From Environmental Awareness to Low-Carbon Mobility: Cognitive Pathways to Sustainable Transport Adoption in Malaysian Tourism

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ABSTRACT

Tourism transportation is one of the key factors contributing to the emissions of sectors. Tourism destinations around the world have introduced low-carbon tourism transport technologies that have environmental benefits which rely on the willingness of tourists to use the technology. Using Technology Acceptance Model (TAM), this paper examines the influence of EA on AI, and how PU and PEOU act as the mediators between the two variables. The research used a cross-sectional survey design and collected data from 304 potential users of sustainable tourism transport technologies in Malaysia using PLS-SEM in SmartPLS 4 with 5,000 resamples. The measurement model demonstrated satisfactory indicator reliability (loadings .687–.924), internal consistency (α = .867–.908; ρA = .870–.916; ρC = .904–.932) and convergent validity (AVE = .654–.734). Discriminant validity was not established: HTMT values ranged from .981 to 1.030 and no bias-corrected confidence interval fell below .90. EA predicted PU (β = .913) and PEOU (β = .919), and both beliefs predicted AI (β = .262 and β = .148). It is critical to note that the other component of this investigation, Environmental Awareness (EA) also contributes substantially to the Adoption Intention (AI) in terms of its direct effect (β = .527, t = 6.144, p < .001). The presence of this phenomenon demonstrates the process of complementary partial mediation since the combined contribution of both pathways of indirect effect is responsible for only 41.6% of the total effect (β = .901), meaning that the remaining effect is direct. The measures of effect size also support this statement (f^2 = .224 for EA → AI in comparison with .043 and .013 for the belief-based pathways).

Keywords: low-carbon transport; technology acceptance; pro-environmental behaviour; tourist mobility; PLS-SEM; emerging destinations

INTRODUCTION

Climate change, environmental pollution, and unsustainable consumption patterns are some of the most critical threats to the sustainability of the environment, the economy, and society at large. Transport is one of the major sources of greenhouse gas emissions worldwide, while tourism transport emerges as one of the key contributors through its dependency on fuel-based systems. With the rise in domestic and international tourists' numbers, the carbon footprints of tourism have become an increasingly worrying matter, as well as a growing interest in sustainable tourism development and sustainable ways of traveling (Gössling & Mei, 2025; Zhang & Deng, 2024). Current studies indicate that achieving sustainable tourism goals necessitates significant changes to destination transport systems rather than mere improvements (Karim et al., 2025).

There have been investments in technology by governments along with the tourism and transport industry to counter environmental damage without jeopardizing the access and quality of tourism mobility services to the destinations. Electric cars, solar-powered transportation, intelligent mobility, autonomous systems, and low emission tourism mobility services have gained much recognition around the world in recent times (Trilaksono et al., 2026). It is expected that such technologies will help in decarbonizing processes, improve sustainability at destinations, and protect the environment. Digitalization of the tourism mobility services has further provided scope for efficiency and environmental protection (Jokom et al., 2025; Sukma et al., 2025).

But the investment has been exceeding the adoption of these sustainable technologies. Many sustainable transport projects do not adopt at expected rates, but it is not due to the lack of technological readiness or policy support. Past studies have revealed that the success of sustainable transport projects depends on the perceptions, values, and behavioural intentions of their users (Deng et al., 2025). Although people have grown more environmentally conscious, the availability of low carbon emission transportation, travellers continue to use traditional modes. This issue has become one of the focal points of tourism sustainability research.

The Technology Acceptance Model (TAM) continues to be one of the most robust theories explaining technology acceptance behaviour. Perceived usefulness and perceived ease of use act as the proximal predictors of behavioural intentions that measure the cognitive evaluation of a technology by the user (Davis, 1989). The application of TAM in tourism-related literature has proven to be successful in digital tourism applications, smart tourism technologies, sustainable transportation, and environmentally-based innovations (Li et al., 2024; Zhang & Deng, 2024). Although the theory is robust, it is still heavily focused on the technological aspects. The value systems related to sustainability and environment have not been included in the model's antecedents.

The relevance of this drawback is especially important for sustainable tourism, since the environmental and ethical perspective impacts consumer decisions. People with a high level of environmental orientation are supportive of sustainability initiatives, are more responsible consumers, and have higher tendencies towards the adoption of green technologies (Hansen et al., 2023). The environmental orientation has already been proven to affect the intention of consumers to be engaged in sustainable behaviours and is considered to be an important factor for consumer acceptance of green technologies, low-carbon mobility, and responsible tourism (Saltik et al., 2025). The lack of knowledge about the intermediary mechanism, namely the psychological mechanism through which environmental orientation is transformed into adoption, has not been sufficiently explained. It has never been directly tested whether people, who are environmentally oriented, find sustainable transport more useful and easy to use.

However, a considerable number of studies regard environmental awareness as a direct determinant of sustainable actions without examining any other cognitive appraisal as an intervening variable. However, the choice of sustainable modes of transport may be influenced not only by environmental motivation but also by technology acceptance, implying that environmental awareness does not tell the whole story. Thus, since the positive impact of environmental awareness on adoption intentions occurs through better attitudes toward the usefulness and usability of technology, the perceptions of usefulness and usability must be seen as the mechanism and, therefore, the focus of any intervention. To prove this point, it is necessary to integrate environmental awareness within the framework of the TAM model.

This study seeks to fill the gap by incorporating environmental awareness into the Technology Acceptance Model and conducting an empirical examination of the proposed model on the intended users of sustainable tourism transport technology in Malaysia. This research is guided by three research questions. The first question asks whether environmental awareness affects the perceived usefulness and perceived ease of use of sustainable tourism transport technology. Does the combination of perceived usefulness and perceived ease of use affect adoption intention? Lastly, can perceived usefulness and perceived ease of use act as mediators between environmental awareness and adoption intention? Tourism transport is chosen as the empirical environment since mobility is the largest contributor to environmental impact in tourism.

There are four main contributions of this research to scholarship. Firstly, it adds to the Technology Acceptance Model by proposing the concept of environmental awareness as a contextual antecedent in the field of sustainable tourism transport, instead of viewing it as a competing predictor. Secondly, the research identifies the mediator of the relationship, explaining the cognitive process behind the transformation of environmental attitudes into technology adoption intentions. Thirdly, this research presents empirical findings from Malaysia, an emerging tourist destination where the development of the low-carbon tourism transport system is still ongoing and research on adoption is scarce (Musa et al., 2026a). Finally, the research helps tourism and transportation providers and policy makers in creating interventions that include environmental communication and increased benefits and usability of the low-carbon transport system.

Similar adoption challenges have been documented for low-carbon tourism mobility in Malaysia. Musa et al. (2024) examined the eBECA innovation and found that its uptake depended on how users and operators perceived its relative advantage, complexity, compatibility, observability and trialability, underscoring that clean transport solutions succeed only when they are perceived as beneficial and easy to integrate into existing tourism practices.

LITERATURE REVIEW

Sustainable Mobility in Tourism

One of the largest sources of carbon emissions, environmental pollution, and resource utilization in the tourism industry is transport, thus making sustainable mobility an important aspect of sustainable tourism development. Sustainable mobility can be defined as transport which is based on a balance between a reduced environmental footprint and efficiency, accessibility, and economic feasibility. The examples of sustainable mobility in tourism destination include electric cars, renewable energy buses, smart mobility solutions, environmentally sustainable mass transit in urban areas, and other environmentally sustainable transport services.

Modern research changes the understanding of sustainable transport as an environmental duty to the element that improves the competitiveness of the destination. Sustainable transport reduces carbon emissions and increases the efficiency of resources while increasing tourists' perception of sustainable destination (Boubker et al., 2024). Therefore, sustainable transport becomes one of the elements of destination systems used to achieve the goals of responsible tourism and sustainability development. The case of Malaysia is relevant for this discussion: the transformation of trishaw into electric vehicle (eBECA) becomes an example of sustainable transport for heritage destinations where the use of the vehicle is systematically different depending on users' characteristics (Musa et al., 2026a) as well as tourists' awareness of the mode (Musa et al., 2026b).

The application of sustainable transport systems is not just a matter of technical feasibility but also a question of users' willingness to use the innovation. The tourists are more likely to choose an eco-friendly transport system if they can see some obvious utility in it, if it is good for environment and if it is convenient for them (Suo et al., 2024; Yang et al., 2022). The study of the use of electric vehicles by customers revealed that values, technology perception and behavior attitude are the key factors determining the adoption of innovations (Boubker et al., 2024).

Environmental Awareness

An environmental awareness is defined by one's understanding of the environment-related problems, care about environmental damage, and responsibility towards the environment protection. Higher levels of environmental awareness have always been associated with preferences for sustainable goods, eco-friendly services, and technologies, and are considered to be one of the major determinants of sustainable consumption and eco-friendly behaviour (Hansen et al., 2023; Tang et al., 2026).

In the tourism industry, environmental consciousness is a factor that shapes tourists' decisions in terms of selecting environmentally friendly destinations, sustainable lodgings, and sustainable transport. Environmental consciousness among tourists promotes pro-environmental behaviours, which include choosing sustainable services, reducing resource usage, and supporting responsible tourism activities (Dong et al., 2024; Farrukh et al., 2022). With the growing importance of climate change, environmental consciousness has become an important aspect of sustainable tourism behaviours (Hansen et al., 2023; Karim et al., 2025).

Environmental consciousness influences how people perceive sustainable technologies and transportation systems that are low in carbon emissions. This is because green technologies are consistent with the values and goals of environmentalism and sustainability. In light of this, those who possess greater levels of environmental consciousness perceive sustainable technologies more positively compared to non-sustainable technologies (Boubker et al., 2024; Tang et al., 2026). Further evidence is found in studies on tourism and sustainable mobility where environmentalism predicts the use of sustainable transportation, electric mobility, and low-carbon

transportation (Suo et al., 2024; Trilaksono et al., 2026). Environmental awareness is therefore treated here as an antecedent of technology acceptance beliefs rather than as a direct substitute for them.

Technology Acceptance Model (TAM)

The Technology Acceptance Model is among the most widely applied theoretical accounts of technology adoption behaviour. Davis (1989) proposed that two cognitive beliefs, perceived usefulness and perceived ease of use, determine users' behavioural intentions. The model holds that individuals are more likely to accept a technology when they believe it confers benefit and can be operated without undue effort.

TAM has been validated across tourism, hospitality, transport and sustainability contexts. A meta-analysis in hospitality and tourism found perceived usefulness to be among the most robust predictors of adoption intention, with perceived ease of use significantly shaping users' evaluations of technological systems (Li et al., 2024). Comparable findings are reported for tourism mobile applications (Hamouda, 2021), virtual tourism technologies (Mohamad et al., 2021), smart tourism systems (Yang et al., 2022) and sustainable mobility solutions (Salim et al., 2024).

Perceived Usefulness

Perceived usefulness is the degree to which an individual believes that using a technology will improve performance, effectiveness, convenience or overall experience (Davis, 1989). In tourism, it reflects the extent to which a technology is judged to enhance travel planning, transport efficiency, accessibility, safety or environmental outcomes.

Prior Malaysian evidence also indicates that users' technical knowledge is positively associated with the adoption of new technologies (Musa et al., 2016), supporting the view that ease-of-use perceptions shape adoption decisions.

Perceived usefulness is consistently identified as a principal driver of adoption. Tourists are more inclined to adopt technologies that demonstrably improve the travel experience (Li et al., 2024; Mohamad et al., 2021). Research on sustainable transport reports the same pattern: users adopt eco-friendly mobility solutions when functional and environmental benefits are apparent (Boubker et al., 2024).

Perceived Ease of Use

Perceived ease of use is the degree to which an individual believes a technology can be used without difficulty or excessive effort (Davis, 1989). Technologies judged simple, intuitive and easy to learn are more likely to be accepted.

Tourism technology research consistently reports a positive effect of perceived ease of use on behavioural intention. Mobile tourism applications, virtual tourism platforms and digital travel services achieve higher adoption when users find them straightforward to understand and operate (Hamouda, 2021; Yang et al., 2022). Sustainable transport research reports comparable effects, with usability contributing to favourable evaluations and stronger adoption intentions (Boubker et al., 2024).

Adoption Intention

Adoption intention refers to an individual's willingness to use, recommend and continue using a technology. In sustainable tourism transport, it reflects the likelihood that a traveller will select environmentally responsible transport options in future. Adoption intention is widely treated as the proximal predictor of actual usage behaviour and serves as the criterion variable in technology acceptance research (Davis, 1989; Li et al., 2024).

Hypothesis Development

Environmental Awareness and Perceived Usefulness

Environmental awareness plausibly conditions how individuals appraise sustainable transport technologies. Environmentally conscious consumers are more attentive to the environmental and societal benefits that low-

carbon mobility delivers. Because such technologies align with their values, these individuals are likely to judge them more beneficial than conventional alternatives. Prior evidence indicates that environmental consciousness improves evaluations of sustainable transport technologies and supports favourable perceptions of their benefits (Boubker et al., 2024; Suo et al., 2024).

H_1: Environmental awareness positively influences perceived usefulness.

Environmental Awareness and Perceived Ease of Use

Individuals with higher environmental awareness may also display greater willingness to engage with environmentally responsible technologies. Motivation to support sustainability can lower perceived barriers to engagement and encourage favourable appraisals of usability. Environmentally conscious users may therefore judge sustainable transport technologies easier to learn and operate. Prior research indicates that environmental concern fosters positive attitudes toward green mobility technologies and supports their acceptance (Boubker et al., 2024).

H_2: Environmental awareness positively influences perceived ease of use.

Perceived Usefulness and Adoption Intention

TAM holds that individuals adopt technologies they perceive as useful. In sustainable transport, perceived usefulness may derive from improved travel convenience, environmental benefit, accessibility, reliability and service quality. Perceived usefulness is consistently reported as a significant predictor of adoption intention across tourism and mobility contexts (Hamouda, 2021; Li et al., 2024; Mohamad et al., 2021).

H_3: Perceived usefulness positively influences adoption intention.

Perceived Ease of Use and Adoption Intention

Users who perceive a technology as easy to use are generally more willing to adopt it, because fewer cognitive and operational barriers stand in the way. Where sustainable transport systems are straightforward to understand and operate, users may form stronger adoption intentions. Tourism technology research consistently reports a positive association between perceived ease of use and behavioural intention (Hamouda, 2021; Li et al., 2024; Yang et al., 2022).

H_4: Perceived ease of use positively influences adoption intention.

Mediating Role of Perceived Usefulness

Environmental awareness may not translate into adoption intention unmediated. Environmentally aware individuals plausibly appraise the usefulness of sustainable transport technologies before forming an intention to adopt them, which positions perceived usefulness as a mechanism linking environmental values to adoption behaviour (Tareke, 2024).

H_5: Perceived usefulness mediates the relationship between environmental awareness and adoption intention.

Mediating Role of Perceived Ease of Use

Environmental awareness may likewise reach adoption intention through appraisals of usability. Environmentally conscious individuals may be more inclined to adopt sustainable transport solutions where they perceive such technologies as simple and user-friendly (Garus et al., 2024).

H_6: Perceived ease of use mediates the relationship between environmental awareness and adoption intention

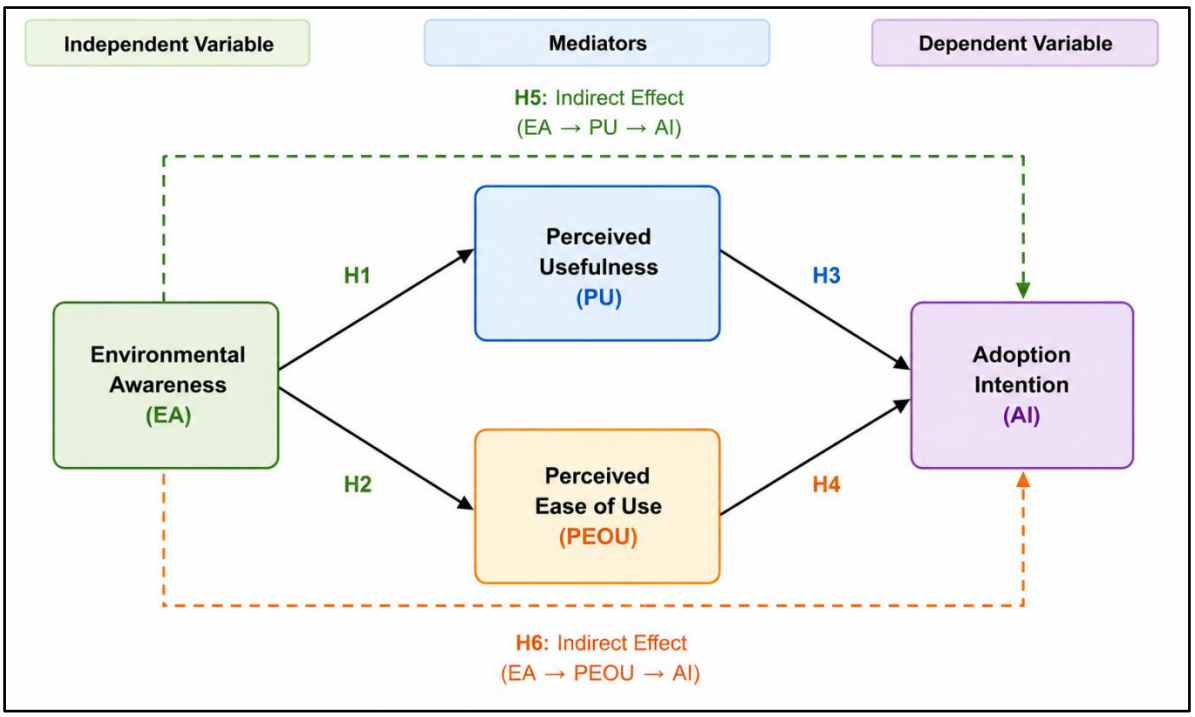

Figure 1. Proposed research framework.

METHODOLOGY

This study adopted a quantitative approach with a cross-sectional survey design to examine relationships among environmental awareness (EA), perceived usefulness (PU), perceived ease of use (PEOU) and adoption intention (AI) toward sustainable tourism transport technologies. A quantitative design was selected to permit empirical testing of the hypothesised relationships among latent constructs within a TAM-based framework. Cross-sectional surveys are widely used in tourism, sustainability and technology adoption research because they allow behavioural intentions and perceptions to be measured across a large number of respondents at a single point in time (Hair et al., 2022; Sarstedt et al., 2019).

The target population comprised prospective users of sustainable tourism transport technologies in Malaysia, defined as individuals who may reasonably encounter environmentally responsible transport services in a tourism context, including electric vehicles, solar-powered transport and other low-carbon mobility solutions. This population was selected because Malaysia is an emerging destination in which low-carbon tourism transport is being introduced but is not yet widely established, making prospective rather than current users the theoretically appropriate respondents (Musa et al., 2026b). In the absence of a comprehensive sampling frame for this population, non-probability convenience sampling was employed, a technique commonly applied in tourism and behavioural research where respondents hold relevant knowledge or exposure to the phenomenon under investigation (Sekaran & Bougie, 2020).

The questionnaire comprised two sections. The first collected demographic information including gender, age and education level. The second measured the four study constructs. Measurement items were adapted from established instruments in the technology acceptance, sustainable tourism and environmental behaviour literatures and modified to the sustainable transport context; the full instrument, with the source publication for each item, is reported in Appendix A. All items were rated on a five-point Likert scale anchored at 1 (strongly disagree) and 5 (strongly agree). A five-point scale was adopted to support respondent comprehension and response consistency, in line with prior technology adoption and behavioural intention research (Davis, 1989; Venkatesh et al., 2003).

Data were analysed using partial least squares structural equation modelling (PLS-SEM) in SmartPLS 4. PLS-SEM was selected because it suits predictive and exploratory research, theory extension, mediation analysis and the estimation of complex relationships among latent constructs (Hair et al., 2022). It is also robust to non-normal

data and is widely applied in tourism, sustainability and technology acceptance research. Analysis followed the standard two-stage procedure of measurement model assessment followed by structural model assessment.

The measurement model was evaluated for reliability and validity. Indicator reliability was assessed through outer loadings, and internal consistency through Cronbach's alpha, composite reliability (ρC) and ρA. Convergent validity was assessed through average variance extracted (AVE), with values above .50 indicating adequacy. Discriminant validity was examined using the Fornell–Larcker criterion and the heterotrait–monotrait ratio of correlations with bias-corrected bootstrap confidence intervals, following Henseler et al. (2015) and Franke and Sarstedt (2019). The structural model was then assessed for collinearity (variance inflation factors), explanatory power (R^2 and adjusted R^2), effect size (f^2) and path significance. Path coefficients were estimated using bootstrapping with 5,000 resamples, two-tailed, at the .05 significance level with a fixed seed (Hair et al., 2022), yielding robust standard errors, t-values and percentile and bias-corrected confidence intervals.

Mediation was tested through the specific indirect effects procedure recommended by Nitzl et al. (2016), with mediation type classified according to the decision procedure of Zhao et al. (2010) and the variance accounted for computed as the ratio of total indirect to total effect. Approximate model fit was assessed using the standardised root mean square residual (SRMR).

RESULTS

Demographic Background

Demographic characteristics of the respondents are summarised in Table 1. Sample size comprised 304 people, 54.3% of which were females and 45.7% males. Most participants fell within the age group of 20-29 years old (46.7%) and 50+ years old (21.4%). All participants had Malaysian citizenship. Educational level varied as follows: 43.1% of participants were masters, 27.0% - bachelors, and 20.4% - diploma holders. In consequence, the sample consists of well-educated Malaysian adults. The structure of the sample is adequate to investigate adoption intention towards new transportation technologies as such participants are more prone to have experience with technological innovations and issues of sustainability; but the sample structure does not allow generalisation to the whole Malaysian population, which will be discussed in section 5.3.

Table 1. Demographic background (N = 304)

Variable	Category	Frequency (n)	Valid Percentage (%)
Gender	Male	139	45.7
	Female	165	54.3
Age Group	Under 20 years old	28	9.2
	20–29 years old	142	46.7
	30–39 years old	32	10.5
	40–49 years old	37	12.2
	50 years and above	65	21.4
Nationality	Malaysian	304	100.0
Education Level	Primary / Secondary School	7	2.3
	Diploma	62	20.4

	Bachelor's Degree	82	27.0
	Master's Degree	131	43.1
	Ph.D or higher	22	7.3

Table 2 depicts descriptive statistics for constructs used in the research study. For all constructs, the mean value was high, varying within the range of 4.68 to 4.77 with a five-point scale. Thus, favorable perceptions have been found. The maximum mean value corresponds to environmental awareness (M = 4.77, SD = 0.52), followed by the perceived ease of use (M = 4.76, SD = 0.51), intention to adopt (M = 4.75, SD = 0.52), and perceived usefulness (M = 4.68, SD = 0.52). Small standard deviations indicate a large agreement between respondents. In relation to distributions at the level of items, an obvious presence of a ceiling effect can be detected since the median is equal to 5 for all twenty indicators, while item skewness varies from −2.358 to −5.747, and item excess kurtosis from 9.284 to 35.463.

The normality of distribution was rejected for every item using Cramér-von Mises test ($p < .001$). This leads to compression of the variance between constructs and increasing inter-construct correlations that has specific implications regarding the results related to the discriminant validity (Section 4.2). It should be mentioned that there is no assumption about the normality in PLS-SEM. Therefore, the inferences based on 5,000 bootstrap samples are admissible; however, the range is restricted (see Section 5.3).

Table 2. Descriptive statistics for the main constructs (N = 304)

Construct	**Min**	**Max**	**M**	**SD**
Adoption Intention (AI)	1.20	5.00	4.75	0.52
Environmental Awareness (EA)	1.20	5.00	4.77	0.52
Perceived Ease of Use (PEOU)	1.20	5.00	4.76	0.51
Perceived Usefulness (PU)	1.00	5.00	4.68	0.52

Note. M = mean; SD = standard deviation; N = 304 (listwise).

Measurement Model Assessment

The measurement model was assessed for reliability of indicators, reliability of internal consistency, and convergent validity, the results of which are shown in Table 3. The outer loadings varied between 0.687 and 0.924, and all of them were above the minimum of 0.60 necessary for reliability of indicators. The smallest outer loading was found for EA4 (0.687), while the highest was for EA1 (0.923). Even though the former does not reach the stricter criteria of 0.70, it was kept since its deletion did not improve the AVE for the corresponding construct.

All constructs demonstrated satisfactory internal consistency. Cronbach's alpha ranged from .867 to .908, ρA from .870 to .916 and composite reliability (ρC) from .904 to .932. All values fall within the .70 to .95 range recommended by Hair et al. (2022), indicating adequate reliability without redundancy at the indicator level. Outer variance inflation factors ranged from 1.537 to 4.501, all below the critical value of 5.0, confirming the absence of problematic indicator collinearity.

Convergent validity was supported. As shown in Table 3, AVE values ranged from .654 to .734, exceeding the .50 threshold and indicating that each construct accounts for more than half of the variance in its indicators. Taken together, these results confirm adequate indicator reliability, internal consistency and convergent validity at the construct level.

Table 3. Factor loadings, construct reliability and convergent validity

Constructs	Items	Outer Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Adoption Intention	AI1	0.843	0.867	0.904	0.654
	AI2	0.823			
	AI3	0.790			
	AI4	0.743			
	AI5	0.869			
Environmental Awareness	EA1	0.923	0.892	0.922	0.704
	EA2	0.919			
	EA3	0.773			
	EA4	0.687			
	EA5	0.785			
Perceived Ease of Use	PEOU 1	0.808	0.906	0.930	0.729
	PEOU 2	0.840			
	PEOU 3	0.924			
	PEOU 4	0.903			
	PEOU 5	0.909			
Perceived Usefulness	PU1	0.863	0.908	0.932	0.734
	PU2	0.829			
	PU3	0.902			
	PU4	0.774			
	PU5	0.843			

Discriminant validity was assessed first through the heterotrait–monotrait ratio of correlations, reported in Table 4. HTMT values should fall below .90, and below .85 under the more conservative criterion, for discriminant validity to be established (Hair et al., 2022; Henseler et al., 2015). The values obtained in this study ranged from .981 to 1.030 and exceeded the recommended threshold for every construct pair. Three ratios exceeded unity: EA–AI (1.016), PEOU–EA (1.009), PU–EA (1.004) and PU–PEOU (1.030). A ratio above 1.00 indicates that

the average correlation between indicators of different constructs exceeds the average correlation among indicators of the same construct.

Bias-corrected bootstrap confidence intervals confirm this conclusion rather than softening it. No interval fell below the .90 threshold: EA–AI 1.016 [0.993, 1.061], PEOU–EA 1.009 [0.990, 1.039], PU–EA 1.004 [0.978, 1.030], PU–AI 0.986 [0.927, 1.008], PEOU–AI 0.981 [0.903, 1.001] and PU–PEOU 1.030 [1.011, 1.093]. For the PU–PEOU pair the entire interval lies above unity. These results indicate that environmental awareness, perceived ease of use, perceived usefulness and adoption intention are not empirically distinct in the present sample, and the HTMT criterion for discriminant validity is therefore not satisfied. The finding is reported in full rather than omitted; its implications and the remedial steps required are set out in Section 5.3.

Table 4. Discriminant validity: heterotrait–monotrait (HTMT) ratio

Constructs	**AI**	**EA**	**PEOU**	**PU**
Adoption Intention (AI)	–			
Environmental Awareness (EA)	1.016	–		
Perceived Ease of Use (PEOU)	0.981	1.009	–	
Perceived Usefulness (PU)	0.986	1.004	1.030	–

Discriminant validity was assessed second through the Fornell–Larcker criterion, reported in Table 5. The criterion is satisfied when the square root of the AVE for each construct exceeds its correlations with all other constructs. The square roots of AVE were .809 for AI, .839 for EA, .854 for PEOU and .857 for PU.

Several inter-construct correlations exceeded the corresponding square roots of AVE. The correlation between EA and AI (r = .901) exceeded the square root of AVE for both constructs, as did the correlations between EA and PEOU (r = .919), PU and EA (r = .913), and PU and PEOU (r = .937).

The Fornell–Larcker criterion was therefore not satisfied, consistent with the HTMT results. Both criteria converge on the same conclusion: the four latent constructs exhibit substantial empirical overlap in this sample. The most plausible explanation is the ceiling effect documented in Section 4.1, which compresses between-construct variance and inflates correlations toward unity. The structural results reported below should accordingly be read as provisional, and Section 5.3 sets out the re-specification required before they can be regarded as confirmatory.

Table 5. Discriminant validity: Fornell–Larcker criterion

Constructs	**AI**	**EA**	**PEOU**	**PU**
Adoption Intention (AI)	0.809			
Environmental Awareness (EA)	0.901	0.839		
Perceived Ease of Use (PEOU)	0.877	0.919	0.854	
Perceived Usefulness (PU)	0.881	0.913	0.937	0.857

Structural Model Assessment

Table 6 reports the results of hypothesis testing for the six hypothesised relationships, estimated using bootstrapping with 5,000 resamples in SmartPLS 4. All six were statistically significant at the .05 level. Table 7

reports the full set of direct, specific indirect and total effects, including the direct path from environmental awareness to adoption intention, and Table 8 reports explanatory power, effect sizes and structural collinearity.

Environmental awareness exerted a significant positive effect on both perceived usefulness ($\beta = .913$, $t = 13.245$, $p < .001$) and perceived ease of use ($\beta = .919$, $t = 16.728$, $p < .001$), supporting H1 and H2. Respondents with higher environmental awareness were therefore more likely to perceive sustainable tourism transport technologies as both beneficial and easy to use.

Both technology acceptance beliefs significantly predicted adoption intention. Perceived usefulness had a positive effect on adoption intention ($\beta = .262$, $t = 3.253$, $p = .001$), as did perceived ease of use ($\beta = .148$, $t = 2.004$, $p = .045$), supporting H3 and H4. The effect of perceived usefulness was the stronger of the two, indicating that appraisals of benefit weigh more heavily than appraisals of usability in forming adoption intentions. The marginal significance of the perceived ease of use path should be interpreted with caution given the high correlation between the two beliefs ($r = .937$) reported in Table 5, which is likely to inflate structural collinearity and depress the estimated coefficient.

Mediation analysis identified significant indirect effects. Perceived usefulness mediated the relationship between environmental awareness and adoption intention ($\beta = .239$, $t = 3.289$, $p = .001$), supporting H5, and perceived ease of use mediated the same relationship ($\beta = .136$, $t = 2.046$, $p = .041$), supporting H6. Environmentally aware respondents were therefore more likely to intend to adopt sustainable tourism transport technologies in part because they judged those technologies useful and easy to use.

The structural model also estimated a direct path from environmental awareness to adoption intention, reported in Table 7. This path is strong and highly significant ($\beta = .527$, $t = 6.144$, $p < .001$, 95% bias-corrected CI [0.367, 0.686]). Because the direct effect and both specific indirect effects are significant and share the same sign, the mediation is complementary partial mediation under the classification of Zhao et al. (2010), not full mediation. The total effect of environmental awareness on adoption intention is $\beta = .901$ ($t = 12.993$, $p < .001$), of which the two indirect paths account for $\beta = .375$, or 41.6% of the total. The remaining 58.4% is transmitted directly.

Effect sizes reinforce this asymmetry. Following Cohen's benchmarks ($f^2 = .02$ small, .15 mediums, .35 large), environmental awareness exerted very large effects on perceived usefulness ($f^2 = 5.016$) and perceived ease of use ($f^2 = 5.456$), and a medium effect on adoption intention ($f^2 = .224$). By contrast, the effect sizes of the two belief paths on adoption intention were small to negligible and not statistically significant (PU → AI, $f^2 = .043$, $p = .116$; PEOU → AI, $f^2 = .013$, $p = .332$). Once environmental awareness is included as a direct predictor, the incremental explanatory contribution of the technology acceptance beliefs to adoption intention is therefore marginal.

The model explains a substantial proportion of variance in all three endogenous constructs: $R^2 = .835$ for adoption intention, .845 for perceived ease of use and .834 for perceived usefulness, with adjusted values of .833, .845 and .833 respectively. Structural collinearity is nonetheless severe. Inner variance inflation factors were 7.517 for EA → AI, 9.563 for PU → AI and 10.263 for PEOU → AI, far exceeding the critical threshold of 5.0 and the conservative threshold of 3.3 (Hair et al., 2022). Coefficient estimates for the paths into adoption intention are consequently unstable, and the small and marginally significant PEOU → AI coefficient should be attributed at least partly to this collinearity rather than to a weak underlying relationship. Approximate model fit was acceptable, with SRMR values of .063 for the saturated model and .068 for the estimated model, both below the .08 threshold.

Table 6. Hypothesis testing results

Hypothesis	Relationship	B (Path Coefficient)	T value	P value	Decision
H1	EA → PU	0.913	13.245	<0.001	Supported
H2	EA → PEOU	0.919	16.728	<0.001	Supported

H3	PU → AI	0.262	3.253	0.001	Supported
H4	PEOU → AI	0.148	2.004	0.045	Supported
H5	EA → PU → AI	0.239	3.289	0.001	Supported
H6	EA → PEOU → AI	0.136	2.046	0.041	Supported

Table 7. Direct, specific indirect and total effects with bias-corrected bootstrap confidence intervals

Effect	**β**	**SD**	**t**	**p**	**95% CI [LL, UL]**	**f²**
Direct effects						
EA → PU	0.913	0.069	13.245	< .001	[0.768, 0.951]	5.016
EA → PEOU	0.919	0.055	16.728	< .001	[0.801, 0.952]	5.456
EA → AI	0.527	0.086	6.144	< .001	[0.367, 0.686]	0.224
PU → AI	0.262	0.080	3.253	.001	[0.104, 0.413]	0.043
PEOU → AI	0.148	0.074	2.004	.045	[0.014, 0.297]	0.013
Specific indirect effects						
EA → PU → AI	0.239	0.073	3.289	.001	[0.098, 0.382]	–
EA → PEOU → AI	0.136	0.066	2.046	.041	[0.014, 0.277]	–
Total indirect effect	0.375	–	–	–	–	–
Total effect						
EA → AI (total)	0.901	0.069	12.993	< .001	[0.750, 0.944]	–
Variance accounted for (VAF)	41.6%	–	–	–	–	–

Note. β = standardised path coefficient; SD = bootstrap standard deviation; CI = 95% bias-corrected bootstrap confidence interval; 5,000 resamples, two-tailed.

Table 8. Explanatory power, effect size and structural collinearity

Construct / path	**R^2**	**Adjusted R^2**	**f^2**	**Inner VIF**
Adoption Intention (AI)	0.835	0.833	–	–
Perceived Ease of Use (PEOU)	0.845	0.845	–	–
Perceived Usefulness (PU)	0.834	0.833	–	–
EA → PU	–	–	5.016	1.000
EA → PEOU	–	–	5.456	1.000

EA → AI	–	–	0.224	7.517
PU → AI	–	–	0.043	9.563
PEOU → AI	–	–	0.013	10.263

Note. R^2 values are reported for endogenous constructs; f^2 and VIF are reported per structural path. f^2 benchmarks: .02 small, .15 mediums, .35 large. VIF above 5.0 indicates critical collinearity.

Figure 2 presents the structural model and the significance of relationships among environmental awareness, perceived usefulness, perceived ease of use and adoption intention. Environmental awareness exerts significant positive effects on both technology acceptance beliefs, indicating that environmentally conscious respondents appraise sustainable tourism transport technologies as both beneficial and straightforward to operate.

Both beliefs in turn influence adoption intention, with perceived usefulness exerting the stronger effect. This suggests that respondents weigh the practical and environmental benefits of a technology more heavily than its usability when forming adoption intentions.

Figure 2 also depicts the mediating paths. Environmental awareness reaches adoption intention indirectly through both perceived usefulness and perceived ease of use, indicating that environmentally aware individuals are more inclined to adopt sustainable tourism transport technologies where they judge those technologies useful and easy to operate.

The structural model is consistent with the proposed conceptual framework and indicates that environmental awareness, in combination with the core Technology Acceptance Model beliefs, contributes to explaining adoption intentions toward sustainable tourism transport technologies, subject to the measurement constraints set out in Section 4.2.

Figure 2. Structural model results for environmental awareness, perceived usefulness, perceived ease of use and adoption intention.

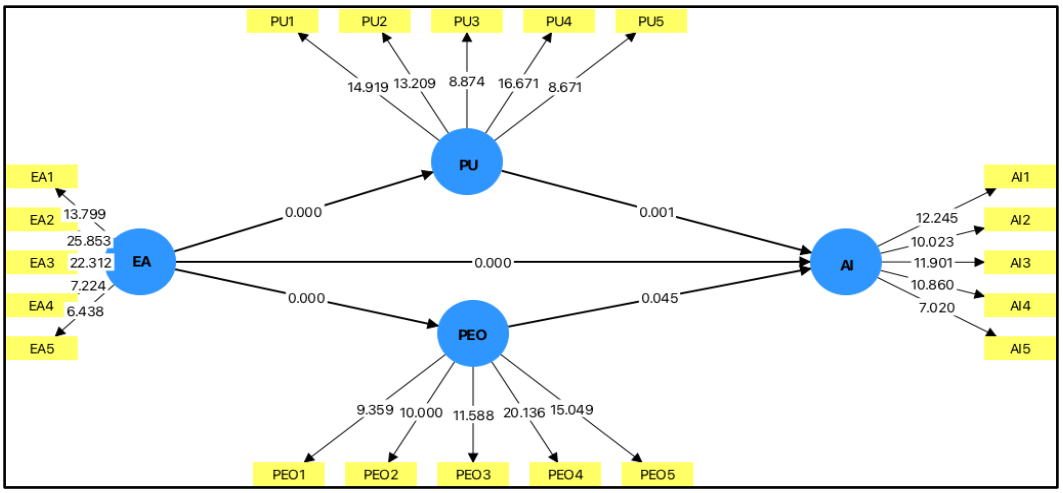

Figure 2. Structural Model

DISCUSSION

This study finds that environmental awareness is consequential for the adoption of sustainable tourism transport technologies, and that its influence operates in part through the cognitive appraisals specified by the Technology Acceptance Model. Environmentally conscious respondents judged these technologies both useful and easy to use, and those judgements strengthened adoption intention. The strong positive association between environmental awareness and perceived usefulness indicates that environmentally concerned individuals recognise the tangible benefits of low-carbon mobility, including reduced emissions and support for

environmentally responsible travel. This is consistent with evidence that environmental awareness shapes consumer evaluations of sustainable tourism services (Wang et al., 2024a) and of green technologies more broadly (Zhan et al., 2025).

Environmental awareness also exerted a significant effect on perceived ease of use. This suggests that environmental motivation lowers the perceived effort associated with engaging a new transport technology, leaving environmentally aware users more open to learning it. Prior work has argued that pro-environmental attitudes increase willingness to engage with novel technologies directed at sustainable outcomes (Al-Emran, 2023; Wang et al., 2024b), thereby strengthening perceptions of usability and accessibility.

This aligns with the broader shift from pro-economic to pro-environmental motives in Malaysian innovation adoption (Rajiani et al., 2016), in which environmental considerations increasingly act as a direct driver of behaviour rather than operating solely through perceived functional benefits.

Both beliefs predicted adoption intention, supporting the core premise of TAM in this context, but the effect size evidence tempers that support. Perceived usefulness exerted the stronger of the two path coefficients, consistent with adoption research reporting perceived usefulness as the dominant predictor of behavioural intention in sustainability settings (Al-Emran & Griffy-Brown, 2023; Salim et al., 2024). Yet the f^2 values for both belief paths were small to negligible and statistically non-significant (.043 and .013), indicating that neither belief adds meaningful explanatory power to adoption intention once environmental awareness is modelled as a direct predictor. Two readings are possible. The substantive reading is that in a context where environmental awareness is near-universal, that orientation rather than technology appraisal governs stated intention. The methodological reading is that inner VIF values between 7.5 and 10.3 have destabilised the partitioning of variance between three highly collinear predictors. The two readings are not separable with the present data, and Section 5.3 sets out the design required to distinguish them.

The mediation analysis clarifies the mechanism linking environmental awareness to adoption intention, and it does so in a way that qualifies the prevailing account. Both beliefs carried significant indirect effects, confirming that environmental awareness reaches behavioural intention partly through technology appraisal. The direct path, however, remained strong and highly significant once both mediators were specified ($\beta = .527$, $p < .001$), and the two indirect paths together accounted for only 41.6% of the total effect. The mediation is therefore complementary and partial (Zhao et al., 2010) rather than full. Environmental awareness does not require the TAM beliefs in order to reach adoption intention; it reaches it substantially on its own, and the beliefs supplement that pathway. Studies reporting full mediation of environmental values through acceptance beliefs (Garus et al., 2024; Tareke, 2024) may therefore have understated the direct contribution of environmental orientation, particularly where the direct path was not estimated.

Taken together, the findings indicate that environmental awareness is the dominant driver of stated adoption intention in this sample, and that technology acceptance beliefs operate as a secondary and complementary channel rather than as the mechanism through which environmental concern must pass. This inverts the emphasis of much of the extended-TAM literature. The practical implication is not that usability and perceived benefit are unimportant, but that in an emerging destination where environmental concern is already high, the binding constraint on adoption is more likely to lie in the availability and credibility of low-carbon options than in travellers' appraisals of them. By integrating environmental awareness into the Technology Acceptance Model as a direct as well as an indirect antecedent, the study offers a more complete account of sustainable mobility adoption in tourism.

Theoretical Implications

This study makes three theoretical contributions. First, it specifies environmental awareness as a contextual antecedent within the Technology Acceptance Model rather than as a parallel predictor of intention. This positioning matters: it implies that environmental values influence adoption not by bypassing cognitive appraisal but by shaping it, and it offers a testable account of how sustainability-orientated values enter technology acceptance processes.

Second, the study responds to calls for process-level explanation in pro-environmental behaviour research. By modelling perceived usefulness and perceived ease of use as mediating mechanisms, it identifies the appraisals through which environmental concern is translated into behavioural intention, moving beyond the direct-effect specifications that dominate the literature (Tareke, 2024).

Third, the study extends technology acceptance research into the sustainable tourism transport domain in an emerging destination, where low-carbon mobility infrastructure is still being established and adoption dynamics may differ from those observed in mature markets (Musa et al., 2026a; Trilaksono et al., 2026). The results also identify a boundary condition for extended TAM specifications. Where environmental awareness is near-universal and strongly skewed, technology acceptance beliefs discriminate weakly between respondents, and the assumption that environmental values must be routed through cognitive appraisal to influence intention does not hold. Researchers extending TAM with value-based antecedents should therefore estimate the direct path as a matter of course rather than assuming full mediation, since omitting it both overstates the role of the mediators and misclassifies the mediation type.

Practical Implications

For destination managers and tourism operators, the findings indicate that environmental communication and technology design should be pursued together rather than sequentially. Awareness campaigns that are not matched by demonstrable improvements in the benefit and usability of low-carbon transport are unlikely to shift adoption, because the appraisals that carry environmental concern into intention depend on the attributes of the technology itself.

Because perceived usefulness exerted the stronger effect on adoption intention, operators should make the functional and environmental benefits of low-carbon transport explicit and verifiable at the point of decision: journey time, cost, coverage and emissions avoided relative to conventional alternatives. For transport agencies and policymakers, the results support investment in service reliability, network coverage and clear onboarding as complements to, not substitutes for, environmental messaging. For technology developers, the marginal effect of perceived ease of use should not be read as evidence that usability is unimportant; the high correlation between the two beliefs in this sample indicates that usability and perceived benefit are difficult to separate in the user's evaluation.

Limitations and Future Research

Four limitations qualify these findings and define the agenda for further work. The first and most consequential concerns measurement. Discriminant validity was not established: HTMT values ranged from .981 to 1.030 and the Fornell–Larcker criterion was breached for every construct pair. The four constructs are therefore not empirically distinct in this sample, and the structural estimates must be regarded as provisional rather than confirmatory. Future work should re-examine item wording for semantic overlap between the environmental awareness and perceived usefulness scales, remove or rewrite overlapping items, and re-estimate the model. Where perceived usefulness and perceived ease of use cannot be separated, a second-order specification treating the two as dimensions of a single technology acceptance beliefs construct should be tested using the disjoint two-stage approach.

Second, the response distribution exhibits a pronounced ceiling effect, with all construct means between 4.68 and 4.77 on a five-point scale. Compression of this kind restricts variance, inflates inter-construct correlations and is the most plausible source of the discriminant validity failure. Acquiescence and social desirability are likely contributors, since environmental awareness and sustainable transport are normatively loaded topics on which respondents can readily identify the approved answer. Future studies should employ a seven-point scale, include reverse-coded items, incorporate procedural remedies for common method variance at the design stage, and report the full collinearity assessment of Kock and Lynn (2012).

Furthermore, the extent of structural collinearity restricts the size of path estimates that can be made. Inner VIF values of 7.517, 9.563, and 10.263 for the three paths to adoption intention are larger than typical criteria, suggesting that there is uncertainty regarding the variance partitioning between environmental awareness,

perceived usefulness, and perceived ease of use. The lack of significance of the f^2 values for the two belief paths is a result of either their marginal role or collinearity-induced coefficient suppression. It will be difficult to establish which is the case, unless an alternative measurement model is formulated where the constructs are distinct from one another or a different experimental framework is adopted whereby the perceived usefulness and perceived ease of use are independently manipulated. Also, the predictive relevance of the model outside the sample was not assessed; researchers need to report blindfolding for Q^2 and PLSpredict (Shmueli et al., 2019).

Fourth, there are limits to the validity of the inferences that can be made and the ability to generalize findings. In terms of the design, the cross-sectional survey makes causality impossible, while longitudinal and experimental studies would allow for the testing of the model's temporal sequencing assumption. Non-probability convenience sampling and the high level of education of the sample group 50.4% have attained master's degrees or higher make it impossible to generalize findings to the greater Malaysian population. Another issue that future studies should take into account is that sustainable tourism transport technologies were considered as one entity including electric cars, solar transport, and smart transportation systems. These transportations differ greatly in terms of costs and availability. Finally, intention was studied and not behaviour, and this is well recognized in environmental studies.

CONCLUSION

This study examined the influence of environmental awareness on adoption intention toward sustainable tourism transport technologies, incorporating perceived usefulness and perceived ease of use from the Technology Acceptance Model as mediating mechanisms. Environmental awareness significantly influenced both beliefs, indicating that environmentally conscious individuals are more likely to recognise the benefits and usability of low-carbon transport technologies.

Both perceived usefulness and perceived ease of use positively influenced adoption intention, with perceived usefulness exerting the stronger of the two effects, and both carried significant indirect effects. Environmental awareness nonetheless retained a strong direct effect on adoption intention ($\beta = .527$, $p < .001$). The mediation is accordingly complementary and partial: the two indirect paths account for 41.6% of a total effect of $\beta = .901$, leaving the majority transmitted directly.

The study concludes that environmental awareness is the principal driver of adoption intention toward sustainable tourism transport technologies in this setting, and that technology acceptance beliefs function as a complementary rather than a necessary channel. The negligible and non-significant effect sizes of the two belief paths indicate that they add little explanatory power once environmental awareness is specified as a direct predictor. Integrating environmental awareness into TAM as both a direct and an indirect antecedent therefore provides a more accurate account of behavioural intention toward sustainable technology adoption in tourism than mediation-only specifications.

These findings should be read alongside the measurement limitations reported in Section 5.3. The constructs examined here did not achieve discriminant validity in the present sample, and the structural estimates are accordingly provisional. The direction and theoretical plausibility of the relationships are supported, but confirmatory claims require the re-specification and re-estimation set out below.

Subject to those qualifications, the study contributes evidence on the role of environmental awareness, perceived usefulness and perceived ease of use as determinants of adoption intention toward sustainable tourism transport technologies, and offers a framework for further research on sustainable mobility adoption in emerging destinations.

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Ethics Statement

This study received ethical approval from the UTeM Research Ethics Committee (REAC), Universiti Teknikal Malaysia Melaka (UTeM), Malaysia, under Reference Number REAA/2026/06-01. The study was conducted in accordance with the ethical principles and research governance requirements established by Universiti Teknikal Malaysia Melaka and applicable national research ethics guidelines.

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