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Pioneering Eco-Cart: Carbon Reduction Solutions for Thai Online Shoppers

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Abstract. *This research aims to identify effective strategies for reducing carbon emissions in online shopping by examining the perspectives of Thai consumers and utilizing sociodemographic data to anticipate their choices for carbon mitigation. The study encompasses eco-logistics, last-mile innovations, and responsible consumer behavior. Data collected from a questionnaire gathered responses from 800 participants across diverse regions, resulting in a 96.50% response rate. Using a multinomial logit model in Stata 15, the analysis reveals factors influencing consumer decisions. Eco-logistics is the preferred choice for 35.74% of individuals aiming to reduce carbon emissions from online shopping. Regular purchases of clothing and shoes correlate with a 46% higher likelihood of selecting eco-logistics, while responsible purchasing shows a 33.03% adoption rate. Last-mile innovations, chosen by 31.23%, appeal to higher-income individuals, while women, older age groups (46+), and those with higher education lean toward eco-logistics. Higher education enhances responsible purchasing, influenced by critical thinking, income, and professional networks. Additionally, suburban consumers prefer eco-logistics due to longer distances, while urban residents opt for last-mile innovations. Addressing these challenges facilitates environmentally conscious practices in the e-commerce supply chain, providing insights for policymakers and businesses to formulate sustainable and equitable strategies.*

Keywords: carbon reduction, carbon emissions, online shopping, responsible consumer, eco-logistics, last-mile innovations.

Please cite the article as follows: Ut-tha, V. (2023), "Pioneering Eco-Cart: Carbon Reduction Solutions for Thai Online Shoppers", *Management and Marketing*, Vol. 18, No. 4, pp. 515-536, DOI: 10.2478/mmcks-2023-0028.

Introduction

The rise of e-commerce has transformed consumer shopping practices, offering convenience, diversity, and easy access (Oliveira et al., 2017; Poon & Tung, 2022; Ranieri et al., 2018; Shaw et al., 2022). However, the swift expansion of e-commerce has also sparked concerns over its environmental impact, particularly regarding carbon emissions due to the prevalent use of traditional delivery methods that often rely on fossil fuel-powered transportation (Laghaei et al., 2016). In China, home delivery emerged as the favored final delivery approach. Although respondents showed high adoption rates for e-shopping and frequent repeat purchases, there remains substantial potential for further growth in consumer consumption (Xiao et al., 2018). As the demand for online purchases continues to surge in numerous

countries (Duin et al., 2016; Oliveira et al., 2017; Van Loon et al., 2015; Xiao et al., 2018), the identification of sustainable solutions to reduce the carbon footprint associated with this mode of shopping becomes increasingly vital (Deloison et al., 2020).

The adverse environmental effects of transportation encompass greenhouse gas emissions that contribute to climate changes, local emissions of air pollutants which have a negative impact on human health and the local natural environment, and noise pollution (Bąk et al., 2019; Choi et al., 2019; Ranieri et al., 2018; Van Loon et al., 2015). Historically, a significant issue related to carbon emissions arising from online shopping was the insufficient consideration of the ecological repercussions of delivery speed. The consumer demand for rapid delivery often resulted in the utilization of expedited shipping methods that consumed excessive energy and emitted greater amounts of carbon dioxide (Cui et al., 2020; De Koster, 2003; Lee, 2002).

Another concern revolved around the inefficient use of shipping resources. Small individual orders, frequently delivered separately, led to an increased frequency of transportation and the accompanying emissions (Soler et al., 2021). Similarly, the occurrence of multiple orders involving various products exacerbated pollution issues, necessitating multiple shipments. For example, the transportation of goods from warehouses to customers' homes or businesses led to elevated energy consumption, congestion, and emissions (Deloison et al., 2020). Additionally, these multiple shipments were susceptible to lost items and incorrect deliveries, resulting in supplementary shipments and compounding the negative environmental impact. Furthermore, missed deliveries due to absent recipients resulted in repeated delivery attempts, further exacerbating carbon emissions (Duin et al., 2016; Oliveira et al., 2017).

The regular online purchases of specific types of goods can impact the available options for reducing CO_2 emissions from transportation. For instance, the transportation of perishable items like food necessitates specialized logistics and packaging to preserve freshness and quality, potentially increasing the carbon footprint associated with online shopping (Ranieri et al., 2018; Wakeland et al., 2012). Similarly, transporting bulky or heavy goods such as furniture or electronics can also contribute significantly to the carbon footprint, particularly if they require long-distance shipping or multiple deliveries (Xiao et al., 2018). The carbon footprint of online shopping further escalates when customers opt to return items. A study conducted in Germany revealed that approximately one in three online purchases is returned. In the USA, returned merchandise worth nearly US$326 million is sent back each year, with two billion kilograms ending up in landfills, resulting in the release of 13 tonnes of CO_2 (Weltevreden, 2008; Xiao et al., 2018). The issue of high return rates, especially prevalent in the clothing sector, stems from customers being unable to try items on before purchase. The provision of free returns encourages customers to order multiple sizes and colors, but not all returned garments are properly cleaned and resold. This leads to waste, with some perfectly fine items finding their way to landfills or being discarded (Xiao et al., 2018).

According to a 2014 survey by the Ministry of Commerce in Thailand, which included 7,499 samples, clothing and accessories emerged as the most popular online purchases, accounting for 48.75% of respondents and 14.37% of total online expenditure. Following closely were food and beverage products, representing 47.82% of respondents and 13.22% of online spending. Additionally, 19.34% of respondents acquired mobile phones and devices, constituting the highest share of online expenses at 17.54%. Notably, online spending was

notably high among young individuals aged 20-29, with 87% participating in online purchases. Leading in terms of regional online spending were Bangkok and metropolitan areas, which accounted for 81.62% (Trade Policy and Strategy Office, 2021). Similarly, Thailand's e-commerce shares of retail sales experienced a notable growth from 0.8% in 2015 to a projected 5.5% by 2025, indicating an escalating demand for energy in the transportation sector (Statista Research Department, 2023). Existing literature supports the notion that road transport is the prevailing mode for last-mile delivery (Ranieri et al., 2018). In 2022, carbon emissions from the transport sector contributed to 32% of total emissions, marking a significant 14.9% increase from the preceding year (EPPO, 2023). This trend aligns with historical data, where greenhouse gas (GHG) emissions from the road transport sector in Thailand escalated from 0.881 per capita in 2004 to 1.053 per capita in 2018 (Office of the Permanent Secretary, 2023). GHG emissions play a pivotal role in climate change, and the emission of air pollutants associated with transportation is influenced by geographical location, local factors, existing transportation methods, and traffic patterns. All these elements collectively impact GHG emissions on both a national and global scale (Ranieri et al., 2018).

To address the mitigation of carbon emissions from online shopping, a range of solutions has emerged, including eco-logistics operations aimed at conserving energy and decreasing emissions. Approaches such as the adoption of hybrid trucks, parcel consolidation, and self-service electronic lockers offer sustainable transportation alternatives that contribute to reduced fuel consumption. In the realm of last-mile innovations, options like electric vehicles (EVs), hydrogen fuel cell electric vehicles (FCEVs), autonomous vehicles (AVs), drones, and cargo bikes for urban freight play a role in emission reduction (Caspersen & Navrud, 2021; Choi et al., 2019; Lachapelle et al., 2018; Morganti et al., 2014; Patella et al., 2020; Ranieri et al., 2018; Van Loon et al., 2015). The majority of previous research has predominantly focused on providing solutions to mitigate the carbon footprint within the entrepreneurial sector. These studies present innovative strategies to reduce carbon emissions by introducing environmentally friendly transportation methods. Importantly, they also consider customer satisfaction in terms of expedited delivery and fostering repeat purchases, thereby enhancing business competitiveness (Abukhader & Jonson, 2004; Ageron et al., 2012; Auclair & Burgos, 2021; Awwad et al., 2018; Bąk et al., 2019; Birney et al., 2017; Brown & Guiffrida, 2014; Deloison et al., 2020; Dorozińska et al., 2016; Hayashi et al., 2022; Poon & Tung, 2022). Research focused on consumer decision-making within the context of reducing carbon emissions from online shopping remains limited. Nonetheless, it's important to highlight that consumer cooperation, responsible purchasing, and purposeful shopping can significantly contribute to carbon emissions reduction (Lorenzen, 2014; Van Loon et al., 2015).

Moreover, a gap exists in the literature concerning the exploration of sociodemographic data among consumers and its influence on their decisions to minimize carbon emissions during online shopping. A comprehensive grasp of factors such as gender, education, income, and geographic location can provide valuable insights for policymakers and businesses aiming to devise targeted strategies for fostering sustainable and equitable e-commerce practices (Caspersen & Navrud, 2021; Hayashi et al., 2022; Lorenzen, 2014; Shaw et al., 2022; Soler et al., 2021; Xiao et al., 2018). This research is dedicated to investigating effective strategies for diminishing carbon emissions in the realm of online shopping, with a specific focus on the perspectives of Thai consumers and their

sociodemographic data to predict choices related to carbon mitigation. By tackling these challenges, tangible approaches can be formulated to promote environmentally conscious practices across the entire e-commerce supply chain.

Theoretical background

Eco-logistics and last-mile innovations

The issue of negative environmental impact has spurred various positive changes aimed at mitigating this adverse influence. Consequently, the increased interest among entrepreneurs in the online shopping market has led to the emergence of eco-logistics operations. Eco-logistics pertains to the transportation and delivery of goods in an environmentally friendly and sustainable manner, while last-mile innovations encompass novel strategies to enhance the efficiency and sustainability of last-mile logistics operations. In essence, eco-logistics constitutes a broader concept encompassing all facets of logistics operations, whereas last-mile innovations focus on specific tactics to enhance the last-mile delivery process (Awwad et al., 2018; Choi et al., 2019; Lachapelle et al., 2018).

Numerous businesses have embraced eco-logistics practices, yet they have not yet integrated last-mile innovations. For instance, a company utilizing hybrid or electric trucks to convey goods from their warehouse center to a distribution hub practices eco-logistics. However, they might not have implemented last-mile innovations such as deploying drones or electric vehicles for last-mile deliveries. Similarly, a company utilizing sustainable packaging materials and optimizing delivery routes to minimize fuel consumption engages in eco-logistics, yet may lack last-mile innovations (Awwad et al., 2018). Choi et al. (2019) delve into the significance of sustainable logistics and its correlation with CO_2 reduction. They propose that sustainable logistics solutions, such as recycling and reusing delivery packaging, present cost-effective means for online businesses to ensure eco-friendly same-day deliveries that satisfy their customers. Various ideas related to eco-logistics are explored to curtail carbon emissions in the e-commerce sector. For example, adopting night-time deliveries can help diminish carbon emissions linked to transportation. Implementing consolidation measures like load-pooling, micro-hubs, and goods trams can reduce the volume of vehicles on the road, thus lowering carbon emissions (Deloison et al., 2020). Furthermore, the importance of secure delivery systems that thwart theft, damage, or loss of goods during transit is highlighted as a means to decrease the necessity for redelivery and consequently reduce carbon emissions in the e-commerce sector (Abukhader & Jonson, 2004; Choi et al., 2019; Patella et al., 2020; Ranieri et al., 2018; Van Loon et al., 2015).

The parcel locker system stands out as an automated self-service alternative situated in public spaces like shopping centers, train stations, and high-traffic locales. This system offers customers the convenience of collecting and depositing parcels at their own convenience. Particularly valuable in car-centric cities, these lockers present an alternative to traditional parcel delivery methods dependent on personal vehicles. By curtailing the necessity for individuals to make multiple trips for parcel pickups, these systems have the potential to alleviate traffic congestion and diminish carbon emissions (Lachapelle et al., 2018). While Parcel Locker systems can indeed contribute to sustainable travel and diminish automobile trips associated with parcel retrievals, their effectiveness in achieving these objectives hinges on ensuring accessibility and usability for consumers who opt for

non-motorized transportation modes and public transit. Thus, the promise of Parcel Locker systems to abate carbon emissions relies on their careful implementation and use.

Traditionally, the last-mile delivery process, spanning from warehouses or distribution hubs to consumers' doorsteps, has heavily relied on conventional vehicles (Bąk et al., 2019). However, the rapid growth of e-commerce has triggered a surge in delivery vehicles, emissions, and traffic congestion, underscoring the urgency to address the carbon footprint associated with this sector (Deloison et al., 2020). In response to these environmental challenges, a range of interventions has been proposed. These include trunk delivery, office delivery, multi-brand parcel lockers and boxes, and the adoption of eco-friendly transportation options like electric vehicles (EVs), hydrogen fuel cell electric vehicles (FCEVs), autonomous vehicles (AVs) equipped with runners, drones (unmanned aerial vehicles), and cargo bikes (Awwad et al., 2018; Brown & Guiffrida, 2014; Caspersen & Navrud, 2021; Choi et al., 2019; Colucci & Vecchi, 2021; Cui et al., 2020; de Oliveira et al., 2017; Deloison et al., 2020). These innovations proffer solutions for trimming operational energy demands across diverse scenarios. Urban deliveries, in particular, stand to gain from last-mile innovations due to the constraints of battery power supply and charging stations usually accessible in urban areas. For instance, the integration of compact electric vehicles unhindered from accessing inner city centers, capable of navigating easily through narrow streets in historic districts, markedly streamlines the delivery process (Patella et al., 2020). Overall, substantial research underscores the significance of last-mile innovations in amplifying the efficiency and sustainability of the e-commerce sector (Awwad et al., 2018; Lachapelle et al., 2018).

The responsible consumers

Numerous academic works (Johnstone & Hooper, 2016; Nanayakkara et al., 2022) demonstrate that responsible consumption behaviors significantly contribute to achieving the United Nations' sustainable development goal 12, focusing on responsible consumption and production (United Nations, 2023). This objective aims to optimize resource utilization while reducing waste.

Consumers can lessen carbon emissions linked to online shopping by adopting responsible consumption practices (Hamzah & Tanwir, 2021). This involves researching products, opting for sustainable or recycled items, such as organic cotton clothing or energy-efficient electronics (Dangelico et al., 2022; Gray et al., 2022). Purposeful shopping to minimize returns is another strategy, as returns entail additional transportation and emissions (Xiao et al., 2018). Informed purchase decisions decrease the need for returns (Nanayakkara et al., 2022).

Responsible consumers can reduce CO_2 emissions by being present for deliveries and using convenient collection points (Nanayakkara et al., 2022; Waßmuth et al., 2023). Urban areas offer multi-brand parcel lockers that consolidate deliveries and minimize transportation emissions (Ghaderi et al., 2022; Lachapelle et al., 2018). Effective use of these lockers necessitates integrating them into daily routines and timely parcel retrieval (Lachapelle et al., 2018). Van Loon et al. (2015) propose optimizing behavior by minimizing trips, maximizing delivery items, and selecting eco-friendly packaging and energy-efficient devices.

By combining informed choices and sustainable delivery options, individuals actively advance responsible consumption and a greener future. Consumer responsibility implies

eco-conscious choices contributing to environmental sustainability. Literature reviews indicate that addressing carbon emissions requires a multifaceted approach involving consumer responsibility, eco-logistics, and last-mile innovations.

Sociodemographic data and regular online purchases

Understanding the factors influencing online shopping behaviors can inform targeted strategies for sustainable and equitable e-commerce. Addressing disparities, such as rural access to digital tools and income-related consumption patterns, can guide improvements in digital infrastructure and eco-conscious consumption (Soler et al., 2021).

Sociodemographic traits, including factors like education and income, have a significant influence on online shopping habits, as highlighted by Xiao et al. (2018). Tailoring approaches based on characteristics such as education, income, and residence can promote eco-friendly behaviors, as suggested by several studies (Caspersen & Navrud, 2021; Hayashi et al., 2022; Lorenzen, 2014; Shaw et al., 2022). Xiao et al. (2018) found that marital status, education, and gender impact e-shopping frequency and spending, while Soler et al. (2021) associated education, income, and urban residence with online shopping engagement. Within specific age groups, such as Generation Z, responsible consumption aligns with climate concerns and encourages actions like reducing plastic usage, supporting fair trade, and practicing recycling (Kymäläinen et al., 2021). Other evidence supports that online shopping is primarily studied among young people, particularly those under the age of forty (Choi et al., 2019. Furthermore, Caspersen et al. (2022) conducted a survey with female online shoppers in Norway to explore their willingness to pay (WTP) for reducing carbon emissions in last-mile deliveries. They employed multinomial logit analysis to study the variables influencing the WTP. The results revealed that female shoppers, especially those with higher incomes, are willing to pay extra to reduce emissions. Notably, the study did not clearly specify the types of commodities being considered. Additionally, it's interesting to note that some respondents ranked the delivery location as one of their top three important attributes.

Nguyen et al. (2019) emphasized the crucial role of last-mile delivery in online retailing, as it significantly influences customer experiences and online ordering behavior. They recommended that online retailers closely consider various delivery attributes to enhance customer satisfaction. However, expedited delivery may raise concerns about environmental pollution. Therefore, efficient logistics in e-commerce is vital for customer satisfaction, underlining the importance of sustainable practices (Choi et al., 2019). The consumption of various online products can lead to environmental issues, notably in the electronics sector, where the carbon footprint is largely due to resource-intensive production and disposal (Hankammer et al., 2021; Vasan et al., 2014). Similarly, overconsumption and returns in clothing contribute to waste (Van Rensburg et al., 2020), while failed delivery attempts generate environmental harm (Bozzi et al., 2022). These challenges underscore the need for sustainable e-commerce practices.

Online food delivery's convenience can also lead to waste due to over-ordering and disposable packaging (Poon & Tung, 2022). Reducing food waste significantly mitigates emissions (Birney et al., 2017; Wilson et al., 2019). Implementing circular economy principles in Thailand tackles overconsumption and waste (United Nations Development Programme, 2022). Extending product lifetimes and promoting recycling are vital strategies (World Bank Group, 2022). Businesses can align with this by offering eco-friendly transportation options, empowering consumers in reducing their carbon footprint (World Bank Group, 2022).

Based on the aforementioned research studies, it becomes evident that there are research gaps to explore how sociodemographic factors, the distance between consumer addresses and delivery hubs, shopping habits, and types of commodities might influence consumers' environmental preferences for mitigating carbon emissions in online shopping. Understanding the diverse factors that affect online shopping behavior enables the development of targeted strategies for promoting sustainability and equity in e-commerce.

Building upon the insights from these research studies, the following research hypothesis emerges.

Research Hypothesis: Consumer characteristics, including gender, age, education, income, and buying behaviors (such as regular online purchases of clothes and shoes, food, electronic devices, and miscellaneous items), along with their geographic location, influence their decisions in selecting solutions for carbon emission mitigation through online shopping.

Methods and data

Data for this research were collected through a questionnaire from respondents residing in Thailand during November to December 2022. The stratified sampling method was employed to select eight provinces, with two provinces chosen from each of the northern, central, southern, and northeastern regions. Within each region, respondents were sampled from both the major province, representing the economic, trade, transportation, societal, cultural, and educational centers, and a secondary province selected through a lottery method. A quota sample size of 100 was set for each province, and random sampling was then used to select the participants, resulting in a total sample size of 800 individuals. The study received 772 returned questionnaires, yielding a response rate of 96.50%.

Multinomial logit and model development

The analysis focused on factors that influence consumer decisions to reduce carbon emissions from online shopping, which may include purchasing from businesses with eco-friendly logistics, utilizing last-mile innovations for transportation, or adopting responsible consumer behaviors. The multinomial logit model was employed for modeling, estimating the probability of each option occurring (Greene, 2003). The data analysis was conducted using Stata 15.

Let Pr(Y = *j*) represent the probability of an individual consumer choosing solution *j* to reduce carbon emissions through online shopping. Hence, the probability of each event occurring can be calculated as shown in equation (1).

$$Pr(Y=j) = e^{v_j}/(e^{v_j} + \sum_{c=2}^{M}(e^{v_c})) \quad (1)$$

In the above model estimation, the maximum likelihood method (Greene, 2003) was applied by constructing a log likelihood function as shown in Equation (2).

$$lnL = \sum_{i=1}^{n}\sum_{j=1}^{m}(d_{ij}\, ln\, Pr\,(Y = j) \quad (2)$$

The equation represents d_{ij}, taking the value of 1 when an individual consumer (i) chooses a carbon reduction method from their online shopping through solution j, and 0 when they opt for other solutions.

The research variables, formulated based on literature reviews in the 'Sociodemographic data and regular online purchases' section within the 'Theoretical background,' have been restated in equation (3). A consumer's preference for carbon emission mitigation in online shopping is defined by a utility function (equation 3), which includes attributes like gender, age, education, income, online shopping habits, and address. This utility function, denoted as Y_{ij}, is as follows:

$$Y_{ij} = \propto_{1j} + \propto_{2j} Sex_i + \propto_{3j} Age_i + \propto_{4j} Edu_i + \propto_{5j} Inc_i + \propto_{6j} Clo_i + \propto_{7j} Food_i + \propto_{8j} Elec_i + \propto_{9j} Misc_i + \propto_{10j} Address_i + \mu_i \quad (3)$$

Where subscripts (ij) represent a set of solutions for carbon emission mitigation (j) available to individual (i). These solutions include actions such as purchasing from businesses with eco-logistic operations (j=1) or adopting last-mile delivery innovations (j=2), as well as assuming the role of responsible consumers (j=3). 'α' denotes a set of parameters for the alternative variable 'ij.' Sex_i denotes the gender of respondents, Age_i represents the age of respondents, Edu_i stands for the level of education, Inc_i denotes the monthly income, Clo_i represents regular online purchases of clothes and shoes, $Food_i$ stands for regular online purchases of food, $Elec_i$ represents regular online purchases of electronic devices, $Misc_i$ represents regular online purchases of miscellaneous items, and $Address_i$ denotes the place of residence of the respondent. The model's variables and their definitions are presented in Table 1.

Table 1. Factors employed in the multinomial logit analysis

Variables	**Descriptive of variables**
Dependent variables	
Y_{ij}	The solutions (j) of individual (i) for mitigating carbon emissions j = 1 Eco-logistics j = 2 Last-mile innovations j = 3 Become responsible consumers
Independent variables	
Sex_i	Gender (1 = Female; 0 = Male)
Age_i	Age of the respondents (1 = 25 years and lower; 2 = 26-35 years; 3 = 36-45 years; 4 = 46 and higher)
Edu_i	Levels of educations (1 = master degree and higher; 0 = bachelor degree and lower)
Inc_i	Income per month (1 = less than THB 25,000; 2 = THB 25,000-39,999; 3 = THB 40,000 and higher)
Clo_i	Regularly buying clothes and shoes online (1 = yes; 0 = no)
$Food_i$	Regularly buying food online (1 = yes; 0 = no)
$Elec_i$	Regularly buying electronic devices online (1 = yes; 0 = no)
$Misc_i$	Regularly buying miscellaneous items online (1 = yes; 0 = no)
$Address_i$	Respondent's place of residence (1 = rural; 2 = suburban; 3 = urban)

Source: Authors' own research.

Results

The demographic characteristics of the survey respondents

Among 772 participants, women slightly outnumbered men (51.81% vs. 48.19%). Respondents' ages were distributed as follows: 46 years and older (26.68%), 36-45 years (25.65%), 26-35 years (24.61%), and 25 years and younger (23.06%). Most respondents held a master's degree or higher (65.54%), while others had a bachelor's degree or lower (34.46%). In terms of income, the majority reported earnings below THB 25,000 per month (64.77%), followed by THB 25,000 to 39,999 (22.80%), and THB 40,000 and above (12.44%).

Moreover, 736 respondents (95.3%) had prior online shopping experiences, frequently purchasing across categories like miscellaneous items (70.47%), clothes and shoes (61.66%), electronic devices (59.59%), and food (35.49%). Spending-wise, 45.9% spent THB 1,000 or less per month, 29.1% spent THB 1,001-3,000, and 14.1% exceeded THB 5,000. The majority (81.5%) shopped online 1-5 times monthly, with 13.9% shopping 6-10 times, and 4.6% over 10 times. Among these regular online shoppers, 75% reported high satisfaction, 22.3% moderate, and 2.7% low.

Regarding potential carbon emission reduction, 60.1% showed high interest if suitable options were provided by online retailers. Conversely, 20.9% had low interest, and 19% moderate. Geographically, respondents were concentrated in urban (40.41%), suburban (37.82%), and rural (21.76%) areas.

More insights into consumer characteristics: 38.3% were employed in educational institutions, followed by university students (34.5%). A significant portion worked in manufacturing (8.8%) or were self-employed (7.3%). Fewer respondents were in agriculture (4.7%), commerce (3.6%), or identified as housewives/husbands (1.6%). The remaining 1.3% belonged to various other occupations.

The results of the crosstab analysis

Based on the categorization of consumers and their approaches to carbon emissions reduction (as shown in Table 2), findings from the total of 772 respondents reveal that regular online shoppers (n = 736), mainly engaging in 1-5 monthly purchases (81.5%), prioritize responsible consumerism (35.3%), eco-logistics (35%), and last-mile innovations (29.7%). In contrast, those making over ten monthly purchases (4.6%) favor last-mile innovations (52.9%) for carbon emissions reduction. Among those spending THB 1,000 or less monthly (45.9%), eco-logistics is the preferred approach. For consumers spending THB 3,001-5,000 (10.9%), an equal preference exists for eco-logistics and last-mile innovations. Among those spending over THB 5,000 (14.1%), last-mile innovations are favored.

Additionally, a significant majority (75%) of experienced online shoppers express satisfaction and embrace responsible consumer practices for carbon emissions reduction. Conversely, those reporting moderate and low satisfaction lean towards eco-logistics (39%) and eco-logistics (50%) respectively. Among those highly interested in emission reduction (60%), responsible consumer practices are favored (38.4%), while moderately interested participants (19%) prefer last-mile innovations (44.5%). Those less interested lean towards eco-logistics (46.7%) for carbon emissions mitigation.

Table 2. Crosstab analysis of regular online shoppers' experiences

Experiences of Online Shopping Consumers	Solution for carbon emission reduction			Total
	Eco-logistics	Last-mile innovations	Become responsible purchaser	
Frequency of online shopping in a month				
-1 to 5 times per month	210(35.0%)	178(29.7%)	212(35.3%)	600(81.5%)
-6 to 10 times per month	24(23.5%)	46(45.1%)	32(31.4%)	102(13.8%)
-more than 10 times per month	14(41.2%)	18(52.9%)	2(5.9%)	34(4.6%)
Average monthly spending on online shopping				
-THB 1,000 and lower	118(34.9%)	106(31.4%)	114(33.7%)	338(45.9%)
-THB 1,001-3,000	74(34.6%)	66(30.8%)	74(34.6%)	214(29.1%)
-THB 3,001-5,000	28(35.0%)	28(35.0%)	24(30.0%)	80(10.9%)
-Higher than THB 5,000	28(26.9%)	42(40.4%)	34(32.7%)	104(14.1%)
Satisfaction with online shopping				
-Low	10(50.0%)	4(20.0%)	6(30.0%)	20(2.7%)
-Moderate	64(39.0%)	52(31.7%)	48(29.3%)	164(22.3%)
-High	174(31.7%)	186(33.7%)	192(34.8%)	552(75%)
Interested in helping mitigate carbon emission through online shopping				
-Low	72(46.7%)	40(26%)	42(27.3%)	154(20.9%)
-Moderate	44(31.4%)	62(44.3%)	34(24.3%)	140(19%)
-High	132(29.9%)	140(31.7%)	170(38.4%)	442(60%)
Total	248(33.7%)	242(32.9%)	246(33.4%)	736(100%)

Source: Authors' own research.

The multinomial logit analysis

Utilizing Equation 3, the multinomial logit analysis, executed via maximum likelihood, produces the subsequent probabilities (Table 3): 35.74% for individuals who choose eco-logistics to decrease carbon emissions associated with online shopping, 33.03% for individuals who opt for responsible purchasing to minimize carbon emissions during online shopping, and 31.23% for individuals who prefer last-mile innovations to mitigate carbon emissions.

The adoption of eco-logistic solutions by Thai consumers, offered by businesses to reduce carbon emissions in online shopping, is influenced by a multitude of factors. These factors encompass regular online purchases of clothing and shoes, food, and electronic devices. Similarly, the adoption of last-mile innovations as a strategy for reducing carbon emissions in online shopping is shaped by various elements, including gender, age, education level, and income.

Furthermore, the projected likelihood of individuals choosing responsible purchasing to counteract carbon emissions in online shopping is impacted by factors such as gender, age, education level, income, regular online food and miscellaneous item purchases, as well as the consumer's address.

Table 3. Results of multinomial logit model

Variables	Eco-logistics		Last-mile innovations		Become responsible purchaser	
	Marginal effects	***t*-value**	**Marginal effects**	***t*-value**	**Marginal effects**	***t*-value**
	***Y* = 35.74%**		***Y* = 31.23%**		***Y* = 33.03%**	
Gender	0.05	1.34	-0.19	-5.45***	0.14	4.00***
Age	0.02	1.17	-0.06	-3.63***	0.04	2.45*
Education	0.03	0.64	-0.14	-4.06***	0.12	3.02**
Income	0.04	1.52	0.08	2.84**	-0.12	-3.97***
Clothes and shoes	0.07	1.96*	-0.02	-0.42	-0.06	-1.51
Food	-0.11	-2.89**	0.03	0.67	0.08	2.08*
Electronic devices	-0.09	-2.29**	0.04	1.10	0.05	1.26
Miscellaneous items	0.07	1.73	0.06	1.60	-0.13	-3.12**
Address	0.02	0.90	0.03	1.32	-0.05	-2.19*
Number of observations = 772 MacFadden Pseudo R-square = 0.089 Cox and Snell = 0.178 Nagelkerke = 0.200 Restricted log likelihood = -772.40488 Percent correctly predicted = 53.4%						

Source: Authors' own research.
Note: *$p<.05$. **$p<.01$. ***$p<.001$

Referring to Table 4, the coefficients and odds linked to consumers' carbon emissions mitigation strategies in online shopping reveal distinct patterns. Females favor eco-logistics by a substantial 98% over males, while their preference diminishes by 34% for eco-logistics compared to responsible consumerism. Among age groups, those aged 36-45 exhibit a heightened preference for eco-logistics (116% more likely) over last-mile innovations compared to those 25 and under. Similarly, individuals aged 46 and above favor eco-logistics (94% more likely) over last-mile innovations in contrast to the younger group. Regarding education, those with a master's degree or higher significantly prefer eco-logistics (80% more likely) over last-mile innovations than those with a bachelor's degree or lower. Notably, for income, respondents earning THB 40,000 and above exhibit a strong bias for eco-logistics (383% more likely) over responsible consumerism, compared to those earning THB 25,000 and below.

Regarding regular online purchases of clothes and shoes, individuals frequently shopping for apparel show a 46% higher likelihood of preferring eco-logistics over responsible consumerism. However, among those routinely buying food online, the inclination for eco-logistics diminishes by 39% compared to last-mile innovations and by 51% compared to responsible consumerism. Conversely, regular online electronics buyers prioritize responsible consumerism, reducing the likelihood of opting for eco-logistics by up to 32%. Conversely, frequent online shoppers of miscellaneous goods exhibit a strong preference for eco-logistics (98% likelihood) over responsible consumerism. Comparing suburban and rural consumers, the former displays a 133% elevated likelihood of choosing

eco-logistics over responsible consumerism, which is approximately twice as high as rural residents.

Influencing factors for consumers choosing between last-mile innovations and responsible purchasing reveal gender differences. Females exhibit a 67% lower likelihood for last-mile innovations compared to males, favoring responsible purchasing. Similarly, individuals aged 46 and above, compared to those aged 25 and below, display a 66% reduced likelihood for last-mile innovations, preferring responsible purchasing. Those with a master's degree or higher also lean towards responsible purchasing, reducing the likelihood for last-mile innovations by 50% compared to those with a bachelor's degree or lower. In terms of income, those earning THB 40,000 and above per month highly favor last-mile innovations (up to 458% or five times higher) over responsible purchasing. The income range of THB 25,000 to THB 39,999 also inclines towards last-mile innovations (up to 91% higher) compared to responsible purchasing. Furthermore, among regular online consumers of miscellaneous goods, a preference for last-mile innovations over responsible consumption exists. Urban consumers prioritize last-mile innovations over responsible consumption by up to 68%, in contrast to rural residents.

Table 4. Comparison between two groups of solutions for mitigating carbon emissions

Variables	Eco-logistics Vs. Last-mile innovations			Eco-logistics Vs. Become responsible purchase			Last-mile innovations Vs. Become responsible purchaser		
	β	**Odds ratio**	**Percent change in the odds**	***β***	**Odds ratio**	**Percent change in the odds**	***β***	**Odd ratio**	**Percent change in the odds**
1. Gender (Reference = Male)									
-Female	3.54	1.98***	98.00	-2.14	0.66*	-34.00	-5.52	0.33***	-67.00
2. Age (Reference = 25 years and lower)									
-26-35 years	-1.41	0.68	-32.00	-0.79	0.80	-20.00	0.63	1.18	18.00
-36-45 years	2.71	2.16**	116.00	2.73	2.19**	119.00	0.04	1.01	1.00
-46 years and higher	2.18	1.94*	94.00	-1.43	0.66	-34.00	-3.51	0.34***	-66.00
3. Education (Reference = Bachelor degree and lower)									
- Master degree and higher	2.76	1.80**	80.00	-0.52	0.90	-10.00	-3.21	0.50**	-50.00
4. Income (Reference = less than THB 25,000)									
-THB 25,000-39,999	-1.85	0.63	-37.00	0.76	1.20	20.00	2.56	1.91*	91.00
-THB 40,000 and higher	-0.46	0.87	-13.00	4.24	4.83***	383.00	4.43	5.58***	458.00
5. Clothes and shoes (Reference = Not regularly buying clothes and shoes online)									
-Regularly buying clothes and shoes online	1.27	1.28	28.00	1.96	1.46*	46.00	0.66	1.14	14.00
6. Food (Reference = Not regularly buying food online)									
-Regularly buying food online	-2.33	0.61*	-39.00	-3.36	0.49**	-51.00	-1.01	0.81	-19.00
7. Electronic devices (Reference = Not regularly buying electronic devices online)									
-Regularly buying electronic device online)	-1.67	0.72	-28.00	-1.97	0.68*	-32.00	-0.29	0.94	-6.00
8. Miscellaneous items (Reference = Not regularly buying miscellaneous items online)									
-Regularly buying miscellaneous items online)	0.36	1.08	8.00	3.26	1.98**	98.00	2.75	1.83**	83.00

Cont'd. Table 4.

Variables	Eco-logistics Vs. Last-mile innovations			Eco-logistics Vs. Become responsible purchase			Last-mile innovations Vs. Become responsible purchaser		
	β	**Odds ratio**	**Percent change in the odds**	**β**	**Odds ratio**	**Percent change in the odds**	**β**	**Odd ratio**	**Percent change in the odds**
9. Address (Reference = rural)									
-Suburban	1.44	1.46	46.00	3.36	2.33**	133.00	1.80	1.59	59.00
-Urban	-0.13	0.96	-4.00	1.83	1.62	62.00	1.97	1.68*	68.00

Source: Authors' own research.

Note: *$p<.05$. **$p<.01$. ***$p<.001$

Discussion

This study aims to uncover effective strategies for reducing carbon emissions in online shopping by examining the viewpoints of Thai consumers and utilizing sociodemographic data to predict their choices in carbon mitigation. The research encompasses eco-logistics, last-mile innovations, and responsible consumer behavior. Data from a survey in Thailand were analyzed using a multinomial logit model in Stata 15. In addition, this study gathers data across diverse age groups, moving beyond the typical focus on tech-savvy younger generations. This broader perspective sheds light on various technological familiarity levels among students, working individuals, and middle-aged adults. Understanding the online shopping behaviors of this diverse demographic can help businesses shape marketing strategies and tailored promotions, extending beyond youth, to reduce carbon emissions through online shopping.

The probability of individuals choosing eco-logistics to decrease carbon emissions from online shopping stands at 35.74%. An analysis of the multinomial logit model uncovers a range of factors that impact the inclination of Thai consumers towards embracing eco-logistic alternatives. These factors encompass regular online purchases spanning various categories such as clothing and shoes, food, and electronic devices. Of particular interest, those who engage frequently in online shopping for clothing and shoes exhibit a notably higher likelihood, approximately 46%, of favoring eco-logistics. This finding is consistent with prior research from Xiao et al. (2018), confirming that consumers who shop more frequently are more likely to use alternative delivery solutions, such as parcel lockers or pickup points. This also corresponds to Nanayakkara et al. (2022), who suggest that optimizing transportation due to e-commerce relies heavily on transportation, which generates greenhouse gas emissions and air pollution. By optimizing transportation through eco-logistics, such as route planning, vehicle efficiency, and alternative modes of transportation, it can lead to a reduced carbon footprint and improved air quality.

In addition, frequent online shoppers of clothing and shoes may value convenience and seamless experiences, making eco-logistics a suitable match without disrupting their routine. However, adopting a responsible consumer role demands conscious effort and mindset change, involving active choices to reduce carbon footprint. While some shoppers embrace this approach, others might find eco-logistics aligning with their existing behavior and carbon reduction goals, offering convenience within their eco-friendly journey as suggested by Kang et al. (2021); Van Loon et al. (2015).

It is worth noting that regular online purchases of electronic devices have a significantly negative influence on the probability of individuals choosing eco-logistics. In this sense, regular online buyers of electronics prioritize responsible consumption and exhibit reduced interest in eco-logistics, resulting in a 32% decrease in their selection of eco-logistics. The need for precise features in electronic devices often prompts research, leading to higher return rates if expectations aren't met. While responsible consumers prioritize purposeful purchases, they might lack awareness of eco-logistics' carbon impact. Educating consumers about eco-logistics importance and tailor-made options for electronics delivery could bridge this gap, given the variability in eco-logistics visibility across product categories.

Similarly, regular online purchases of food have a significantly negative influence on the probability of individuals choosing eco-logistics. In this regard, consistent online food

buyers exhibit a 51% decrease in selecting eco-logistics compared to prioritizing responsible consumption. They focus on freshness and quality, achieving this through purposeful shopping, reducing returns, and supporting local food systems. Food-responsible consumers also reduce environmental impacts by minimizing excessive packaging and ensuring efficient delivery, aligning with diverse priorities beyond just eco-logistics. This is consistent with the study by Deloison et al. (2020), which suggested that personal preferences guide responsible consumer practices, surpassing the role of eco-logistics in shaping sustainable food purchasing decisions.

Furthermore, when compared to other choices, consistent online food buyers show a 39% decrease in choosing eco-logistics over last-mile innovations like electric vehicles or drone deliveries, which offer enhanced convenience. Convenience might overshadow environmental concerns, driven by limited awareness of eco-logistics or region-specific availability. Costs associated with broader eco-logistics implementation could deter cost-sensitive consumers. Last-mile innovations may seem more direct in reducing carbon emissions than eco-logistics, influenced by consumers' varying priorities and evolving awareness, as suggested by Ranieri et al. (2018).

In terms of the probability of individuals choosing responsible purchasing practices to reduce carbon emissions from online shopping, there is a noted adoption rate of 33.03% for responsible purchasing practices aimed at curbing carbon emissions. Elements such as gender, age, education, income, online food purchases, miscellaneous items, and consumer location wield influence over choices tied to responsible consumption. These results corroborate the earlier findings of Caspersen et al. (2022), suggesting that gender as female is related to responsible consumer purchasing. Their study focused on female consumers' willingness to pay for low or no CO_2 emissions from item deliveries, as well as the role of female consumers in mitigating this impact. Specifically, the study found that employed females or those with incomes above 600,000 NOK are willing to pay more than others, suggesting that freight operators and online retailers can transfer some of the costs of climate-friendly last-mile delivery to their customers, particularly those with higher incomes and employment.

In distinct age groups, individuals aged 46 and above prioritize responsible purchasing due to familiarity with conventional methods, environmental awareness, and autonomy in decision-making. Higher education enhances responsible purchasing through advanced sustainability knowledge, while critical thinking skills, income levels, and professional networks contribute to an affinity for eco-friendly choices. Other related research also supports the influence of these elements over choices of responsible consumption, as indicated by studies such as those by Choi et al. (2019), Kymäläinen et al. (2021), Lachapelle et al. (2018), Shaw et al. (2022), Soler et al. (2021), and Xiao et al. (2018), which have provided significant sociodemographic data regarding responsible consumer behavior in the literature related to e-commerce.

The probability of opting for last-mile innovations to reduce carbon emissions from online shopping is 31.23%. Income significantly influences this choice, favoring higher-income individuals. This finding is confirmed by Caspersen et al. (2022), who found that respondents with higher income and employment are willing to pay more for sustainable last-mile delivery options. However, it is important to note that this current study also reveals nuances that enrich the existing literature. While previous research has explored the positive effects of consumer sociodemographic data, the current research analysis shows that

the impact may be opposite. For instance, gender, age, and education have a negative and significant influence on the probability of opting for last-mile innovations.

In this regard, females, older individuals (aged 46+), and those with higher education tend to prefer alternatives to last-mile options. Older individuals prioritize eco-logistics due to familiarity over valuing last-mile innovations. This differs from the findings of Choi et al. (2019), where young Chinese consumers preferred last-mile innovations or advanced logistics to optimize delivery routes, reduce delivery times, and enhance customer satisfaction. Similarly, other research has also found that younger people care about sustainable consumption practices, as demonstrated by Kymäläinen et al.'s (2021) study, which highlights Generation Z's emphasis on sustainable food consumption practices, including reducing single-use plastics and supporting fair trade. Females, in contrast to males, exhibit a weaker inclination toward last-mile innovations compared to eco-logistics and responsible purchasing. Consumers with higher education tend to encourage responsible purchasing instead of opting for last-mile innovations. This extended perspective adds a valuable dimension to the ongoing discourse.

In addition, among regular online shoppers of miscellaneous goods, last-mile innovations are favored due to convenience, while suburban consumers lean towards eco-logistics because of longer delivery distances. In contrast, urban consumers opt for last-mile innovations due to technological advancements and sustainability considerations, as mentioned by the study by Soler et al. (2021).

This study offers valuable insights into the intricate factors that influence consumers' choices concerning carbon mitigation strategies in online shopping. It contributes significantly to mitigating carbon emissions by advocating for climate-friendly options such as electric parcel vehicles. Policymakers and businesses should prioritize facilitating simplified eco-conscious decisions through precise carbon pricing, attractive eco-products, and transparent carbon labeling, as suggested by Thøgersen (2021). The role of last-mile logistics is pivotal in the e-commerce realm, directly impacting customer satisfaction and loyalty. A streamlined and sustainable last-mile delivery system can confer a competitive edge, swaying consumers towards e-commerce entrepreneurs who prioritize these methods over conventional transportation (Awwad et al., 2018). Despite responsible consumer behavior involving pre-purchase research, there might be limited awareness regarding the environmental advantages of eco-logistics and specific actions to curtail carbon emissions in the delivery process. Bridging this awareness gap by educating consumers about the significance of eco-logistics and its potential to reduce carbon emissions can be instrumental in fostering more environmentally conscious decisions.

Conclusion

This study examines effective strategies for reducing carbon emissions in online shopping by analyzing Thai consumers' perspectives and utilizing sociodemographic data to predict their carbon mitigation choices. The research covers eco-logistics, last-mile innovations, and responsible consumer behavior. The multinomial logit model is chosen for its suitability in analyzing outcomes with multiple alternatives, applicable in real-world contexts for carbon emissions reduction. The study expands beyond tech-savvy generations to encompass diverse age groups.

The hypotheses were partially confirmed, revealing that various sociodemographic factors influence carbon emissions reduction from online shopping. Factors include gender, age, education, income, regular online shopping for various categories (clothing and shoes, food, electronic devices, miscellaneous items), and consumer location. These elements influence the likelihood of opting for eco-logistics and responsible purchasing, driven by familiarity, awareness, convenience, sustainability knowledge, and technological familiarity. Specifically, individuals with higher incomes tend to favor last-mile innovations, such as advanced delivery methods like electric vehicles or drone deliveries. This inclination may stem from affordability, convenience, and a willingness to embrace innovation.

This study brings a fresh perspective to the realm of carbon emissions reduction in online shopping by delving into the viewpoints of Thai consumers. It distinguishes itself by employing sociodemographic data to predict consumer choices in carbon mitigation while encompassing eco-logistics, last-mile innovations, and responsible consumer behavior. What sets this research apart is its comprehensive data analysis across diverse age groups, moving beyond the typical focus on tech-savvy younger generations, thereby revealing varying technological familiarity levels among students, working individuals, and middle-aged adults. This novel approach offers a broader understanding of online shopping behaviors, helping businesses tailor marketing strategies and promotions to extend beyond youth and foster reduced carbon emissions through online shopping.

This study contributes significantly to both theory and practice. It advances the understanding of consumer behavior in mitigating carbon emissions through online shopping. The findings demonstrate the influence of various sociodemographic factors on carbon emissions reduction, shedding light on the significance of gender, age, education, income, shopping preferences, and location. These insights can inform businesses and policymakers in fostering climate-friendly actions, such as implementing accurate carbon pricing, offering eco-friendly products, and transparent carbon labeling. Additionally, the study encourages collaboration on policies that incentivize energy-efficient products, electric vehicles, public transportation, and renewable energy adoption. The regulatory framework, including measures like carbon pricing, promotes sustainable lifestyles and addresses climate change. The outcomes of this research provide a solid foundation for future studies seeking to explore similar themes and offer practical guidance for achieving more sustainable online shopping practices.

The research has some limitations. Firstly, the sample size, though diverse, may not fully represent the entire Thai population. Using a larger, more varied sample would enhance generalizability. Additionally, relying on self-reported survey data can impact reliability. To improve future questionnaires, ensure concise instructions and well-designed questions to keep completion within 10 minutes. Moreover, the study's focus on three aspects of online shopping carbon reduction overlooks intriguing dimensions like reverse logistics. Future research should comprehensively explore these facets to understand the full range of carbon emission reduction strategies and uncover emerging trends among Thai consumers in their pursuit of reducing carbon emissions.

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