

Green logistics adoption among manufacturing enterprises in Thai Nguyen province, Vietnam: Integrating Planned Behaviour and Technology–Organisation–Environment perspectives

**Authors:**

Thi Thanh Mai Pham¹ 
Trung Kien Dang² 
Manh Hung Nguyen² 

Affiliations:

¹Logistics Division, Faculty of Business and Logistics, Thai Nguyen University of Economics and Business Administration, Thai Nguyen, Vietnam

²Urban Development Consulting Services Center, Thai Nguyen University, Thai Nguyen, Vietnam

Corresponding author:

Trung Dang,
dtkien@tueba.edu.vn

Dates:

Received: 12 Mar. 2026

Accepted: 02 Apr. 2026

Published: 14 May 2026

How to cite this article:

Pham, T.T.M., Dang, T.K. & Nguyen, M.H., 2026, 'Green logistics adoption among manufacturing enterprises in Thai Nguyen province, Vietnam: Integrating Planned Behaviour and Technology–Organisation–Environment perspectives', *Journal of Transport and Supply Chain Management* 20(0), a1374. <https://doi.org/10.4102/jtscm.v20i0.1374>

Read online:

Scan this QR code with your smart phone or mobile device to read online.

Background: Green logistics can reduce emissions and waste while sustaining cost and service performance, yet adoption remains uneven in emerging-economic provinces because of heterogeneous enforcement, technology access and managerial capabilities.

Objectives: This study examines the key determinants of green logistics adoption (GLP) among manufacturing enterprises in Thai Nguyen province, Vietnam, by integrating the Theory of Planned Behaviour (TPB) and the Technology–Organisation–Environment (TOE) framework, and by testing whether environmental – social awareness mediates the effect of external pressure (EXT) on adoption.

Method: A cross-sectional survey was conducted with 30 manufacturing enterprises, yielding 60 valid responses (two informants per firm). The model assesses the effects of environmental-social awareness (ENV), EXT, perceived cost-effectiveness, internal capabilities (INT) and technological infrastructure (TEC) on GLP. The data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) with 2000 bootstrap resamples.

Results: Perceived cost-effectiveness, TEC, ENV and EXT show significant positive effects on adoption, whereas INT is not significant. External pressure significantly increases environmental – social awareness, and the indirect effect EXT → ENV → GLP is significant, indicating partial mediation. The model explains 63.8% of the variance in adoption and demonstrates predictive relevance.

Conclusion: Green logistics adoption in Thai Nguyen province is primarily driven by a clear business case, enabling technologies, and institutional and market pressures that are partly internalised through managerial awareness.

Contribution: The study provides provincial-level evidence from Vietnam, extends prior work that typically applies TPB or TOE in isolation, and clarifies an awareness-based mechanism through which EXT is translated into GLP.

Keywords: green logistics; manufacturing enterprises; TPB; TOE; PLS-SEM; Vietnam; Thai Nguyen province.

Introduction

Sustainability transitions are reshaping how firms design and manage supply chains and logistics, as firms face growing pressure to cut emissions, reduce waste and comply with environmental and social expectations. Logistics activities (transportation, warehousing, packaging, inventory positioning and reverse flows) can generate substantial environmental impacts through fuel use, air pollution, noise and solid waste (Dekker, Bloemhof & Mallidis 2012; Sbihi & Eglese 2010). In response, green logistics promotes the systematic integration of environmental considerations into logistics decisions, aiming to reduce negative impacts while maintaining delivery reliability and cost competitiveness (Dekker et al. 2012). Research increasingly shows that greener logistics is not only a compliance response but can also create operational and reputational value when the economic and technological conditions are

Copyright: © 2026. The Authors. Licensee: AOSIS. This work is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license (<https://creativecommons.org/licenses/by/4.0/>).

favourable (Porter & Van der Linde 1995). For example, optimisation of routing and load consolidation, adoption of cleaner technologies, and waste-reducing packaging can lower fuel and material costs, improve service quality, and strengthen customer trust. However, adoption is still uneven across countries and within countries, especially in emerging economies where financial constraints, uneven infrastructure and variable enforcement complicate implementation (Lin & Ho 2011; Rastegardebidi & Su 2025). Firms operating in provincial industrial clusters often face a distinct mix of barriers: they may be subject to global buyer requirements and national regulations, yet have limited access to green technologies, skilled personnel, and specialised support services (Centobelli, Cerchione & Esposito 2017; Evangelista 2014). Vietnam has experienced rapid industrialisation and deepened participation in global supply chains. Thai Nguyen province has emerged as an important manufacturing location, attracting both domestic firms and export-oriented production. In this context, green logistics can be a critical enabling capability for sustainable industrial growth. Yet empirical evidence about what drives manufacturing enterprises in provincial settings to adopt green logistics practices remains limited. Much of the existing evidence is either focused on national-level analyses or on developed economies, where institutional and resource conditions differ (Rastegardebidi & Su 2025). Understanding provincial determinants is important because local firms often operate under tighter resource constraints, making adoption decisions highly sensitive to perceived economic feasibility and practical enablers.

To address this gap, the present study examines determinants of green logistics adoption (GLP) among manufacturing enterprises in Thai Nguyen province, Vietnam. We integrate the Theory of Planned Behaviour (TPB), which explains behaviour through attitudes, norms and perceived control (Ajzen 1991), with the Technology–Organisation–Environment (TOE) framework, which highlights technological readiness, organisational capabilities, and environmental context as drivers of innovation adoption (Tornatzky, Fleischer & Chakrabarti 1990). This integrated lens is suitable for green logistics because adoption is simultaneously shaped by managerial cognitions (e.g. awareness of environmental and social value) and by contextual constraints (e.g. external market and policy pressures, economic viability and technology availability).

More specifically, the study advances prior work in two ways. Firstly, rather than applying TPB or TOE in isolation, it combines a TPB-consistent cognitive driver (environmental-social awareness [ENV]) with TOE-based contextual determinants in a single model. Secondly, it theorises and tests an awareness-based mechanism through which external pressure (EXT) is partly translated into adoption, thereby explaining not only whether EXT matters, but how it becomes internalised by managers. Using survey data and Partial Least Squares Structural

Equation Modelling (PLS-SEM) (Hair et al. 2021), we test the direct effects of ENV, EXT, perceived cost-effectiveness (ECO), internal capabilities (INT) and technological infrastructure (TEC) on adoption (GLP), and we evaluate the mediating role of ENV in the EXT-GLP relationship. This study contributes in three ways. Firstly, it offers provincial-level empirical evidence from an emerging economy, a setting that is underrepresented in GLP research. Secondly, it validates an integrated TPB-TOE explanation for GLP in manufacturing enterprises, highlighting the joint roles of cognition and context. Third, it clarifies how EXTs can translate into adoption partly by shaping managerial awareness, strengthening theorising about the internalisation of institutional signals.

Literature review and hypothesis development

Green logistics and adoption challenges

Green logistics can be viewed as a set of operational and managerial practices that reduce the environmental footprint of logistics while maintaining or improving service outcomes. Practices often include route optimisation and load consolidation, energy-efficient warehousing, waste-minimising packaging, reverse logistics, greener purchasing and the adoption of information systems that improve visibility and resource utilisation; collaborative freight solutions can also reduce emissions through better pooling and coordination (Dekker et al. 2012; Pan, Ballot & Fontane 2013; Sbihi & Eglese 2010). Green logistics is closely related to green supply chain management, but it emphasises the logistics function (inbound and outbound physical flows, storage and distribution activities), which is often a major contributor to emissions and waste (Seuring & Müller 2008).

Although green logistics is increasingly discussed as a strategic capability, adoption is constrained by practical and contextual factors. Firstly, the investment profile can be demanding; firms may need to invest in vehicles, monitoring systems, warehouse retrofits, staff training or new processes. Secondly, firms frequently face uncertainty about returns, especially if cost savings depend on scale or sustained demand for green services. Thirdly, implementation requires coordination across internal departments and supply chain partners, which can be difficult where information sharing and trust are limited (Evangelista 2014). Finally, access to enabling infrastructure and technology differs substantially across regions and sectors, affecting both feasibility and speed of adoption (Lin & Ho 2011). These constraints are particularly salient for small and medium-sized manufacturers and for firms located outside major metropolitan centres. Therefore, an effective explanation of adoption should include both: (1) how managers perceive the environmental and business value of green logistics and (2) the organisational and environmental conditions that make adoption easier or harder.

Theoretical foundations

Theory of Planned Behaviour and awareness as a cognitive driver

The TPB posits that behavioural intentions (and thus behaviours) are shaped by attitudes towards the behaviour, subjective norms and perceived behavioural control (Ajzen 1991). In organisational adoption contexts, TPB is often operationalised through managerial perceptions and beliefs. Environmental-social awareness captures a firm's recognition that green logistics can reduce pollution, improve reputation and signal corporate social responsibility. Such awareness is conceptually aligned with an attitude component in TPB and may also reflect perceived normative desirability, particularly when sustainability is becoming an expected standard in many supply chains. In practice, managers who believe that green logistics deliver environmental and social benefits are more likely to support investments, allocate attention and overcome implementation inertia. Awareness can also shape how managers interpret signals from regulators and customers, making them more willing to translate external expectations into concrete operational changes.

Technology–Organisation–Environment framework and contextual readiness

The TOE framework explains innovation adoption through three contexts: technological, organisational and environmental (Tornatzky et al. 1990). In the case of green logistics, the technological context includes the availability of logistics-related technologies and infrastructure (e.g. tracking, optimisation tools, digital platforms and transport infrastructure) that enable greener operations. The organisational context includes INT, resources and managerial systems that support implementation. The environmental context includes EXTs from regulation, customers and competitors that can motivate adoption, particularly when firms operate in markets where sustainability is becoming a baseline requirement. Because GLP involves both motivation (why adopt) and capability (how to adopt), combining TPB (cognitive motivation and perceived value) with TOE (contextual readiness and pressure) provides a stronger foundation for explaining adoption behaviour than either framework alone.

Integrating Theory of Planned Behaviour and Technology–Organisation–Environment: Theoretical positioning of the study

Green logistics adoption is unlikely to be fully explained by a single theoretical lens. A purely behavioural explanation may overlook whether firms possess the necessary technological and organisational conditions for implementation, whereas a purely contextual explanation may understate the role of managerial interpretation and internalisation of sustainability signals. The present study, therefore, combines TPB and TOE to capture both motivational and contextual mechanisms. In this model, ENV represents a TPB-consistent cognitive pathway, whereas EXT, ECO, INT and TEC represent TOE-aligned contextual conditions. This integration enables a more precise explanation of why firms adopt green logistics and why EXT may influence adoption both directly and indirectly through managerial awareness.

Hypotheses development

Environmental-social awareness and adoption

When managers perceive that green logistics reduces pollution, improves corporate reputation, and demonstrates social responsibility, they are more likely to view green logistics favourably and to support adoption decisions. This mechanism aligns with TPB's attitude-behaviour logic, where favourable attitudes promote intention and behaviour (Ajzen 1991). The following hypothesis (H) were formulated:

H1: Environmental-social awareness (ENV) positively influences green logistics adoption (GLP).

External pressure and adoption

Institutional theory suggests that organisational practices are shaped by coercive (regulatory), normative (stakeholder expectations) and mimetic (competitor) pressures (DiMaggio & Powell 1983). In green supply chain and logistics settings, EXT from regulators and customers can push firms to adopt environmental practices, especially when compliance and market access depend on it (Zhu, Sarkis & Lai 2007):

H2: External pressure (EXT) positively influences green logistics adoption (GLP).

Perceived cost-effectiveness and adoption

Green logistics is more likely to be adopted when firms perceive that the long-term economic and competitive benefits outweigh initial investments. Porter and Van der Linde (1995) argue that well-designed environmental practices can stimulate innovation and resource efficiency, producing competitive advantages. In manufacturing supply chains, evidence also suggests that environmental practices can be connected to operational performance when implemented effectively (Zhu & Sarkis 2004):

H3: Perceived cost-effectiveness (ECO) positively influences green logistics adoption (GLP).

Internal capabilities and adoption

The resource-based view posits that valuable, rare and inimitable resources can enable sustained competitive advantage (Barney 1991). Internal capabilities such as skilled staff, managerial systems and supportive programmes can facilitate the implementation of new practices and reduce adoption barriers. Within TOE, organisational readiness is a central condition for adopting innovations (Tornatzky et al. 1990):

H4: Internal capabilities (INT) positively influence green logistics adoption (GLP).

Technological infrastructure and adoption

Digitalisation and analytics can enable greener logistics by improving visibility, planning and optimisation, while Industry 4.0 technologies support data-driven resource efficiency and sustainable operations (Kamble, Gunasekaran & Gawankar 2018). Big data analytics and digital logistics platforms can also help firms monitor performance, reduce waste, improve operational excellence and optimise transport decisions (Bag et al. 2020; Wang et al. 2016):

H5: Technological infrastructure (TEC) positively influences green logistics adoption (GLP).

Mediating role of environmental-social awareness

External pressure can influence adoption directly, but it can also work by shaping managerial beliefs and awareness. Under institutional mechanisms, repeated regulatory and market signals can alter organisational norms and cognition (DiMaggio & Powell 1983). When EXT increases ENV, awareness can, in turn, increase adoption propensity (Ajzen 1991):

H6: Environmental-social awareness (ENV) mediates the relationship between external pressure (EXT) and green logistics adoption (GLP).

Figure 1 illustrates the conceptual research model underpinning the proposed hypotheses.

Research methods and design

Research design and context

A quantitative, cross-sectional survey design was used to examine determinants of GLP in Thai Nguyen province, Vietnam. Manufacturing enterprises were selected as the focal population because they generate significant logistics demand through inbound materials and outbound distribution, and because they are frequently exposed to supply chain sustainability requirements. The unit of analysis is the enterprise. Respondents were key informants with direct knowledge of logistics and operations (e.g. supply chain managers, logistics supervisors, operations staff). Using key informants is common in sustainability and logistics adoption studies, but it can introduce single-informant bias; therefore, two responses were collected from each enterprise to strengthen the reliability of firm-level assessments.

Sampling and data collection

Enterprises were included if they were: (1) registered manufacturing firms operating in Thai Nguyen province and (2) engaged in logistics activities such as transportation coordination, warehousing, packaging or inbound and outbound flow management. A purposive sampling strategy was used to target respondents likely to understand both current practices and strategic plans related to green logistics. Data were collected using a structured questionnaire distributed through a combination of direct interviews and online administration (Google Forms). Respondents were informed about the study purpose, that participation was voluntary, and that responses would be used only for academic research. A total of 60 valid responses were obtained from 30 enterprises (two responses per enterprise). Partial Least Squares Structural Equation Modelling is well-suited to exploratory models and to situations with modest sample sizes and non-normal survey data. Following a commonly used heuristic, the 10-times rule suggests a minimum sample size equal to 10 times the maximum number of structural paths directed at any endogenous

construct (Hair et al. 2021). In the proposed model, the dependent construct GLP has five incoming paths (ENV, EXT, ECO, INT, TEC), implying a minimum of 50 observations. The achieved sample ($N = 60$) satisfies this criterion.

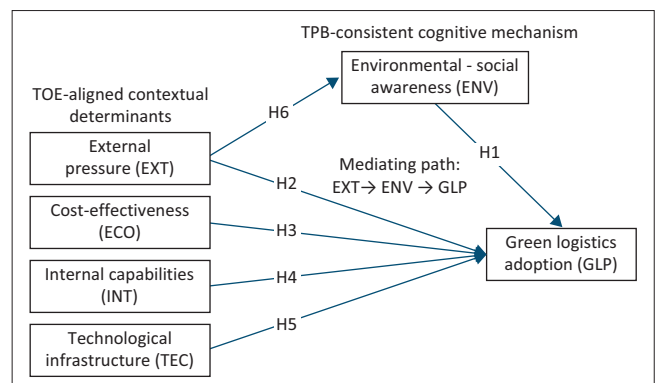
Measurement instrument

All constructs were measured reflectively with three indicators each, adapted from prior research on innovation adoption and green logistics and green supply chain practices and then contextualised to provincial manufacturing enterprises (Ajzen 1991; Lin & Ho 2011; Zhu & Sarkis 2004; Zhu et al. 2007). Items captured: (1) perceived ENV, (2) EXT from customers, competitors, and government policy, (3) ECO of green logistics, (4) INT such as human resources and programmes, (5) TEC enabling green logistics and (6) adoption of green logistics (GLP) measured by current implementation and strategic integration.

All items were rated on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). To improve clarity and ensure relevance, the questionnaire was reviewed and refined through a small pilot with managers, with wording adjustments based on feedback.

Data analysis procedure

Data analysis followed recommended PLS-SEM procedures (Hair et al. 2021) in two stages: (1) measurement model assessment and (2) structural model evaluation. The measurement model was assessed for indicator reliability (outer loadings), internal consistency reliability (Cronbach's alpha and composite reliability), convergent validity (average variance extracted [AVE]) and discriminant validity using the Fornell–Larcker criterion and the heterotrait-monotrait (HTMT) ratio (Fornell & Larcker 1981; Henseler, Ringle & Sarstedt 2015). The structural model was evaluated by examining collinearity (VIF), path coefficients, coefficient of determination (R^2), predictive relevance (Q^2), effect sizes (f^2) and mediation effects. Effect size benchmarks were interpreted following Cohen (1988). Statistical significance of direct and indirect effects was tested using bootstrapping with 2000 resamples (Hair et al. 2021).



TOE, Technology–Organisation–Environment; TPB, theory of planned behaviour.

FIGURE 1: Conceptual research model.

To address potential common method bias (CMB), both design-based and statistical considerations were applied. Collecting two responses per enterprise reduced reliance on a single informant, and statistically, collinearity-based diagnostics were examined. Specifically, full-collinearity VIF values below 3.3 are commonly interpreted as suggesting that CMB is unlikely to be a major concern (Kock 2015).

Ethical considerations

An application for full ethical approval was made to the Thai Nguyen University of Economics and Business Administration, and ethics consent was received on 25 February 2026. The Thai Nguyen University of Economics and Business Administration issued an ethics waiver for the study because based on the nature of the study, this research is considered minimal risk and therefore does not require formal ethical clearance from an Institutional Review Board. Participation was voluntary, informed consent was obtained from all respondents, and data were collected anonymously and used solely for academic research purposes.

Results

Descriptive statistics

Table 1 summarises the measurement items and descriptive statistics for the constructions. Mean values are above the midpoint of the five-point scale (3.42–3.51), indicating that respondents generally report moderate-to-positive conditions for green logistics and adoption. However, standard deviations close to or above 1.0 highlight heterogeneity across enterprises, consistent with uneven diffusion of green practices across firms in emerging-economy settings.

As shown in Table 1, respondents report moderately positive perceptions across constructs (means around 3.4–3.5), while the relatively large dispersion (s.d. $\approx$ 1.0–1.15) indicates meaningful heterogeneity across firms.

Measurement model assessment

Table 2 indicates that all standardised loadings are high (>0.89), confirming indicator reliability and showing that the items capture their intended latent constructs. Cronbach's alpha and composite reliability exceed the 0.70 threshold, and AVE exceeds 0.50 for all constructs, supporting internal consistency and convergent validity (Fornell & Larcker 1981). At the same time, several loadings are very high (>0.95), which warrants caution because such values can sometimes signal item redundancy. We therefore re-examined the wording and substantive scope of the indicators and retained them because each item captures a distinct facet of the construct. In addition, the discriminant validity and full-collinearity results reported below suggest that the high loadings are not primarily an artefact of CMB.

Discriminant validity is supported by both the Fornell–Larcker criterion and HTMT values. In detail, from Table 3 (Fornell–Larcker), the square root of each construct's AVE (diagonal) is greater than its correlations with other constructs, providing evidence of discriminant validity. While HTMT ratios in Table 3 are below 0.85, reinforcing discriminant validity under a stricter criterion (Henseler et al. 2015).

TABLE 1: Measurement items ($N = 60$).

Construct	Indicator	Item	Mean	s.d.	Min	Max
ENV	-	-	3.433	1.100	1.0	5.0
	ENV1	Green logistics helps reduce environmental pollution	-	-	-	-
	ENV2	Green logistics improves corporate reputation	-	-	-	-
	ENV3	Green logistics demonstrates corporate social responsibility	-	-	-	-
EXT	-	-	3.422	1.101	1.0	5.0
	EXT1	Customers demand green logistics activities	-	-	-	-
	EXT2	Competitors adopt green logistics practices	-	-	-	-
	EXT3	Government policies and regulations promote green logistics	-	-	-	-
ECO	-	-	3.439	1.102	1.0	5.0
	ECO1	Green logistics helps reduce logistics costs	-	-	-	-
	ECO2	Creates long-term competitive advantage	-	-	-	-
	ECO3	Initial investment costs are acceptable	-	-	-	-
INT	-	-	3.494	0.992	1.0	5.0
	INT1	The enterprise has the capacity to implement green logistics	-	-	-	-
	INT2	Human resources can support green logistics	-	-	-	-
	INT3	There are specific policies/programmes to support green logistics	-	-	-	-
TEC – Technological infrastructure	-	-	3.506	1.127	1.0	5.0
	TEC1	Local infrastructure supports green logistics	-	-	-	-
	TEC2	Availability of modern technology for green logistics	-	-	-	-
	TEC3	Ability to access green logistics technology from external sources	-	-	-	-
GLP – (dependent variable)	-	-	3.494	1.154	1.0	5.0
	GLP1	The enterprise applies at least one green logistics activity	-	-	-	-
	GLP2	The enterprise has plans to expand green logistics practices	-	-	-	-
	GLP3	Green logistics is integrated into the enterprise's development strategy	-	-	-	-

ENV, environmental-social awareness; EXT, external pressure; ECO, perceived cost-effectiveness; INT, internal capabilities; TEC, technological infrastructure; GLP, green logistics adoption; s.d., standard deviation; Min, minimum; Max, maximum.

Structural model assessment

As reported in Table 4a, the model explains 35.9% of the variance in ENV ($R^2 = 0.359$) through EXT and 63.8% of the variance in GLP ($R^2 = 0.638$) through ENV, EXT, ECO, INT and TEC. Predictive relevance is indicated by cross-validated Q^2 values of 0.317 for ENV and 0.509 for GLP (Hair et al. 2021). Table 4b also reports the bootstrapped path coefficients and hypothesis tests. Perceived cost-effectiveness has the strongest direct effect on adoption (GLP), followed by TEC and EXT, whereas INT are not significant. External pressure also significantly predicts environmental-social awareness (EXT $\rightarrow$ ENV), supporting the proposed awareness mechanism.

In detail, hypothesis testing reveals that ENV ($\beta = 0.300$, $p = 0.009$), EXT ($\beta = 0.379$, $p < 0.001$), ECO ($\beta = 0.486$, $p < 0.001$)

TABLE 2: Indicator loadings, reliability and convergent validity.

Construct	Indicator	Loading	Alpha	CR	AVE
EXT	-	-	0.965	0.977	0.934
	EXT1	0.960	-	-	-
	EXT2	0.971	-	-	-
	EXT3	0.968	-	-	-
TEC	-	-	0.962	0.976	0.930
	TEC1	0.966	-	-	-
	TEC2	0.969	-	-	-
	TEC3	0.958	-	-	-
INT	-	-	0.893	0.934	0.824
	INT1	0.905	-	-	-
	INT2	0.891	-	-	-
	INT3	0.928	-	-	-
ECO	-	-	0.955	0.971	0.918
	ECO1	0.954	-	-	-
	ECO2	0.964	-	-	-
	ECO3	0.957	-	-	-
ENV	-	-	0.955	0.971	0.917
	ENV1	0.958	-	-	-
	ENV2	0.957	-	-	-
	ENV3	0.958	-	-	-
GLP	-	-	0.960	0.974	0.925
	GLP1	0.961	-	-	-
	GLP2	0.961	-	-	-
	GLP3	0.964	-	-	-

EXT, external pressure; TEC, technological infrastructure; INT, internal capabilities; ECO, perceived cost-effectiveness; ENV, environmental-social awareness; GLP, green logistics adoption; AVE, average variance extracted; CR, composite reliability.

TABLE 3: Discriminant validity.

Variable	Construct	ENV	EXT	ECO	INT	TEC	GLP
Fornell–Larcker criterion	ENV	0.958	0.599	-0.189	-0.082	-0.070	0.416
	EXT	0.599	0.966	-0.034	-0.039	-0.057	0.525
	ECO	-0.189	-0.034	0.958	0.258	0.091	0.437
	INT	-0.082	-0.039	0.258	0.908	0.005	0.059
	TEC	-0.070	-0.057	0.091	0.005	0.964	0.324
	GLP	0.416	0.525	0.437	0.059	0.324	0.962
HTMT	ENV	1.000	0.624	0.199	0.095	0.072	0.433
	EXT	0.624	1.000	0.039	0.073	0.058	0.546
	ECO	0.199	0.039	1.000	0.281	0.095	0.455
	INT	0.095	0.073	0.281	1.000	0.065	0.069
	TEC	0.072	0.058	0.095	0.065	1.000	0.339
	GLP	0.433	0.546	0.455	0.069	0.339	1.000

EXT, external pressure; TEC, technological infrastructure; INT, internal capabilities; ECO, perceived cost-effectiveness; ENV, environmental-social awareness; GLP, green logistics adoption; HTMT, heterotrait-monotrait.

and TEC ($\beta = 0.322$, $p < 0.001$) have significant positive effects on GLP, supporting H1, H2, H3 and H5. Internal capabilities are not significant ($\beta = -0.032$, $p = 0.752$), rejecting H4. External pressure significantly predicts ENV ($\beta = 0.593$, $p < 0.001$). The indirect effect of EXT on GLP through ENV is significant ($\beta = 0.178$, $p = 0.009$), supporting H6 and indicating partial mediation.

Effect size estimates in Table 5 suggest a large contribution from ECO ($f^2 = 0.575$), while TEC ($f^2 = 0.285$) and EXT ($f^2 = 0.254$) have medium effects, and ENV has a small-to-medium effect ($f^2 = 0.150$) based on conventional benchmarks (Cohen 1988). Internal capabilities have a negligible effect ($f^2 = 0.002$).

For collinearity assessment, inner VIF values shown in Table 6 range from 1.000 to 1.634, which is well below conservative thresholds commonly used in PLS-SEM (Hair et al. 2021; Kock 2015), indicating no problematic multicollinearity among predictors.

Full collinearity VIF values (shown in Table 6) are below 3.3, suggesting that CMB is unlikely to threaten the substantive conclusions (Kock 2015).

In short, the structural model supports H1, H2, H3 and H5, while H4 is not supported. External pressure strongly predicts ENV (EXT $\rightarrow$ ENV), and the bootstrapped indirect effect (EXT $\rightarrow$ ENV $\rightarrow$ GLP) is significant, indicating partial mediation, with the variance accounted for (VAF) of approximately 32%.

Discussion

This study investigated determinants of GLP among manufacturing enterprises in Thai Nguyen province by integrating a TPB-consistent cognitive mechanism with TOE-based contextual determinants. The results help

TABLE 4a: Structural model results and hypothesis testing (bootstrapping, 2000 resamples).

Endogenous construct	Explained variance and predictive relevance	
	R^2	Cross-validated R^2/Q^2
ENV	0.359	0.317
GLP	0.638	0.509

ENV, environmental-social awareness; GLP, green logistics adoption.

TABLE 4b: Structural model results and hypothesis testing (bootstrapping, 2000 resamples).

Path coefficients	β	s.e.	<i>t</i>	<i>p</i> -value	CI 2.5%	CI 97.5%	Result
EXT → ENV	0.593	0.109	5.442	< 0.001	0.406	0.823	Supported
ENV → GLP	0.300	0.121	2.484	0.009	0.058	0.527	Supported
EXT → GLP	0.379	0.117	3.246	< 0.001	0.160	0.612	Supported
ECO → GLP	0.486	0.088	5.514	< 0.001	0.299	0.660	Supported
INT → GLP	-0.032	0.102	-0.310	0.752	-0.252	0.154	Not supported
TEC → GLP	0.322	0.080	4.008	< 0.001	0.178	0.488	Supported
EXT → ENV → GLP (indirect)	0.178	0.076	2.349	0.009	0.033	0.330	Supported

EXT, external pressure; TEC, technological infrastructure; INT, internal capabilities; ECO, perceived cost-effectiveness; ENV, environmental-social awareness; GLP, green logistics adoption; s.e., standard error; CI, confidence interval.

TABLE 5: Effect size (f^2) for predictors of green logistics adoption.

Predictor	f^2
ENV → GLP	0.150
EXT → GLP	0.254
ECO → GLP	0.575
INT → GLP	0.002
TEC → GLP	0.285

EXT, external pressure; TEC, technological infrastructure; INT, internal capabilities; ECO, perceived cost-effectiveness; ENV, environmental-social awareness; GLP, green logistics adoption.

TABLE 6: Collinearity assessment.

Variable	Endogenous construct	Predictor	VIF	Construct (as DV)	Max full collinearity VIF
Inner VIF	GLP	ENV	1.634	-	-
	GLP	EXT	1.577	-	-
	GLP	ECO	1.124	-	-
	GLP	INT	1.073	-	-
	GLP	TEC	1.013	-	-
	ENV	EXT	1.000	-	-
Full collinearity VIF (common method bias check)	-	-	-	ENV	2.398
	-	-	-	EXT	2.210
	-	-	-	ECO	1.895
	-	-	-	INT	2.760
	-	-	-	TEC	2.153
	-	-	-	GLP	1.634

EXT, external pressure; TEC, technological infrastructure; INT, internal capabilities; ECO, perceived cost-effectiveness; ENV, environmental-social awareness; GLP, green logistics adoption; DV, dependent variable; VIF, variance inflation factor.

explain both why managers are willing to adopt green logistics and under what conditions such adoption becomes feasible in a provincial emerging-economy setting.

Firstly, ECO is the strongest predictor of adoption. This supports the view that firms in resource-constrained environments prioritise practices that have a clear business case. When managers believe that green logistics can reduce logistics costs, yield long-term competitive advantage and justify initial investment, they are substantially more likely to adopt. This is consistent with the ‘innovation offsets’ argument that environmental improvements can improve resource efficiency and competitiveness (Porter & Van der Linde 1995), and it aligns with evidence from green supply chain practice research in manufacturing contexts (Zhu & Sarkis 2004). The strong effect size suggests that economic feasibility perceptions may be a decisive lever for accelerating green logistics diffusion in provincial settings.

Secondly, EXT matters both directly and indirectly. The direct path indicates that customer demands, competitor behaviour

and policy signals can motivate adoption without necessarily being fully internalised as values. This is consistent with institutional arguments that coercive, normative and mimetic pressures shape organisational practices (DiMaggio & Powell 1983). The significant indirect effect through ENV suggests that pressures become more influential when they are interpreted as meaningful and aligned with environmental and social values. The partial mediation indicates a dual mechanism: compliance and market access on the one hand, and value internalisation on the other.

Thirdly, TEC is a significant enabler. Firms with better access to modern logistics technologies and supporting infrastructure are more capable of implementing greener practices. This aligns with the TOE view that technological readiness shapes adoption feasibility and with evidence that digitalisation and analytics improve logistics efficiency and sustainability by enabling monitoring, optimisation and coordination (Kamble et al. 2018; Wang et al. 2016). In provincial settings where technological access is uneven, improving infrastructure and digital readiness can therefore have a meaningful impact on GLP.

Fourthly, INT are not a significant direct predictor. This may indicate that general organisational capabilities are not sufficient unless they are specifically oriented towards green logistics. Another explanation is that external and economic factors dominate decision-making, reducing the apparent importance of internal capability differences. From a resource-based perspective, only certain specialised and difficult-to-imitate capabilities may drive green adoption (Barney 1991). This implies that capability-building initiatives should focus on targeted green logistics competencies, such as emissions accounting for logistics, green procurement, transport planning and cross-functional governance.

Practical and policy implications

Managerial implications

For managers, the findings highlight the need to quantify and communicate the cost-benefit case for green logistics internally (Porter & Van der Linde 1995). Because ECO is the strongest driver, managers should quantify the financial and operational benefits of green logistics. Useful approaches include total cost of ownership and life-cycle costing for transport and warehouse investments, fuel and energy audits and pilot projects that demonstrate measurable savings (e.g. fuel reduction via route optimisation or improved load

planning). Communicating results internally can strengthen organisational commitment and reduce resistance.

Leverage technology to enable visible gains: Investments in tracking, planning and analytics can generate early wins by improving visibility and optimising resource use. Even relatively low-cost digital tools (e.g. basic fleet monitoring, inventory visibility, transport management modules) can help firms reduce waste and improve performance, reinforcing cost-effectiveness perceptions and facilitating scaling (Wang et al. 2016).

To Translate EXT into internal commitment, because EXT has both direct and awareness-mediated effects, firms should treat customer and regulatory requirements as opportunities for capability development rather than as short-term compliance tasks. Managers can institutionalise sustainability by embedding green logistics goals into performance metrics, supplier evaluation and logistics strategy, converting external signals into internal routines.

Develop specialised green logistics capabilities: The non-significant INT result does not imply that capabilities are irrelevant; rather, it suggests that generic capabilities may not be enough. Firms can invest in targeted training for logistics staff, establish cross-functional sustainability teams, and create specific programmes (e.g. green transport planning standards, packaging reduction initiatives, reverse logistics planning) that directly support green logistics implementation.

Policy implications

For policymakers and local authorities, interventions should reduce economic barriers and perceived risk. Incentives such as tax benefits for green logistics investments, subsidised loans, green financing programmes or shared facilities can improve the economic feasibility of adoption and strengthen cost-effectiveness perceptions.

Strengthen awareness-building and diffusion mechanisms. Because awareness mediates part of the EXT effect, policy tools should not rely solely on enforcement. Training programmes, dissemination of best practices, and local demonstration projects can increase ENV and help firms interpret sustainability requirements as beneficial and legitimate (Rastegardebidi & Su 2025).

Improve access to enabling technologies and infrastructure. Public investment in transport and digital infrastructure, along with programmes that help firms adopt logistics information systems, can increase technological readiness. Supporting collaboration platforms (e.g. shared logistics services or consolidation hubs) may help smaller firms access green logistics solutions that require scale.

Conclusion

Limitations and future research

This study examined drivers of GLP among manufacturing enterprises in Thai Nguyen province, Vietnam, by integrating

TPB and TOE and applying PLS-SEM. Environmental-social awareness, EXT, ECO and TEC significantly and positively influence adoption, whereas INT are not significant. Environmental-social awareness also partially mediates the effect of EXT on adoption, indicating that institutional and market signals promote adoption both directly and through internalised managerial awareness. Overall, the model explains a substantial share of adoption variance and shows predictive relevance.

In addition, limitations should be considered when interpreting the findings. Firstly, the cross-sectional design cannot fully capture dynamic adoption processes. Secondly, the sample is modest and focused on one province; results may not generalise to other regions or sectors. Thirdly, measures are self-reported and may be influenced by perceptual bias, although reliability and validity checks and collinearity-based diagnostics suggest robust measurement. Finally, collecting two responses per enterprise helps mitigate single-informant bias, but future studies could further examine within-firm agreement, apply multilevel methods or aggregate measures at the firm level.

Future research could extend the model to multiple provinces and industries, incorporate longitudinal data and combine perceptual measures with objective indicators (e.g. logistics emissions, energy use, delivery performance). Additional antecedents such as green financing access, supply chain integration, organisational culture and collaboration with logistics service providers could be incorporated to further explain adoption heterogeneity.

Acknowledgements

We would like to express our sincere gratitude to Thai Nguyen University of Economics and Business Administration in particular, and Thai Nguyen University in general, for providing the opportunity and support that enabled our research group to complete this study.

Our appreciation also extends to colleagues and collaborators who contributed insightful feedback and valuable discussions that enriched the quality of this work.

Finally, we would like to acknowledge the support and understanding of our families and friends, whose patience and encouragement were vital during this research.

During the preparation of this work, the authors used ChatGPT 5.0 to correct the language only. The content was reviewed and edited by the authors, who take full responsibility for its accuracy.

Competing interests

The authors reported that they received funding from Thai Nguyen University, which may be affected by the research reported in the enclosed publication. The authors has disclosed those interests fully and has implemented an

approved plan for managing any potential conflicts arising from their involvement. The terms of these funding arrangements have been reviewed and approved by the affiliated University in accordance with its policy on objectivity in research.

CRedit authorship contribution

Thi Thanh Mai Pham: Investigation, Supervision, Writing – original draft. Trung Kien Dang: Conceptualisation, Methodology, Validation, Writing – review & editing. Manh Hung Nguyen: Funding acquisition, Project administration, Resources. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

Funding information

This work was supported by the Thai Nguyen University, Vietnam (grant number: ĐH2025- TN01-02).

Data availability

The datasets generated and analysed during the current study were collected by the authors through survey instruments. The data that support the findings of this study are not openly available due to privacy and confidentiality considerations and are available from the corresponding author, Trung Kien Dang, upon reasonable request.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings, and content.

References

- Ajzen, I., 1991, 'The theory of planned behavior', *Organizational Behavior and Human Decision Processes* 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Bag, S., Wood, L.C., Xu, L., Dhamija, P. & Kayikci, Y., 2020, 'Big data analytics as an operational excellence approach to enhance sustainable supply chain performance', *Resources, Conservation and Recycling* 153, 104559. <https://doi.org/10.1016/j.resconrec.2019.104559>
- Barney, J., 1991, 'Firm resources and sustained competitive advantage', *Journal of Management* 17(1), 99–120. <https://doi.org/10.1177/014920639101700108>
- Centobelli, P., Cerchione, R. & Esposito, E., 2017, 'Environmental sustainability in the service industry of transportation and logistics service providers: Systematic literature review and research directions', *Transportation Research Part D: Transport and Environment* 53, 454–470. <https://doi.org/10.1016/j.trd.2017.04.032>
- Cohen, J., 1988, *Statistical power analysis for the behavioral sciences*, 2nd edn., Lawrence Erlbaum Associates, Hillsdale, NJ.
- Dekker, R., Bloemhof, J.M. & Mallidis, I., 2012, 'Operations research for green logistics – An overview of aspects, issues, contributions and challenges', *European Journal of Operational Research* 219(3), 671–679. <https://doi.org/10.1016/j.ejor.2011.11.010>
- DiMaggio, P.J. & Powell, W.W., 1983, 'The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields', *American Sociological Review* 48(2), 147–160. <https://doi.org/10.2307/2095101>
- Evangelista, P., 2014, 'Environmental sustainability practices in the transport and logistics service industry: An exploratory case study investigation', *Research in Transportation Business & Management* 12, 63–72. <https://doi.org/10.1016/j.rtbm.2014.10.002>
- Fornell, C. & Larcker, D.F., 1981, 'Evaluating structural equation models with unobservable variables and measurement error', *Journal of Marketing Research* 18(1), 39–50. <https://doi.org/10.1177/002224378101800104>
- Hair, J.F., Hult, G.T.M., Ringle, C.M. & Sarstedt, M., 2021, *A primer on partial least squares structural equation modeling (PLS-SEM)*, 3rd edn., Sage, Thousand Oaks, CA.
- Henseler, J., Ringle, C.M. & Sarstedt, M., 2015, 'A new criterion for assessing discriminant validity in variance-based structural equation modeling', *Journal of the Academy of Marketing Science* 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- Kamble, S.S., Gunasekaran, A. & Gawankar, S.A., 2018, 'Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives', *Process Safety and Environmental Protection* 117, 408–425. <https://doi.org/10.1016/j.psep.2018.05.009>
- Kock, N., 2015, 'Common method bias in PLS-SEM: A full collinearity assessment approach', *International Journal of e-Collaboration* 11(4), 1–10. <https://doi.org/10.4018/ijec.2015100101>
- Lin, C.-Y. & Ho, Y.-H., 2011, 'Determinants of green practice adoption for logistics companies in China', *Journal of Business Ethics* 98(1), 67–83. <https://doi.org/10.1007/s10551-010-0535-9>
- Pan, S., Ballot, E. & Fontane, F., 2013, 'The reduction of greenhouse gas emissions from freight transport by pooling supply chains', *International Journal of Production Economics* 143(1), 86–94. <https://doi.org/10.1016/j.ijpe.2010.10.023>
- Porter, M.E. & Van der Linde, C., 1995, 'Toward a new conception of the environment-competitiveness relationship', *Journal of Economic Perspectives* 9(4), 97–118. <https://doi.org/10.1257/jep.9.4.97>
- Rastegardebidi, P. & Su, Z., 2025, 'Key drivers of green logistics: A systematic literature review and conceptual framework', *Sustainability* 17(21), 9604. <https://doi.org/10.3390/su17219604>
- Sbihi, A. & Egglese, R., 2010, 'Combinatorial optimization and green logistics', *Annals of Operations Research* 175(1), 159–175. <https://doi.org/10.1007/s10479-009-0651-z>
- Seuring, S. & Müller, M., 2008, 'From a literature review to a conceptual framework for sustainable supply chain management', *Journal of Cleaner Production* 16(15), 1699–1710. <https://doi.org/10.1016/j.jclepro.2008.04.020>
- Tornatzky, L.G., Fleischer, M. & Chakrabarti, A.K., 1990, *The processes of technological innovation*, Lexington Books, Lexington, MA.
- Wang, G., Gunasekaran, A., Ngai, E.W.T. & Papadopoulos, T., 2016, 'Big data analytics in logistics and supply chain management: Certain investigations for research and applications', *International Journal of Production Economics* 176, 98–110. <https://doi.org/10.1016/j.ijpe.2016.03.014>
- Zhu, Q. & Sarkis, J., 2004, 'Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises', *Journal of Operations Management* 22(3), 265–289. <https://doi.org/10.1016/j.jom.2004.01.005>
- Zhu, Q., Sarkis, J. & Lai, K.-H., 2007, 'Green supply chain management: Pressures, practices and performance within the Chinese automobile industry', *Journal of Cleaner Production* 15(11–12), 1041–1052. <https://doi.org/10.1016/j.jclepro.2006.05.021>