

Assessing consumer adoption of smart lockers for sustainable e-commerce delivery

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ABSTRACT

The growth of e-commerce has intensified last-mile delivery challenges, including failed deliveries, repeated delivery attempts, and fragmented parcel flows. Smart parcel lockers offer a flexible delivery alternative that may facilitate parcel consolidation and reduce failed delivery attempts when supported by sustained consumer use and appropriate service conditions. This study applies the Decomposed Theory of Planned Behavior (DTPB) to examine continued smart locker usage intention among 316 experienced consumers in Taiwan. Data were analyzed using confirmatory factor analysis and structural equation modeling. The results show that perceived usefulness, perceived ease of use, and compatibility positively influence attitude, with compatibility exerting the strongest effect. Peer and platform influence strengthen subjective norms, while self-efficacy and contextual conditions enhance perceived behavioral control. Attitude, subjective norms, and perceived behavioral control all positively affect continued usage intention. The study provides a contextual application of DTPB to a technology-enabled parcel-delivery service and highlights the importance of service fit, social influence, user confidence, and facilitating conditions. The findings identify behavioral conditions that may support wider locker utilization and more coordinated last-mile delivery, while the associated operational and environmental outcomes remain dependent on actual usage and service implementation.

1. Introduction

The rapid growth of e-commerce has intensified pressure on last-mile delivery systems. Global e-commerce sales exceeded US\$6.3 trillion in 2024 and are expected to surpass US\$6.8 trillion in 2025 (eMarketer, 2025). As online shopping becomes embedded in everyday consumption, parcel delivery has become central to customer service and logistics performance. This expansion has also increased sustainability concerns in urban distribution, where fragmented orders, recipient absence, repeated delivery attempts, and inefficient vehicle movements may increase operating costs, resource use, and environmental burdens.

Failed delivery is particularly problematic in densely populated urban areas, where parcel growth coincides with mobile lifestyles and limited recipient availability. An unsuccessful delivery may require another vehicle trip and additional handling, thereby reducing route efficiency and increasing transport activity. Re-delivery is therefore more than a service inconvenience; it is also a potential barrier to cleaner and more resource-efficient last-mile distribution. Logistics providers and e-commerce platforms have responded through delivery

notifications, flexible scheduling, collection points, and other alternative delivery arrangements (Lyu et al., 2025). Smart parcel lockers are one such option. These automated terminals allow consumers to retrieve parcels securely at flexible times, reducing dependence on attended home delivery and potentially avoiding repeated delivery attempts (Chen et al., 2023). Delivering several parcels to a shared location may also improve consolidation and delivery predictability. Previous research has associated smart lockers with convenience, parcel security, temporal flexibility, and more efficient last-mile operations (Duong et al., 2024).

Taiwan offers a relevant setting for examining continued smart locker use. Its e-commerce delivery system combines attended home delivery with extensive convenience-store pickup and self-service collection. Convenience stores have become familiar logistics nodes that allow consumers to send and collect parcels beyond conventional business hours. Chunghwa Post has also expanded its iBox network and linked it with convenience-store parcel channels. In 2024, cooperation with FamilyMart enabled domestic parcels to be sent from more than 4000 stores to 2408 iBox units nationwide (Chunghwa Post Co, 2024).

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These services illustrate the diversification of Taiwan's last-mile delivery environment and place smart lockers in direct competition with well-established home-delivery and store-pickup options.

This context makes service compatibility especially important. Continued use depends not only on locker availability but also on whether locations, collection procedures, access conditions, and collection deadlines fit consumers' commuting routes and daily routines. Smart lockers may support cleaner logistics by facilitating parcel consolidation and replacing failed or attended delivery attempts. Their environmental value, however, is conditional rather than automatic. Locker location, network density, compartment capacity, utilization, and consolidation efficiency influence whether delivery operations improve. A dense and well-used network may allow carriers to deliver multiple parcels to shared points, whereas poorly located or underused lockers may offer limited operational benefits while adding installation, maintenance, and replenishment requirements. Consumer travel behavior is equally important. Collection from a locker located along an existing commute or shopping trip may require little additional travel, whereas a dedicated trip by private vehicle may offset part of the potential environmental gain. Smart lockers should therefore be viewed as a delivery arrangement that may enable cleaner logistics under suitable network and behavioral conditions, not as an inherently low-emission solution. These potential benefits also depend on sustained consumer participation. Infrastructure alone does not ensure use, particularly where consumers can choose familiar home-delivery or convenience-store services. Perceived inconvenience, limited awareness, unsuitable locations, unfamiliar procedures, or insufficient value may discourage continued locker use. Consumer participation is thus an enabling condition for locker utilization and consolidated delivery, but it does not by itself establish improved environmental performance.

Research on smart lockers has mainly addressed facility location, network optimization, cost, and delivery efficiency (Yin et al., 2022; Yang et al., 2023). Less attention has been given to the consumer-side beliefs that sustain use after initial experience. This distinction matters because a technically sound locker system may remain underutilized when it does not fit users' routines, provide clear benefits, receive social support, or offer adequate facilitating conditions. Experienced users may also evaluate smart lockers differently from non-users: once basic operation is understood, continued use may depend more strongly on service fit, accumulated experience, and perceived control.

This study applies the Decomposed Theory of Planned Behavior (DTPB) to examine continued smart locker usage intention among consumers with prior experience in Taiwan. DTPB decomposes attitude, subjective norms, and perceived behavioral control into specific belief dimensions. In this study, perceived usefulness, perceived ease of use, and compatibility shape attitude; peer and platform influence shape subjective norms; and self-efficacy and contextual conditions shape perceived behavioral control. The framework provides a structured explanation of the functional, social, and control-related beliefs associated with continued use. The intended contribution is contextual and empirical rather than a substantive extension of DTPB. The study assesses the relevance and relative importance of established DTPB beliefs in a technology-enabled parcel-delivery setting and clarifies how consumer participation may affect the utilization of alternative last-mile infrastructure. It also links technology-adoption research with logistics service design by interpreting compatibility as the fit between locker use and established mobility and lifestyle patterns.

The empirical scope remains deliberately bounded. The study examines continued usage intention rather than initial adoption, actual locker transactions, or sustainability performance. It does not measure failed-delivery rates, consolidation levels, vehicle movements, fuel consumption, resource use, emissions, or consumer collection travel. The findings therefore cannot demonstrate that smart locker use produces cleaner logistics outcomes. Instead, they identify behavioral conditions that may support locker utilization and create opportunities for consolidation and fewer failed delivery attempts. The results offer

practical guidance for logistics providers, online retailers, and platform operators seeking to encourage continued use through location planning, service design, communication, and user support. Greater participation may improve the conditions for consolidated delivery, but operational and environmental effects require separate evaluation using objective data on locker utilization, delivery routes, collection travel, resource use, and emissions.

The remainder of this paper is organized as follows. Section 2 reviews the literature on smart lockers, cleaner last-mile logistics, and DTPB. Section 3 presents the research model, hypotheses, measurement design, sampling procedure, and analytical methods. Section 4 reports empirical results. Section 5 discusses theoretical and managerial implications. Section 6 concludes the paper and outlines limitations and future research directions.

2. Literature review

2.1. Current development of smart lockers

Smart lockers have emerged as a technology-enabled solution for last-mile delivery in e-commerce. A smart locker generally refers to an automated parcel storage and retrieval system that enables consumers to collect or return items through secure self-service terminals (Quan et al., 2022). Unlike conventional parcel collection arrangements, smart lockers are usually integrated with electronic locks, sensors, centralized data platforms, and mobile interfaces, allowing authentication, tracking, contactless access, and flexible collection. These features make them increasingly relevant in urban logistics, where failed home deliveries, rising parcel volumes, and consumer demand for convenience continue to pressure last-mile operations (Tang et al., 2021; Zhang and Demir, 2025).

Existing research on smart lockers has developed around several related themes. Studies on consumer perceptions and service quality show that convenience, reliability, security, and timeliness are central to user satisfaction (Tang et al., 2021; Lai et al., 2022). Quan et al. (2022) further indicate that convenience, privacy and security, and reliability significantly influence satisfaction with smart locker services in online shopping. Another stream examines deployment and system design, particularly locker location, capacity, and service-area planning. Che et al. (2022) and Kahr (2022) demonstrate that spatial configuration strongly affects operational efficiency and network coverage.

The diffusion of smart lockers reflects their value as both a logistics innovation and a consumer-facing service innovation. From an operational perspective, they may reduce failed deliveries, consolidate parcel drop-offs, and improve route efficiency, although these benefits depend on network density, parcel volume, and consumer collection behavior. Recent studies also suggest that locker-based and pickup-point solutions can generate efficiency and cost advantages under appropriate conditions (Hovi and Bø, 2024; Mohri et al., 2024). However, consumer adoption remains shaped by accessibility, familiarity, perceived ease of use, and fit with daily routines. Thus, smart lockers require attention to technological design, spatial accessibility, and behavioral acceptance simultaneously. Please see Table 1 for the selected studies on smart lockers.

2.2. Decomposed Theory of Planned Behavior (DTPB)

DTPB was proposed by Taylor and Todd (1995a, 1995b) to enhance the explanatory power of the Theory of Planned Behavior (TPB) in technology adoption research. TPB suggests that behavioral intention is determined by attitude, subjective norm, and perceived behavioral control (Ajzen, 1985). DTPB retains this structure while decomposing each determinant into more specific belief-based antecedents. By integrating insights from the Technology Acceptance Model (TAM) (Davis et al., 1989) and Innovation Diffusion Theory (IDT) (Rogers, 1983), DTPB provides a more detailed explanation of how adoption intentions

Table 1
Current research on investigating smart lockers.

Author	Main focus	Supporting issue
Tang et al. (2021)	Consumer perceptions of IoT-based smart parcel lockers in China	Useful for defining smart lockers and linking service quality to user perceptions
Lai et al. (2022)	Determinants of customer satisfaction with parcel locker services	Supports claims on timeliness, reliability, and security as key service attributes
Quan et al. (2022)	Smart locker adoption and online shopping satisfaction in Vietnam	Supports discussion on customer experience and satisfaction effects
Che et al. (2022)	Multi-objective planning of smart parcel locker service areas	Supports literature on locker placement and network design
Kahr (2022)	Determining parcel locker locations and layouts	Supports optimization and system configuration discussion
Chen et al. (2024)	Stationary versus mobile parcel lockers	Shows recent development toward differentiated locker formats and contextual consumer choice
Hovi and Bo (2024)	Efficiency and environmental performance of parcel lockers and pickup points	Supports discussion of operational efficiency and sustainability
Mohri et al. (2024)	Benefits of on-premises parcel lockers	Supports broader stakeholder value beyond consumers, including carriers and local governments
Kokkinou et al. (2025)	Pre-delivery interventions for encouraging locker use	Supports role of familiarity, perceived ease of use, and distance/accessibility
Zhang and Demir (2025)	Systematic literature review of parcel locker solutions	Supports broad statement on current development trends in the field

are formed.

Within DTPB, attitude is commonly shaped by perceived usefulness, perceived ease of use, and compatibility; subjective norm reflects the influence of important referent groups; and perceived behavioral control is explained through self-efficacy and facilitating conditions. Compared with the broader TPB framework, DTPB offers richer insight into the cognitive, social, and control-related factors influencing technology adoption.

Previous studies have demonstrated the applicability of DTPB across diverse innovation and technology contexts. Garay et al. (2019) applied DTPB to sustainability innovation adoption in the accommodation sector and found that attitudes, social norms, and perceived behavioral control significantly influenced organizational behavior. Jouda et al. (2020) extended the model by incorporating trust in mobile banking adoption, while Sadaf and Gezer (2020) showed that perceived usefulness and self-efficacy strongly influenced teachers' intentions to integrate digital literacy. More recent research further confirms the continuing relevance of DTPB. Al-Adwan et al. (2024a) employed an extended DTPB framework to explain higher education students' adoption of meta-education technologies, whereas Li et al. (2024) demonstrated that perceived usefulness, subjective norms, and self-efficacy significantly shaped older adults' telemedicine usage intentions. Similarly, Hu and Yang (2025) applied a decomposed behavioral framework to autonomous bus adoption and found that interpersonal influence and self-efficacy were important determinants of behavioral intention. Huang et al. (2025) also confirmed the applicability of DTPB in technology-intensive service settings involving older adults' continuous usage intentions.

A keyword search for {"Smart Locker" and "Intention"} on Web of Science from 2014 to 2024 yielded several related studies. While these works (i.e., Cai et al., 2021; Tang et al., 2021; Quan et al., 2022; Nguyen et al., 2024) explored smart locker applications, none explicitly adopted the DTPB. DePLite this, DTPB has proven effective in understanding technology adoption, making it an appropriate framework for investigating consumer intentions to use smart lockers. DTPB breaks down the

components of the Theory of Planned Behavior (attitudes, subjective norms, and perceived behavioral control) into specific factors. For smart lockers, attitudes may include perceived convenience, security, and efficiency, while subjective norms relate to social influences like peer recommendations and trends toward contactless deliveries. Perceived behavioral control encompasses ease of use, accessibility, and locker availability. This approach offers nuanced insights into consumer decision-making, making DTPB a valuable theoretical foundation for studying smart locker services. Given the limited application of DTPB in this context, it provides a robust framework for the current study.

3. Research methodology

3.1. Research hypothesis

Attitude refers to consumers' favorable or unfavorable evaluation of using smart parcel lockers. Within DTPB, attitude is influenced by perceived usefulness, ease of use, and compatibility. Perceived usefulness reflects the extent to which smart lockers enhance convenience, reduce missed deliveries, and improve service quality. Previous studies have shown that perceived usefulness positively influences attitudes toward technology-enabled services and digital innovations (Sadaf and Gezer, 2020; Cai et al., 2021). Similar findings have been reported in cross-border e-commerce, FinTech, and banking contexts (Yang and Kim, 2024; Al Mamun et al., 2025; Tanchangya et al., 2026). In the smart locker context, usefulness is associated with flexible parcel collection and reduced delivery uncertainty. Accordingly, the following hypothesis is proposed:

H1. : Perceived usefulness has a positive impact on attitude.

Perceived ease of use refers to the extent to which consumers believe that smart locker services are simple to understand, learn, and operate. Technologies perceived as intuitive and effortless are more likely to generate favorable evaluations, whereas complex systems may create resistance. Previous studies have consistently shown that perceived ease of use positively influences attitudes toward technology adoption. For example, Yang and Kim (2024) found this relationship in virtual fitting technology adoption, while Tanchangya et al. (2026) and Chen et al. (2025b) reported similar effects in banking services and humanoid robot usage, respectively. In the smart locker context, ease of use may enhance consumers' evaluations of parcel collection services. Accordingly, the following hypothesis is proposed:

H2. : Perceived ease of use has a positive impact on attitude.

Compatibility refers to the extent to which smart locker services align with consumers' existing habits, preferences, and delivery needs. Services that fit users' routines and prior experiences generally require less behavioral adjustment and are therefore more likely to be evaluated positively. Previous studies have highlighted the importance of compatibility in technology adoption contexts. Wang et al. (2020) found that compatibility influenced consumers' attitudes toward innovative last-mile logistics services, while Ursavaş et al. (2025) identified compatibility as a significant antecedent of attitudes toward generative AI adoption in higher education. In the smart locker context, compatibility may enhance positive evaluations when the service aligns with consumers' schedules and parcel collection preferences. Accordingly, the following hypothesis is proposed:

H3. : Compatibility has a positive impact on attitude.

Subjective norms reflect perceived social pressure or support regarding smart locker use. From the DTPB perspective, normative beliefs are shaped by salient referent groups and institutional signals. Peer influence refers to expectations, recommendations, or behavioral cues from family members, friends, and colleagues. When a service is not yet habitual, consumers may rely on close social circles to assess whether its use is desirable, practical, or socially appropriate. Recent studies

confirm that social influence remains important in digital adoption contexts, including metaverse commerce, digital payment adoption, and emerging digital services (Al-Adwan et al., 2024a; He et al., 2025; Li et al., 2025). In the smart locker context, subjective norms may strengthen when close referents signal that locker use is convenient, reasonable, or increasingly common. Accordingly, the following hypothesis is proposed:

H4. : Peer influence has a positive impact on subjective norms.

In this study, platform influence refers to encouragement and recommendation cues provided by e-commerce platforms and service providers. Such influence may occur when retailers promote smart lockers during checkout or present them as efficient and preferred delivery options. Previous studies suggest that platform-related and institutional signals can significantly shape consumer perceptions and behavior in digital commerce environments. Zhang and Li (2024) found that platform-related signals influence consumer responses in online promotional settings, while Chen et al. (2025a) and Usman et al. (2025) showed that recommendation messages and sources affect consumers' evaluations and intentions. In delivery-option selection, these platform signals may shape perceptions of appropriate and convenient choices. Accordingly, the following hypothesis is proposed:

H5. : Platform influence has a positive impact on subjective norms.

Within the DTPB, self-efficacy and perceived behavioral control are related but distinct. Self-efficacy refers to an individual's confidence in performing the tasks required for a specific behavior. In the smart locker context, it reflects consumers' confidence in selecting a locker, understanding notifications, using access codes or mobile applications, operating the interface, and collecting parcels without assistance. Perceived behavioral control is broader because it concerns whether continued smart locker use is generally perceived as manageable and under the consumer's control. It reflects both internal capability and external conditions. A consumer may feel capable of operating a locker but still perceive limited control when lockers are inconveniently located, unavailable, full, inaccessible at suitable times, or supported by unreliable service systems. Self-efficacy is therefore treated as an antecedent of perceived behavioral control rather than an equivalent construct. Confidence in completing the required tasks strengthens consumers' perceptions that smart locker use is manageable, while overall control also depends on contextual and facilitating conditions. Previous technology-adoption studies similarly distinguish personal capability from broader perceptions of behavioral control (Bortne et al., 2025; Jia et al., 2025; Abdalla and Al-Hadhrani, 2025). Accordingly, the following hypothesis is proposed:

H6. : Self-efficacy has a positive effect on perceived behavioral control.

Contextual conditions refer to external resources and facilitating circumstances that enable or constrain behavior. In the smart locker context, these conditions include accessible locations, available compartments, convenient operating access, reliable systems, clear collection procedures, and adequate technical or customer support. They influence whether continued smart locker use is perceived as feasible and under the consumer's control. Contextual conditions are distinct from perceived usefulness. Perceived usefulness reflects the benefits consumers expect from smart locker use, such as greater delivery flexibility, less waiting, time savings, or lower delivery-related costs. Contextual conditions instead concern whether the surrounding service environment provides the resources required to use the service successfully. A consumer may regard smart lockers as useful but still perceive limited control when nearby lockers are unavailable, frequently full, difficult to access, or supported by unreliable notification systems. Thus, perceived usefulness reflects the value of the service, whereas contextual conditions reflect its practical feasibility. Previous studies identify facilitating conditions as an important determinant of

perceived behavioral control and technology-use feasibility (Jouda et al., 2020; Abdul Wahi and Berenyi, 2024). Accessible infrastructure, sufficient capacity, reliable operation, and appropriate support are therefore expected to strengthen consumers' perceived control over continued smart locker use. Accordingly, the following hypothesis is proposed:

H7. : Contextual conditions have a positive impact on perceived behavioral control.

Finally, DTPB proposes that attitude, subjective norms, and perceived behavioral control directly influence behavioral intention. These relationships remain central to the explanatory logic of TPB-based models and continue to be validated in recent technology adoption research. For example, Al-Adwan et al. (2024b) confirm that attitude, social influence, and perceived behavioral control significantly determine consumers' behavioral intentions in digital commerce environments. Similarly, Li et al. (2024) demonstrate that these three dimensions jointly influence users' intentions in telemedicine adoption, reinforcing the robustness of the TPB structure in emerging service contexts. In the smart locker setting, behavioral intention reflects consumers' willingness to use the service in the future, increase their frequency of use, and recommend it to others. When consumers evaluate smart lockers positively, perceive social support from relevant others, and believe they are capable of using the service, they are more likely to form a strong intention to adopt it. Accordingly, the following hypotheses are proposed:

H8. : Attitude has a positive impact on Behavioral intention.

H9. : Subjective norm has a positive impact on Behavioral intention.

H10. : Perceived behavioral control has a positive impact on Behavioral intention.

3.2. Research framework

The primary objective of this study is to investigate the determinants that shape consumers' intentions to adopt smart lockers in the context of e-commerce delivery services. Drawing on the literature reviewed in Section 2, the research framework was developed with reference to the DTPB, while introducing context-specific modifications to better capture the behavioral characteristics of smart locker use. DTPB offers a robust framework for explaining behavioral intention through the decomposition of salient attitudinal, normative, and control-related beliefs. Given the distinctive features of smart locker services as a technology-enabled and service-based delivery option, the present study adapts this framework to reflect the relevant decision factors in this setting. The resulting research framework is presented in Fig. 1.

3.3. Sampling questionnaire design

Data were collected through an online questionnaire because this method offers efficient distribution, broad geographical coverage, and respondent anonymity (Iacobucci and Churchill, 2018). The target population comprised consumers in Taiwan with prior smart parcel locker experience, allowing service attributes to be evaluated based on actual use rather than hypothetical expectations. Before formal distribution, five industry experts and scholars reviewed and pre-tested the questionnaire for clarity, relevance, and contextual appropriateness. Item wording and presentation were refined based on their feedback. Purposive and snowball sampling were then used between January 28 and March 31, 2024. A screening question identified prior locker experience. Of 367 responses, 51 from non-users were excluded, leaving 316 valid questionnaires and an effective response rate of 86.1%.

Because all retained respondents had already used smart lockers, the dependent variable is interpreted as continued usage or post-adoption intention rather than initial adoption intention. The findings therefore

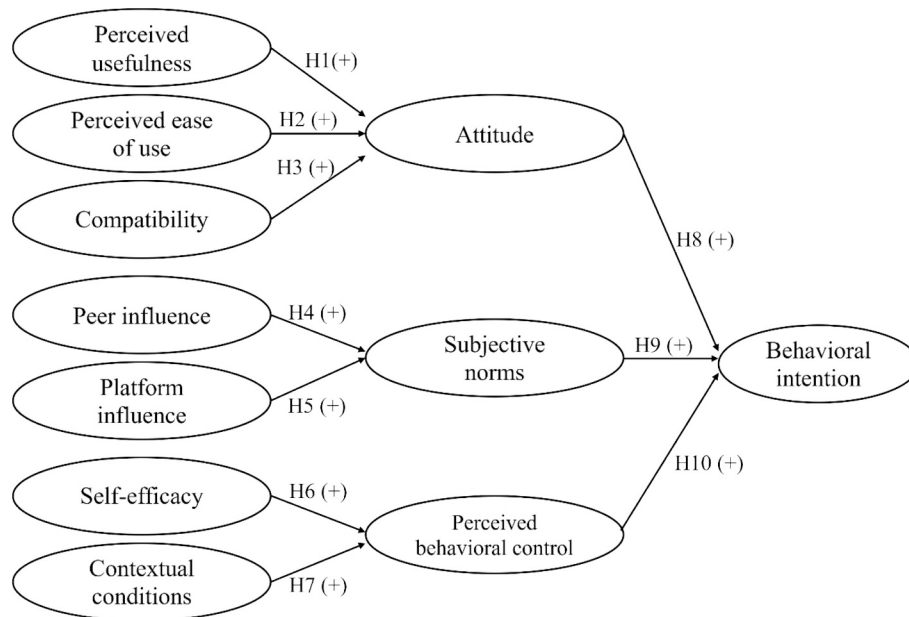


Fig. 1. Research framework.
Source: Authors own work.

explain how experienced users evaluate and intend to continue using the service but do not capture the perceptions or barriers of non-users. The questionnaire was developed from DTPB and related technology-adoption research. All constructs were measured using multi-item scales and a five-point Likert scale ranging from 1, “strongly disagree,” to 5, “strongly agree.” Items covering perceived usefulness, perceived ease of use, compatibility, social influence, self-efficacy, contextual conditions, attitude, subjective norms, perceived behavioral control, and continued usage intention were adapted to the smart locker context. The full items and sources are presented in Table 2.

3.4. Data analysis methods

Data analysis was conducted using software SPSS 21 and AMOS 22. Descriptive statistics were used to summarize respondent characteristics, followed by assessments of non-response bias, common method variance, reliability, validity, and structural relationships. Non-response bias was examined by comparing early and late respondents. The early group comprised 210 questionnaires collected between January 28 and February 27, 2024, while the late group included 106 questionnaires collected between February 29 and March 31, 2024. Independent samples *t*-tests showed no significant differences between the two groups at the 95% confidence level, indicating a limited risk of non-response bias. Common method variance was addressed through procedural and statistical remedies (Podsakoff et al., 2003). Respondents were assured of anonymity and confidentiality and informed that there were no correct or incorrect answers. The measurement perspective for continued usage intention was also differentiated from that of the independent variables. Harman's single-factor test was then conducted using an unrotated exploratory factor analysis. Multiple factors emerged, and no single factor explained most of the variance, suggesting that common method variance was unlikely to dominate the results. However, because the data were cross-sectional and self-reported, this test cannot fully exclude method-related bias.

Internal consistency was assessed using Cronbach's alpha. Confirmatory factor analysis evaluated model fit, standardized loadings, composite reliability, and average variance extracted (Hair JR. et al., 2019). Values above 0.50 for factor loadings and AVE and above 0.70 for composite reliability indicated acceptable convergent validity.

Discriminant validity was supported when the square root of each construct's AVE exceeded its correlations with other constructs. Structural equation modeling was then used to test the proposed relationships. Model-fit indices and standardized path coefficients were examined simultaneously. Because all respondents had prior locker experience, the results reflect continued usage intention rather than initial adoption.

4. Analysis results

4.1. sampling

This study employs a combination of purposive and snowball sampling methods to select research participants, focusing on consumers with prior experience using smart lockers to examine their usage intentions. Data is collected through an online questionnaire survey conducted between January 28, 2024, and March 31, 2024. A total of 367 responses were gathered during this period. After excluding 51 responses from participants who had no experience with smart lockers, 316 valid questionnaires were retained, yielding an effective response rate of 86.1%.

4.2. Non-response bias

To ensure the absence of non-response bias in the collected data, an independent samples *t*-test is conducted. Based on the timeline for questionnaire distribution, the data are divided into two collection phases: the first phase, consisting of 210 questionnaires gathered between January 28, and February 27 in 2024, and the second phase, comprising 106 questionnaires collected between February 29, and March 31 in 2024. At 95% confidence level, the *t*-test results reveal no significant differences between the two phases of data collection. This finding suggests minimal risk of non-response bias, confirming that the sample is appropriate for further statistical analysis.

4.3. Common methods variance

Because all constructs were measured using self-reported responses collected from the same respondents through a single questionnaire,

Table 2
Dimensions, representative items, and literature sources.

Dimension	Code	Items	Literature
Perceived usefulness (PCU)	PCU1	I believe using smart lockers is convenient for retrieving my packages.	Xia et al. (2024); Nguyen et al. (2024); Lin et al. (2025); Nguyen et al. (2025)
	PCU2	I believe using smart lockers can improve the quality of my experience when retrieving my packages.	
	PCU3	I believe using smart lockers meets my requirements when retrieving my packages.	
	PCU4	Overall, I believe using smart lockers is useful.	
Perceived ease of use (PCE)	PCE1	I believe it is easy to learn how to operate a smart locker.	Cai et al. (2021); Xia et al. (2024); Lin et al. (2025) Nguyen et al. (2025)
	PCE 2	I believe the operating instructions for smart lockers are clear and easy to understand.	
	PCE 3	I believe the functions of smart lockers are simple and convenient.	
	PEU4	Overall, I believe smart lockers are easy to use.	
Compatibility (CMP)	CMP1	I believe using smart lockers meets my retrieval habits.	Wang et al. (2020); Mahdaly and Adeinat (2022)
	CMP 2	I believe using smart lockers meets my retrieval requirement.	
	CMP 3	I believe smart lockers are suitable for retrieving my personal packages.	
	CMP 4	I believe using smart lockers for retrieving my package offers the same functionality as having a delivery operator handle it at home.	
Peer influence (PEI)	PEI1	My family, friends, and colleagues highly recommend that I use smart lockers for retrieving my packages.	Talukder and Quazi (2011); Al-Adwan et al. (2024a)
	PEI2	Suggestions from my family, friends, and colleagues influence my willingness to use smart lockers.	
	PEI3	For me, the opinions of my family, friends, and colleagues play a significant role in my decision to use smart lockers.	
Platform influence (PLI)	PLI1	e-commerce operators encourage me to use smart lockers for retrieving my packages.	Garay et al. (2019)
	PLI2	I believe the measures taken by e-commerce operators will influence my willingness to use smart lockers for retrieving my packages.	
	PLI3	Overall, I think e-commerce operators will encourage customers to use smart lockers for retrieving their packages.	

Table 2 (continued)

Dimension	Code	Items	Literature
Self-efficacy (SLE)	SLE1	I can easily operate smart lockers for sending/picking up my package by myself.	Garay et al. (2019); Yang and Lin (2025)
	SLE 2	I am capable of using smart lockers independently.	
	SLE3	I can easily navigate the various functions on the smart lockers interface.	
	SLE 4	I am confident in my ability to operate smart lockers independently, even without instructional demonstrations or guidance.	
Contextual conditions (CTC)	CTC1	I believe using smart lockers for retrieving my package can help me save time.	Garay et al. (2019)
	CTC2	I think utilizing smart lockers can reduce delivery costs.	
	CTC3	I feel I can easily access the locations where smart lockers are set up.	
	CTC4	I believe smart lockers have adequate storage compartments of the right size for my needs.	
Attitude (ATT)	ATT1	I believe using smart lockers for retrieving my package is a good idea.	Garay et al. (2019); Sadaf and Gezer (2020); Jouda et al. (2020); Wang et al. (2020); Pongen et al. (2026)
	ATT2	I believe using smart lockers for retrieving my packages will be a pleasant experience.	
	ATT3	Overall, I have a positive perception of using smart lockers.	
Subjective norms (SBN)	SBN1	I am likely to use smart lockers due to the expectations of individuals who influence my decisions.	Garay et al. (2019); Sadaf and Gezer (2020); Jouda et al. (2020); Pongen et al. (2026)
	SBN2	Those who influence my opinions will encourage me to use smart lockers for retrieving my packages.	
Perceived behavioral control (PBC)	PBC1	I believe I can use smart lockers independently.	Garay et al. (2019); Sadaf and Gezer (2020); Jouda et al. (2020); Pongen et al. (2026)
	PBC2	I feel confident in my ability to use smart lockers for sending and retrieving my packages.	
	PBC3	I think I possess the necessary skills to use smart lockers.	
	PBC4	I believe I have the knowledge required to use smart lockers.	
Behavioral intention (BHI)	BHI1	I am willing to use smart lockers for retrieving my packages in the future.	Garay et al. (2019); Sadaf and Gezer (2020); Wang et al. (2020); Liu et al. (2026)
	BHI2	I will continue to use smart lockers for retrieving my packages in the future.	
	BHI3	If I need to retrieve my packages in the future, I will use smart lockers more frequently.	
	BHI4	I highly recommend others use smart lockers for retrieving their packages.	

common method variance (CMV) was considered a potential methodological concern. Both procedural and statistical remedies were employed in accordance with Podsakoff et al. (2003). Procedurally, respondents were assured that their responses would remain anonymous and confidential and would be used solely for academic purposes. They were also informed that there were no right or wrong answers, thereby reducing evaluation apprehension and the tendency to provide socially desirable responses. In addition, the measurement perspective adopted for continued usage intention was differentiated from that used for the independent variables to reduce consistency motives and common rater effects. Statistically, Harman's single-factor test was conducted as a diagnostic assessment of potential CMV. All measurement items were entered simultaneously into an unrotated exploratory factor analysis. The results produced multiple factors, and no single factor accounted for the majority of the total variance. This finding suggests that common method variance was unlikely to be the predominant explanation for the observed relationships among the constructs.

4.4. Characteristics of respondents

Descriptive statistical analysis is initially conducted on fundamental participant information, which includes variables such as physiological gender, age, education level, and occupation, with the use of smart lockers. Descriptive statistical analysis of participant demographics is presented in Table 3. The sample comprises 183 males (57.9%) and 133 females (42.1%). The age distribution is predominantly young; 60.4% of respondents are aged between 19 and 28, while 26.9% are between 29 and 38. Smaller cohorts include those under 18 (7.3%) and those aged 39 or over (5.4% combined). Educational attainment is high, with 69.9% holding a university degree and 19.0% possessing graduate-level qualifications. Only 11.1% have a high school education or below. Occupationally, the service sector is most prominent (43.0%), followed by manufacturing (17.7%) and students (17.4%). Other sectors include military or public education (9.5%), housekeepers (7.3%), and agriculture (1.0%), with 4.2% choosing not to disclose their profession. These results indicate that most respondents are university-educated young adults employed in the service industry.

4.5. Confirmatory factor analysis

This research employs SPSS 21 statistical software to conduct reliability analysis. The results indicate that Cronbach's Alpha coefficients for each factor exceed the threshold of 0.7, demonstrating good internal consistency.

Subsequently, AMOS 22 statistical software is utilized for CFA to assess the model fit of the adopted research theory. Fitness indicators such as parsimonious fitness, absolute fitness index, and incremental

Table 3
Descriptive statistical results.

Characteristics		Number of respondents	%
Gender	Male	183	57.9
	Female	133	42.1
Age	18 or less	23	7.3
	19–28	191	60.4
	29–38	85	26.9
	39–48	9	2.9
	49 or more	8	2.5
Education level	High school or under	35	11.1
	College/University	221	69.9
	Graduate	60	19.0
Occupation	Manufacturing sector	56	17.7
	Service sector	136	43.0
	Military/Public/Teaching	30	9.5
	Student	55	17.4
	House keeping	23	7.3
	Others	16	5.1

fitness index, which collectively assist in assessing the overall fit of a CFA model, guiding researchers in model refinement, are utilized to examine whether this factor is suitable as a representative in this research. The GFI and AGFI indicate how well the model explains variance, with values closer to 1 (>0.90) preferred. The NFI and TLI compare the model to a null model, with values above 0.90 being ideal. The RMR (Root Mean Square Residual) measures average residuals, with lower values (<0.05) indicating better fit, while RMSEA evaluates fit per degree of freedom, with values below 0.08 suggesting acceptable fit (Hair JR. et al., 2019). The results shown in Table 4 indicate that all the fitness indicators meet the corresponding thresholds.

4.6. Construct and discriminant validity

Construct reliability was assessed using composite reliability (CR) and Cronbach's alpha coefficients. In accordance with the guidelines of Hair JR. et al. (2019), CR values exceeding 0.70 indicate satisfactory internal consistency, while Cronbach's alpha values above the recommended threshold of 0.70 further support the reliability of the measurement scales. To evaluate the validity of the measurement model, both convergent and discriminant validity were examined, with the results summarized in Table 5. Convergent validity was assessed based on standardized factor loadings, composite reliability, and average variance extracted (AVE). Factor loadings greater than 0.50 were considered acceptable, although values exceeding 0.70 provide stronger evidence of convergent validity.

In addition, AVE values above 0.50 indicate that the dimensions explain a sufficient proportion of variance in their indicators. Discriminant validity was evaluated by comparing the square root of the AVE for each dimension with the corresponding inter-dimension correlations. Discriminant validity is established when the square root of AVE exceeds the correlations between dimensions in the model, indicating that each dimension is empirically distinct from the others. The results show that the research model demonstrates strong validity, with factor loadings for all dimensions ranging from 0.70 to 0.89, indicating satisfactory internal consistency and supporting the reliability of the dimensions. This finding, as illustrated in Table 5, affirms that the dimensions are sufficiently distinct from one another while maintaining high internal consistency.

4.7. Results of SEM

The results of SEM indicate that all hypothesized paths are positive and statistically significant. Perceived usefulness positively influences attitude ($\beta = 0.39$), perceived ease of use positively influences attitude ($\beta = 0.33$), and compatibility positively influences attitude ($\beta = 0.48$). Among these three antecedents, compatibility has the strongest standardized effect on attitude, suggesting that consumers' evaluations of smart lockers are shaped not only by instrumental utility but also by how well the service fits their everyday parcel collection routines.

The results further show that peer influence positively affects

Table 4
Goodness fit of confirmatory factor analysis.

	Indicator	Threshold	Results	References
Parsimonious fitness	χ^2/df	<2	1.92	Hair JR. et al. (2019); Lin and Chang (2021); Kanwal et al. (2024); Chang et al. (2024); Xia et al. (2024); Liu et al. (2026)
	GFI	>0.90	0.93	
Absolute fitness index	AGFI	>0.90	0.96	
	RMR	<0.05	0.03	
	RMSEA	<0.08	0.06	
Incremental fitness index	NFI	>0.90	0.95	
	TLI	>0.90	0.93	

Note: GFI: goodness of fit index; AGFI: adjusted goodness-of-fit index; RMR: root mean square residual; RMSEA: root mean square error of approximation; NFI: normed fit index; TLI: Tucker-Lewis index.

Table 5

Results of reliability and validity analysis.

Dimension	Factor	Std. factor loading	Cronbach's Alpha	Composite reliability	Construct reliability	Average variance extracted (AVE)
PCU	PCU1	0.722	0.80	0.76	0.76	0.75
	PCU2	0.808				
	PCU3	0.792				
	PCU4	0.826				
PCE	PCE1	0.886	0.92	0.88	0.89	0.72
	PCE2	0.821				
	PCE3	0.919				
	PCE4	0.778				
CMP	CMP1	0.901	0.92	0.85	0.85	0.65
	CMP2	0.897				
	CMP3	0.801				
	CMP4	0.738				
ATT	ATT1	0.902	0.84	0.80	0.80	0.67
	ATT2	0.833				
	ATT3	0.876				
PEI	PE1	0.842	0.82	0.84	0.84	0.72
	PE2	0.886				
	PE3	0.848				
PLI	PLI1	0.921	0.84	0.89	0.89	0.80
	PLI2	0.901				
	PLI3	0.877				
	PLI4	0.877				
SBN	SBN1	0.899	0.87	0.87	0.87	0.77
SLE	SBN2	0.878	0.84	0.85	0.85	0.74
	SLE1	0.845				
	SLE2	0.851				
	SLE3	0.898				
CTC	SLE4	0.788	0.81	0.70	0.70	0.54
	CTC1	0.801				
	CTC2	0.792				
	CTC3	0.711				
PBC	CTC4	0.702	0.90	0.89	0.89	0.73
	PBC1	0.893				
	PBC2	0.922				
	PBC3	0.887				
BHI	PBC4	0.831	0.88	0.88	0.88	0.78
	BHI1	0.899				
	BHI2	0.873				
	BHI3	0.866				
	BHI4	0.801				

Notes: PCU: Perceived usefulness; PCE: Perceived ease of use; CMP: Compatibility; ATT: Attitude; PEI: Peer influence; PLI: Platform influence; SBN: Subjective norms; SLE: Self-efficacy; CTC: Contextual conditions; PBC: Perceived behavioral control; BHI: Behavioral intention.

subjective norms ($\beta = 0.73$), while platform influence also positively affects subjective norms ($\beta = 0.75$). These coefficients indicate that both close social referents and e-commerce operators contribute to the normative environment surrounding smart locker use. In practical terms, the findings imply that consumers do not make delivery choices in isolation. Their decisions are influenced by interpersonal recommendations and by the cues provided by the retail platform or service provider.

Self-efficacy positively affects perceived behavioral control ($\beta = 0.66$), and contextual conditions also positively affect perceived behavioral control ($\beta = 0.39$). Self-efficacy exhibits a stronger effect, which indicates that confidence in one's ability to operate the system is a particularly important source of control perception. Nevertheless, the significance of contextual conditions confirms that perceived control also depends on whether the surrounding service environment supports use through convenient location access, time savings, and appropriate locker availability.

Finally, attitude ($\beta = 0.49$), subjective norms ($\beta = 0.28$), and perceived behavioral control ($\beta = 0.46$) all positively influence behavioral intention. The pattern suggests that intention is driven most strongly by favorable evaluation and perceived capability, while social norms also play a meaningful but somewhat smaller role. Table 6 summarizes the estimated structural coefficients, and Fig. 2 presents the path diagram. Overall, the structural model provides support for all ten hypotheses and confirms the explanatory value of the DTPB framework in the context of smart parcel locker adoption.

The research findings indicate that perceived usefulness has a

Table 6

Estimated results of SEM coefficients.

Path	Path coefficient		S.E.	C.R.	p-value
	Standardization	Non-standardization			
PCU → ATT	0.39	0.43	0.38	2.76	0.010*
PCE → ATT	0.33	0.39	0.36	2.28	0.022*
CMP → ATT	0.48	0.38	0.61	3.23	<0.001**
PEI → SBN	0.73	0.69	0.89	7.81	<0.001**
PLI → SBN	0.75	0.63	0.75	6.89	<0.001**
SLE → PBC	0.66	0.71	0.97	7.25	<0.001**
CTC → PBC	0.39	0.43	0.42	4.23	<0.001**
ATT → BHI	0.49	0.51	0.94	5.42	<0.001**
SBN → BHI	0.28	0.29	0.51	3.34	<0.001**
PBC → BHI	0.46	0.58	0.89	6.41	<0.001**

Note: *: p -value < 0.05; **: p -value < 0.01.

significant positive impact on attitude, supporting hypothesis H1. Similarly, perceived ease of use and compatibility both exhibit a significant positive effect on attitude, supporting H2 and H3, respectively. Additionally, both peer influence and platform influence significantly enhance subjective norms, supporting hypotheses H4 and H5. Self-

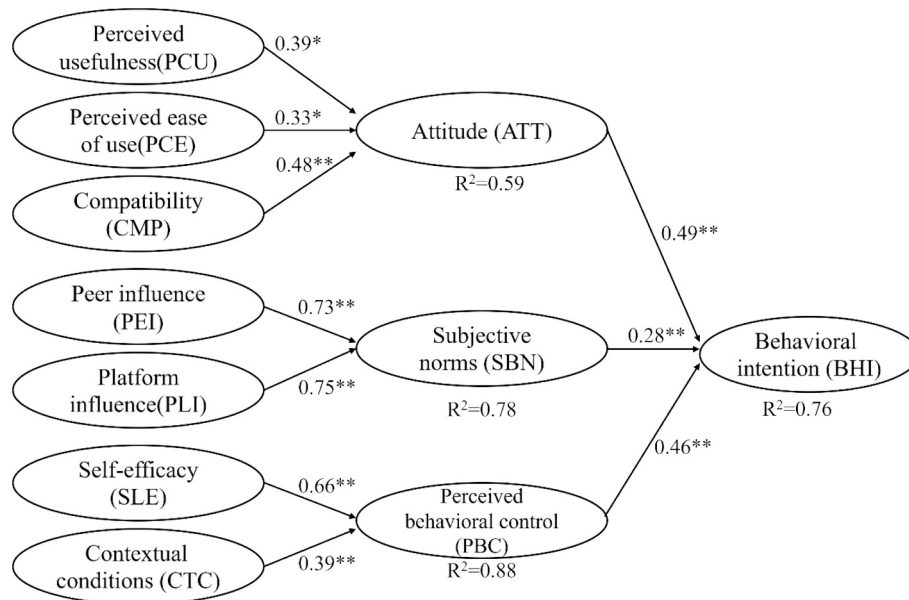


Fig. 2. Result of SEM.

Source: Authors own work.

efficacy demonstrates a significant positive effect on perceived behavioral control, supporting H6, and contextual conditions also positively impact perceived behavioral control, supporting H7. Furthermore, attitude, subjective norms, and perceived behavioral control each show a significant positive influence on behavioral intention (H8, H9, H10 support) within this research framework.

5. Discussion

This study applied the DTPB to examine continued smart locker usage among consumers with prior experience. The results show that continued use is shaped by functional value, ease of use, compatibility with daily routines, social influence, user confidence, and external facilitating conditions. Smart lockers are therefore evaluated not only as digital technologies but also as delivery services embedded in consumers' mobility patterns and everyday activities.

Research findings indicated that perceived usefulness, perceived ease of use, and compatibility positively influence attitude. Perceived usefulness reflects the practical benefits of locker use, including flexible collection and less dependence on attended home delivery, while perceived ease of use concerns the effort required to select a locker, receive notifications, operate the interface, and retrieve a parcel. Compatibility has the strongest effect, suggesting that experienced users place particular emphasis on whether locker collection fits their normal routes, schedules, and parcel-receipt habits. This result deserves attention because smart lockers differ from many digital technologies. Their use requires a physical trip to a collection point and must be coordinated with commuting, shopping, work, or study. A service may be technically simple and useful but still be unattractive when it requires a route deviation, offers inconvenient collection deadlines, or is located outside routine activity areas. Compatibility can therefore be interpreted as service-system fit rather than merely consistency with prior technology experience. This also explains why the physical design of the locker network, including location, accessibility, coverage, capacity, and operating conditions, is closely connected to consumer acceptance. The post-adoption setting strengthens this interpretation. Because respondents had already used smart lockers, they evaluated the service from experience rather than expectation. Basic usefulness and ease of use may already be regarded as minimum service requirements. Continued usage is more likely to depend on whether the service

remains convenient in practice and whether successful collection can be repeated without unnecessary time or travel. The findings therefore suggest that, after initial use, lifestyle and mobility fit may become more important than technological novelty.

Peer influence and platform influence positively affect subjective norms. Continued smart locker use is therefore not determined solely by individual evaluation. Recommendations from family, friends, colleagues, or other users may reduce uncertainty and indicate that locker collection is a familiar and acceptable delivery practice. E-commerce platforms and retailers may create similar effects through the way delivery options are displayed, described, and recommended. Prominent placement during checkout, clear explanations, and credible user guidance may normalize smart locker use. Such communication should focus on verifiable service benefits and should avoid implying environmental gains that have not been measured. Self-efficacy and contextual conditions enhance perceived behavioral control. Self-efficacy reflects confidence in selecting a locker, understanding notifications, using access codes or applications, and completing collection without assistance. Contextual conditions refer to external support, including accessible locations, compartment availability, reliable systems, clear procedures, and customer assistance. These constructs are related but distinct: consumers may be capable of operating a locker yet still feel limited when the nearest unit is full, inconveniently located, or unreliable. Perceived control therefore depends on the alignment between user capability and service availability.

This relationship is especially important for continued use because service experience can either strengthen or weaken perceived control. Successful collection reinforces confidence, whereas unavailable compartments, failed notifications, difficult interfaces, or poor service recovery may discourage future use. Providers should therefore treat system reliability and problem resolution as part of adoption management rather than as separate operational matters. The findings support the contextual relevance of DTPB but do not constitute a substantive extension of the theory. The study retains the established attitudinal, normative, and control structure and shows how these mechanisms operate in a technology-enabled parcel-delivery setting. Its main contribution lies in interpreting compatibility as mobility and lifestyle fit, social influence as a source of legitimacy, and perceived behavioral control as the joint effect of personal confidence and external service support.

The relevance to cleaner logistics is indirect. Continued use may improve locker utilization and create conditions for parcel consolidation and fewer failed delivery attempts, but the study does not measure route efficiency, vehicle movements, energy use, emissions, or consumer collection travel. Environmental outcomes depend on locker density, utilization, delivery substitution, parcel consolidation, and whether consumers combine collection with existing trips. A dedicated motorized pickup trip may offset some of the potential benefits. Consumer participation should therefore be regarded as an enabling condition rather than evidence of cleaner logistics performance.

Several managerial implications emerge from the findings. To strengthen compatibility, logistics providers should locate lockers near destinations that consumers regularly visit, such as residential areas, workplaces, campuses, transit stations, and supermarkets. E-commerce platforms can further support this fit by providing map-based locker selection, saving preferred locations, distance and access information, and clearly stated collection deadlines. User confidence can be improved through intuitive interfaces, concise instructions, timely notifications, multilingual guidance, responsive customer support, and effective service recovery. Adequate compartment capacity and reliable system operation are also essential, as communication and interface design cannot compensate for inconvenient access or repeated service failures. The characteristics of the sample should be considered when interpreting the results. Respondents were relatively young and highly educated and may therefore have been more familiar with digital services than the wider e-commerce population. Older consumers and individuals with lower digital literacy may encounter different usability barriers or require additional support. Moreover, the study did not distinguish respondents according to their frequency of smart locker use. Future research should therefore compare demographic groups and examine differences among occasional, moderate, and frequent users. Linking survey responses with actual transaction records would provide a more objective assessment of usage intensity and strengthen the practical relevance of the findings.

6. Conclusions

This study examined continued smart locker usage intention among experienced consumers through DTPB. Perceived usefulness, perceived ease of use, and compatibility strengthen attitude; peer and platform influence strengthen subjective norms; and self-efficacy and contextual conditions strengthen perceived behavioral control. Attitude, subjective norms, and perceived behavioral control then increase continued usage intention. Compatibility and self-efficacy are particularly important, indicating that continued use depends on both service fit and user confidence.

The contribution is contextual and empirical. The study shows how an established behavioral framework operates in a parcel-delivery setting where digital interaction is combined with physical access and mobility requirements. Smart lockers are not evaluated only as technologies; they are also judged according to whether locations, procedures, and collection times fit established routines. For practice, logistics providers and e-commerce platforms should combine network planning with consumer-centered service design. Lockers should be placed where collection can be integrated into existing trips, while platform interfaces should make suitable locations easy to identify and compare. Clear instructions, dependable notifications, adequate compartment capacity, accessible design, and responsive support can strengthen perceived control and encourage continued use. Platform communication may also normalize locker collection, but environmental claims should remain cautious and evidence based. Smart lockers also involve trade-offs. They transfer part of the final delivery activity to consumers and may require additional travel, effort, and schedule coordination. Poorly located lockers, limited capacity, short collection periods, system failures, accessibility barriers, security concerns, and infrastructure costs may reduce their value. Their performance should therefore be assessed

through utilization, failed-delivery reduction, route efficiency, consumer travel, reliability, accessibility, and user satisfaction rather than installation numbers alone.

The study has several limitations. It focuses on experienced users and therefore explains continued usage rather than initial adoption. Its cross-sectional, self-reported design may still be affected by common method variance, despite the procedural remedies and Harman's single-factor assessment. The model does not include environmental concern or perceived environmental benefits, and the sample is relatively young and highly educated. Usage frequency was also not examined. Future research should compare users and non-users, employ more diverse samples, and examine whether age, digital literacy, and usage intensity alter the proposed relationships. Longitudinal studies could connect intentions with repeated use, while field-based research could combine survey data with locker transactions, delivery success rates, route information, collection modes, energy use, and emissions. Comparisons with home delivery, convenience-store pickup, and attended collection points would provide a stronger basis for assessing when smart lockers support cleaner and more efficient last-mile logistics.

CRedit authorship contribution statement

Chi-Chang Lin: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Zaili Yang:** Writing – review & editing, Validation. **Chia-Hsun Chang:** Writing – review & editing, Writing – original draft, Validation, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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