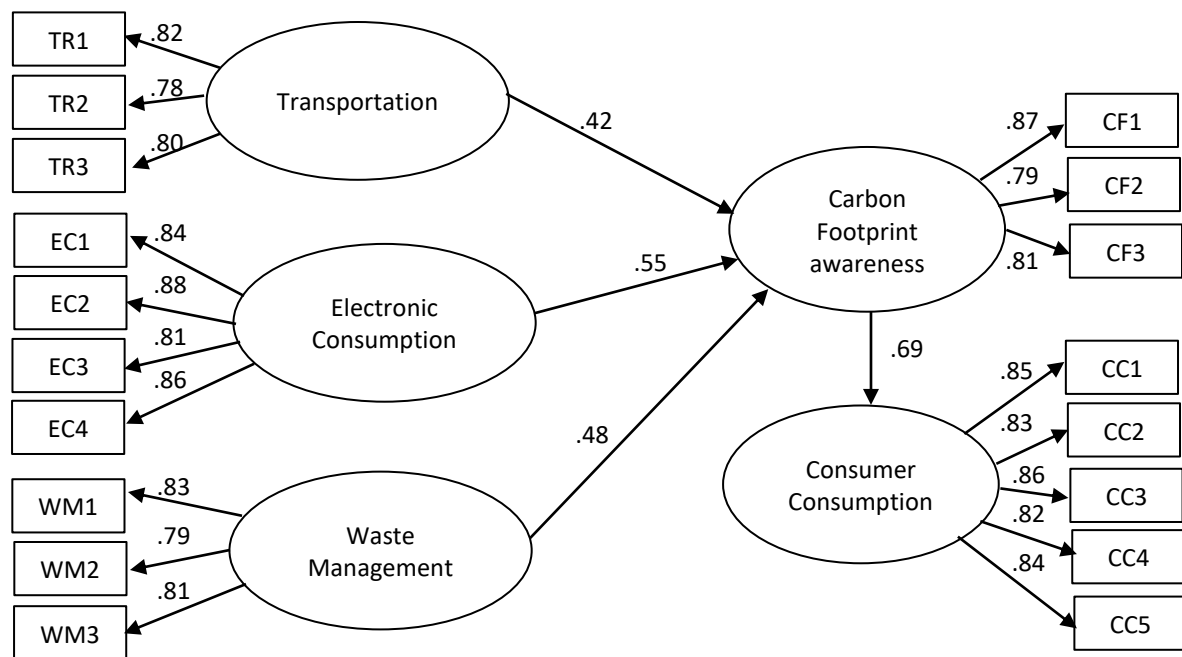
Structural Equation Modelling Analysis

The structural equation model (SEM), presented in Figure 2, examined the relationships among Transportation, Electronic Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption, with carbon footprint awareness specified as a mediating construct. The model was developed to assess whether routine consumption-related behaviors influence sustainable consumption indirectly through enhanced environmental awareness. The measurement model exhibited strong construct validity and internal consistency, as all observed indicators loaded significantly onto their respective latent constructs, with standardized factor loadings exceeding the .70 threshold. This confirmed that Transportation, Electronic Consumption, and Waste Management were reliably operationalized as distinct behavioral domains, while Carbon Footprint Awareness represented a coherent cognitive construct and Consumer Consumption captured integrated sustainable consumption behavior.

At the structural level, Transportation ($\beta = .42$), Electronic Consumption ($\beta = .55$), and Waste Management ($\beta = .48$) exerted significant positive effects on Carbon Footprint Awareness. Among these predictors, electronic consumption showed the strongest influence, suggesting that energy-related behaviors play a particularly salient role in shaping consumers' awareness of carbon emissions.

This pattern is theoretically consistent with the Theory of Planned Behavior, whereby repeated engagement in daily practices reinforces beliefs and attitudes, and with the Value–Belief–Norm framework, which emphasizes the role of habitual behaviors in activating environmental awareness. Carbon Footprint Awareness, in turn, had a strong positive effect on Consumer Consumption ($\beta = .69$), confirming its mediating role in the model. This finding indicated that awareness functions as a key psychological mechanism through which everyday behaviors related to transportation, energy use, and waste management are translated into low-carbon consumption decisions. Rather than acting as passive knowledge, awareness operates as an internalized belief system guiding sustainable purchasing and usage behavior.

Figure 2 *Finalized Model*



$$\chi^2/df = 1.40, CFI = .962, TLI = .951, RMSEA = .043, SRMR = .041, GFI = .937, AGFI = .914$$

Hypothesis Testing

Four hypotheses were tested using the SEM results (Table 4). Transportation had a positive and significant effect on Carbon Footprint Awareness (H_1 : $\beta = .42$, $t = 5.96$, $p < .001$), indicating that sustainable transportation behaviors enhance consumers' awareness of carbon emissions. Electronic Consumption exerted the strongest influence on awareness (H_2 : $\beta = .55$, $t = 8.73$, $p < .001$), suggesting that energy-related consumption practices are a key driver of environmental consciousness. Waste Management also significantly affected awareness (H_3 : $\beta = .48$, $t = 6.44$, $p < .001$), highlighting the role of recycling and waste reduction behaviors in shaping carbon-related understanding. Finally, Carbon Footprint Awareness had a strong positive effect on Consumer Consumption (H_4 : $\beta = .69$, $t = 11.85$, $p < .001$), confirming that higher awareness leads to more sustainable consumption decisions.

Table 4 *Hypothesis Testing*

Hypothesis	Path	Estimate (β)	t-value	p-value	Result
H_1	Transportation → Carbon Footprint Awareness	.42	5.96	< .001	Supported
H_2	Electronic Consumption → Carbon Footprint Awareness	.55	8.73	< .001	Supported
H_3	Waste Management → Carbon Footprint Awareness	.48	6.44	< .001	Supported
H_4	Carbon Footprint Awareness → Consumer Consumption	.69	11.85	< .001	Supported

Direct and Indirect Relation

The mediation analysis (Table 5) further supported the central role of Carbon Footprint Awareness. Transportation showed an indirect effect of .28 on Consumer Consumption through awareness, yielding a total effect of .70. Electronic Consumption exhibited the strongest overall influence, with an indirect effect of .37 and a total effect of .92. Waste Management demonstrated an indirect effect of .33 and a total effect of .81. These findings indicated that awareness functions as a key mechanism through which daily environmental behaviors influence sustainable consumption patterns.

Table 5 *Direct and Indirect Relation*

Latent Variable	Carbon Footprint Awareness			Consumer Consumption		
	DE	IE	TE	DE	IE	TE
Transportation	.42		.42	.42	.28	.70
Electronic Consumption	.55		.55	.55	.37	.92
Waste Management	.48		.48	.48	.33	.81
Carbon Footprint Awareness				.69		.69

Note. DE = Direct Effect; IE = Indirect Effect; TE = Total Effect

Conclusions and Discussions

The results confirmed that the proposed measurement and structural models are both statistically robust and theoretically sound. The confirmatory factor analysis demonstrated strong reliability and convergent validity, as all factor loadings exceeded the recommended threshold of .70 and the overall model fit indices fell within acceptable ranges. The structural equation model further revealed significant relationships among Transportation, Electronic Consumption, Waste Management, Carbon Footprint Awareness, and Consumer Consumption, providing empirical evidence of the mechanisms underlying sustainable consumer behavior in Pathum Thani, Thailand.

From a theoretical perspective, the findings can be explained through the integration of the Theory of Planned Behavior (TPB) and the Value–Belief–Norm (VBN) theory. The significant effects of transportation, electronic consumption, and waste management on carbon footprint awareness suggest that repeated engagement in environmentally relevant behaviors strengthens individuals' beliefs about environmental consequences. In terms of VBN theory, these behaviors reinforce awareness of consequences and personal responsibility, which are key precursors to the activation of pro-environmental norms. At the same time, TPB helps explain how these daily practices shape attitudes and perceived behavioral relevance, thereby increasing the likelihood that awareness will be translated into actual consumption decisions (Ajzen, 1991).

The positive influence of transportation on carbon footprint awareness highlights the role of daily mobility choices as a salient source of environmental feedback. In Pathum Thani, where commuting and private vehicle use are common, transportation-related decisions are highly visible and frequently evaluated, making their environmental implications more cognitively accessible. This finding was consistent with prior studies indicating that transport behaviors significantly shape carbon awareness and indirectly promote sustainable consumption (Asiamah et al., 2025; Wang et al., 2023). From a TPB perspective, repeated exposure to sustainable transport options reinforces positive attitudes toward low-carbon lifestyles and strengthens perceived behavioral relevance.

Electronic consumption emerged as the strongest determinant of carbon footprint awareness, underscoring the pivotal role of energy-related behaviors in shaping environmental consciousness. Contextually, household electricity consumption constitutes a major source of emissions in Pathum Thani, which may heighten sensitivity to energy use and efficiency. Theoretically, VBN explains this effect through heightened awareness of the consequences of energy consumption, while TPB suggests that frequent decision-making about electronic use strengthens outcome evaluations and behavioral

beliefs. This result aligns with empirical evidence showing that energy-related practices are central drivers of carbon awareness and behavioral change (Üstgörül et al., 2024; Fosgaard et al., 2024).

Waste management also exerted a significant influence on carbon footprint awareness, indicating that habitual and socially observable practices such as recycling and waste separation contribute to sustained environmental understanding. This finding supports VBN theory, which emphasizes the role of moral norms activated through routine pro-environmental actions (Stern et al., 1999). In addition, TPB provides an alternative explanation by highlighting the influence of perceived social norms and behavioral routines in reinforcing environmentally responsible behavior. Similar conclusions were reported in studies showing that visible and repetitive environmental actions strengthen long-term awareness and sustainable consumption patterns (Goldstein et al., 2020; Wongsachia et al., 2025).

Most importantly, carbon footprint awareness demonstrated a strong direct effect on consumer consumption, confirming its role as a central mediating mechanism linking environmentally related behaviors to low-carbon consumption. This finding suggests that awareness functions not merely as cognitive knowledge, but as an internalized psychological driver that translates everyday practices into sustainable purchasing decisions. Conceptually, awareness serves as a bridge between VBN's moral activation process and TPB's attitudinal and intentional pathways, thereby facilitating the transition from values and beliefs to actual consumption behavior (Ajzen, 1991; Stern, 1999).

From a policy perspective, these findings suggest that sustainability initiatives in Pathum Thani should prioritize behavior-integrated awareness strategies over stand-alone informational campaigns. Energy policies should focus on household-level efficiency programs and feedback mechanisms that clearly communicate both environmental and economic benefits. Transportation policies should integrate infrastructure development with incentive-based measures and targeted communication to enhance the salience of carbon impacts. Waste management interventions should reinforce habitual practices through community-based programs and consistent regulatory support. By aligning policy design with the behavioral mechanisms identified in this study, policymakers can develop more specific, actionable, and effective strategies to promote long-term sustainable consumption.

Recommendations

Based on the empirical findings and the TPB–VBN framework, several actionable recommendations are proposed for policymakers, local authorities, and relevant stakeholders to promote sustainable consumption and carbon emission reduction in Pathum Thani Province and similar contexts.

First, energy-related behavioral interventions should be positioned as the primary policy leverage point in Pathum Thani Province. Because electronic consumption demonstrated the strongest direct effect on carbon footprint awareness and the largest total effect on sustainable consumption, policymakers should implement real-time electricity feedback systems at the household level, introduce carbon emission labeling for electrical appliances, and apply tiered electricity pricing structures linked to energy efficiency. These measures would directly strengthen consumers' awareness of the carbon consequences of daily energy use, thereby enhancing sustainable consumption decisions through the identified mediation mechanism.

Second, waste management policies should incorporate explicit carbon awareness components rather than relying solely on technical improvements. The significant path coefficient between Waste Management and Carbon Footprint Awareness ($\beta = .48$) suggests that recycling and waste reduction behaviors enhance sustainable consumption through increased awareness. Thus, local authorities should integrate carbon impact information into recycling campaigns, publicly report community-level emission reductions achieved through proper waste separation, and develop incentive systems that link waste reduction efforts to measurable carbon outcomes. Such strategies are consistent with the mediation results, indicating a substantial indirect effect (.33) on consumer consumption.

Third, transportation policy should combine infrastructure development with behavioral and cognitive framing strategies. Although Transportation exhibited a comparatively smaller coefficient ($\beta = .42$), its effect remains statistically significant and contributes meaningfully to sustainable consumption through awareness. Therefore, public transportation systems should incorporate visible

carbon emission information per travel mode, and digital commuting applications should provide personalized carbon emission calculations. These measures would reinforce a cognitive link between commuting behavior and carbon impact, consistent with the model's awareness-centered pathway.

Fourth, the findings support the development of an integrated low-carbon consumption strategy centered explicitly on awareness enhancement. Given that Carbon Footprint Awareness represented the strongest predictor of Consumer Consumption in the structural model, fragmented sector-specific interventions may limit policy effectiveness. Instead, provincial authorities should coordinate transportation, energy, and waste initiatives under a unified awareness-based framework, supported by continuous monitoring of awareness indicators alongside behavioral metrics. Such integration is aligned with the empirically validated mediation structure and ensures policy coherence.

Finally, policy implementation should reflect the demographic characteristics of the sample, which was predominantly composed of working-age, moderately educated, and middle-income consumers. Digital communication tools, workplace-based awareness programs, and mid-income-targeted financial incentives are therefore likely to produce higher behavioral responsiveness in peri-urban contexts such as Pathum Thani Province.

Author Contributions

Pattarapon Chummee: Conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing—original draft, writing—review & editing, project administration.

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