Smart Locker Solutions for Sustainable Urban Logistics: Experimental Research in Ho Chi Minh City

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Abstract. This study explores the factors that influence the intention to use smart lockers in sustainable last-mile delivery. This solution addresses urban challenges such as carbon emissions, traffic congestion, and high costs. A survey of 302 students in Ho Chi Minh City, analyzed using PLS-SEM, identified three main factors impacting usage intentions: convenience, perceived security, and reliability. Convenience had the most significant effect on perceived value ($\beta = 0.472$), followed by perceived security ($\beta = 0.236$). Although reliability did not significantly affect perceived value, it did directly influence intention to use ($\beta = 0.143$). Perceived value also played a key mediating role ($\beta = 0.474$). This research advances the application of self-service technology in urban logistics. It highlights how smart lockers can help reduce impacts such as air pollution, noise, and congestion, supporting last-mile delivery amid rapid urban growth and expanding e-commerce.

1 INTRODUCTION

The rise of e-commerce has significantly increased global transport of consumer goods. Data from [1] shows that e-commerce's share of total retail sales is expected to grow from 19.9% in 2024 to 23.7% in 2030. However, last-mile logistics faces major issues, especially in the context of urbanization and unsustainable costs and wasted resources.

The first-time delivery failure rate ranges from 10% to 20%, accounting for re-delivery, and significantly increases operating costs [2]. Last-mile delivery in large cities such as London accounts for 25-30% of urban traffic congestion and CO_2 emissions [3]. This not only contributes to air pollution but also generates noise, negatively affecting urban life and public health. Smart lockers have emerged as an effective solution for optimizing delivery routes and schedules due to dispersed delivery points and inconsistent delivery times with busy schedules. These issues not only create economic burdens for logistics firms but also raise environmental concerns about the viability of traditional delivery models amid rapid urbanization.

This study addresses the challenges mentioned above, aiming to develop sustainable and efficient solutions for the logistics industry. Smart lockers can help reduce inefficiencies caused by failed deliveries and re-deliveries, saving unnecessary opportunity costs. Studies

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[4] demonstrate that combining smart cabinets with optimized vehicle scheduling such as consolidated shipments and traditional home delivery significantly contributes to sustainable urban development and efforts to mitigate climate change.

In Vietnam, the adoption of smart lockers has significant growth potential, especially as major cities face challenges from air pollution and severe traffic congestion. These issues not only create economic burdens for logistics businesses but also raise environmental concerns about traditional delivery models and consumer habits. Recent surveys [4] show that 78% of surveyed consumers expressed interest in this solution, especially after learning about its environmental benefits.

2 LITERATURE RVIEW

2.1 Last-mile logistics

Last-mile logistics (LML) is the final stage in the supply chain, where goods are delivered to the recipient's home or a collection point [2]. Urbanization has caused over 50% of people to live in cities, with e-commerce growth challenging urban logistics, especially delivery services. This makes each household a potential delivery point, increasing complexity and management challenges. Logistics companies face a tougher last-mile problem due to the need for direct recipient interaction, which is difficult in busy urban areas with varied schedules. Individual deliveries raise wait times, costs, and delivery times, lowering efficiency and incurring opportunity costs [5]. E-commerce also adds challenges for city management and environmental protection, prompting policymakers to seek sustainable solutions that balance growth and environmental impact to preserve urban quality [5].

2.2 Smart Lockers

Smart lockers are modern storage solutions offering benefits to providers, customers, and society [6]. Usually placed in accessible locations like shopping centers, they are simple to use: users select a cabinet, enter details, and receive a QR code [4]. Carriers deliver items directly; recipients can collect them at any time afterward. They can store parcels, food, books, laundry, and medication. This system, functional amid the growth of e-commerce, promotes sharing by enabling item exchanges. Compared to traditional delivery, smart lockers reduce failed deliveries, optimize vehicle use, and lower operators' costs. Customers avoid long waits; their parcels are securely stored for pickup at any time [7]. Environmentally, smart lockers reduce the impacts of urban logistics by reducing CO_2 emissions, pollution, noise, traffic congestion, and illegal parking, while enhancing urban spaces and supporting sustainable last-mile logistics amid urban growth[6], [7].

2.3 Theory of Intent to Use

This study combines and applies two consumption theories to identify the factors that influence a customer's intention to use a smart locker: the resource-matching theory and the perceived-value theory. Resource-matching theory focuses on the features of smart lockers that can lessen effort in usage, thereby encouraging behavioral intention [8]. Perceived value theory explains how reducing effort can boost perceived benefits, thereby increasing the likelihood of use [9]. In the context of sustainable last-mile logistics, the perceived value in this study encompasses not only economic and functional benefits but also sustainability and social responsibility aspects. This approach aligns with current research trends on responsible consumption behavior and green logistics.

Based on the resource-matching theory outlined by Martin [10], it is reasonable to suggest three factors - convenience, security, privacy, and reliability - to help reduce resource requirements. Convenience makes it easier for users to navigate, requiring fewer cognitive resources. Privacy and security lessen anxiety, allowing users to focus on locker usage. Reliability decreases the need for ongoing evaluation of information. All three elements free up cognitive resources, creating an optimal smart locker experience for users with different cognitive needs and sensory search levels. Improving these factors is expected to boost perceived value and lower transaction costs.

According to research by Immonen [5], perceived value includes four aspects: economic, functional, emotional, and social utility. Convenience, security, privacy, and reliability are key factors that can directly influence a customer's perceived value. Specifically, convenience helps improve functional and economic value by saving users time and effort [6]. Privacy boosts emotional value by creating a sense of security and peace of mind. Reliability not only affects functional value but also positively impacts emotional value and social utility by building trust and credibility [8]. When combined, these three elements can create a comprehensive experience that addresses all four aspects of perceived value, thereby increasing customer satisfaction and loyalty [5].

2.4 Proposed research model and research hypothesis

Drawing on resource-matching theory and perceived value theory, this study proposes a comprehensive theoretical model to explain intention to use smart wardrobes. The model comprises five main components: convenience, perceived security , reliability, perception of value, and intent to use. Convenience refers to how easy and accessible a smart locker is to use, including factors such as geographic location, uptime, and user-friendliness. Research indicates that convenience positively influences customers' perceived value. Smart cabinets that are conveniently located, available 24/7, and simple to operate will improve functionality and customer satisfaction [6].

H1: The convenience of smart lockers has a positive impact on the perceived value of customers.

Perceived security involves safeguarding customers' personal and financial information when using a smart locker. Research indicates that perceived security positively influences perceived value. Security features like personal data encryption and multi-factor authentication help customers feel more secure, increasing their sense of control over personal information [8]. This improves both functional and social utility, thereby raising perceived value.

H2: The perceived security of smart lockers has a positive impact on the perceived value of customers

Reliability pertains to the consistency and accuracy of a smart cabinet's service delivery. Research indicates that reliability positively influences perceived value and willingness to use. Reliable smart lockers decrease the chances of late deliveries or failures and reduce human error [9]. This improves functional utility for customers, thereby increasing perceived value and encouraging the intention to use . Consequently, two hypotheses are proposed:

H3: The reliability of smart lockers has a positive impact on the perceived value of customers.

H4: The reliability of the smart lockers has a direct positive impact on the customer's intention to use it.

Additionally, the study suggests that convenience has a direct positive effect on the intention to use. A location that is convenient and easy to access reduces transaction costs such as travel time, transportation expenses, and the effort needed to learn how to operate. This directly encourages customers to continue using it.

H5: The convenience of the smart locker directly increases customers' intention to use it.

Finally, based on perceived value theory, the study suggests that perceived value positively impacts the intention to use smart lockers. Customers will keep using the service that provides the best value compared to other last-mile delivery options [11]; [12].

H6: Perceived value has a positive impact on customers' intention to use smart smartlockers.

In this model, value perception acts as a key mediator between inputs (such as convenience, perceived security , and reliability) and the intention to use. This mediating role can be explained using Pappas's theory of perceived value. Specifically, factors like convenience, perceived security , and reliability not only directly influence the intention to use but also shape a user's perception of value. For example, an easy-to-use (convenient) smart cabinet can enhance its perceived value, thereby increasing the intention to use it. Similarly, high levels of security and strong reliability can boost perceived value, leading to a greater intention to use. In the case of smart wardrobes, this mediating role helps clarify the more complex interactions among various elements that affect a user's final decision.

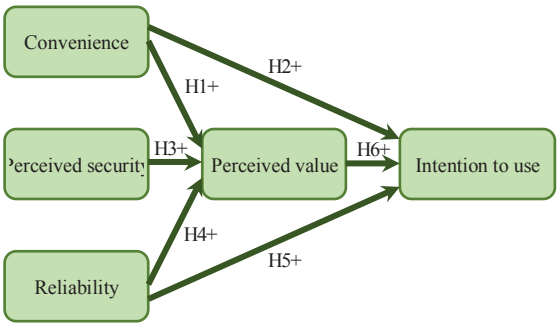

Fig. 1. Proposed research model.

3 RESEARCH METHODOLOGY

3.1 Measurement Scales

The study used a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure key structures. The Convenience Scale (4 variables) and Perceived Value (4 variables) were adapted from Collier [13]; the Perceived security (4 variables) and Reliability (4 variables) scales were developed based on Barua; while the Intent to Use scale (4 variables) is adapted from Liuyan Chen [14]. All scales are translated and tailored to the context of smart lockers in Vietnam.

3.2 Sample

To determine the minimum sample size in PLS-SEM analysis, several guidelines have been suggested. A standard method is the “10 times” rule [15]. According to this rule, the minimum sample size should be at least 10 times the number of indicators in the most complex causal (formative) structure, or 10 times the number of structural paths leading to a specific structure in the model. In this study, since there was no causal structure, the second criterion was used. The research model includes two dependent structures: “Perceived value” and “Intent to use.” Among these, “Intention to use” has the most connections (3 links). Therefore, the minimum sample size = 10 x number of paths to “Intention to use” = 10 x 3 = 30 (samples). With an actual sample size of 302, this study greatly exceeds the minimum requirement. This ensures that further analyses can be conducted reliably.

3.3 General Information About the Survey Participants

Using survey tools, the team collected 311 responses about their intention to use smart lockers. After cleaning the data and removing 09 invalid votes, the research team was left with 302 responses. Characteristics of the surveyed subjects are detailed in Table 1:

Table 1. General Information About the Survey Participants.

No	General Information	Frequency	Percentage
Sample (n)		302	100,00%
Gender			
1	Male	110	39,15%
2	Female	191	67,97%
3	Others	1	0,36%
Age			
1	Maximum	26	
2	Minimum	20	
3	Average	22,4	
Average income			
1	Maximum	Above 30 millions VND per month	
2	Minimum	Below 3 millions VND per month	
3	Average	3.625.828 VND per month	

4 FINDINGS AND DISCUSSIONS

4.1 Measurement results calculate the value of the structure

To evaluate the reliability of the scales, Cronbach's Alpha and Composite Reliability should be 0.7 or higher to ensure optimal levels. According to Table 2, the Cronbach's Alpha reliability coefficients for Convenience, Perceived security , Reliability, and Perceived Value all exceed 0.7. For the composite confidence factor (CR), all four factors have indices of 0.81 or higher, indicating that the scale used in the model is highly reliable.

Table 2: Load Factor Results in PLS- SEM Model.

Construct	Code	Factor loadings	Cronbach's Alpha	CR	AVE
Convinience	CON1	0,776	0,783	0,860	0,605
	CON2	0,790			
	CON3	0,776			
	CON4	0,770			
Perceived security	PS1	0,807	0,827	0,885	0,657
	PS2	0,822			
	PS3	0,821			
	PS4	0,792			
Reliability	RE1	0,837	0,824	0,883	0,654
	RE2	0,857			
	RE3	0,794			
	RE4	0,742			
Perceived value	PV1	0,743	0,797	0,868	0,621
	PV2	0,816			
	PV3	0,798			
	PV4	0,794			
Intention to use	INT1	0,866	0,829	0,879	0,645
	INT2	0,822			

Construct	Code	Factor loadings	Cronbach's Alpha	CR	AVE
	INT3	0,781			
	INT4	0,738			

4.2 Assessment of the scale's convergence and distinctiveness

To evaluate the convergent validity of the latent variables, researchers often use the average extraction variance, known as AVE. According to the standard guidelines, a structure is considered to have acceptable convergent validity when the AVE exceeds 0.5. In this study, the analysis results showed that the AVEs for all factors exceeded 0.5, confirming the model's convergent validity (see Table 3). Regarding the calculation of the discriminant value, two common methods are employed: the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. According to the Fornell-Larcker criterion, a scale is regarded as having discriminant validity if the square root of the AVE for each construct is higher than its correlation with other constructs in the model.

Table 3: Discrimination Value (Fornell-Larcker criterion).

	Perceived security	Reliability	Perceived value	Convinience	Intention to use
Perceived security					
Reliability	0,845				
Perceived value	0,621	0,527			
Convinience	0,487	0,377	0,757		
Intention to use	0,545	0,503	0,835	0,704	

The analysis results in Table 4 confirm the model's discriminant validity. This is demonstrated by the fact that the square root values of AVE (highlighted in bold on the diagonal) are both higher than the correlation coefficients outside the diagonal. Another way to assess discriminant validity is through the HTMT index. According to the standard, an HTMT value below 1.0 indicates adequate discrimination. The results in Table 5 show that all HTMT values are less than 1.0, indicating that the model's structures achieve discriminant validity.

Table 4: Heterotrait-Monotrait Ratio.

	Perceived security	Reliability	Perceived value	Convinience	Intention to use
Perceived security	0,811				
Reliability	0,701	0,809			
Perceived value	0,507	0,432	0,788		
Convinience	0,397	0,313	0,603	0,778	
Intention to use	0,454	0,423	0,680	0,569	0,803

Source: Calculation results of the authors

4.3 Evaluate the suitability of the structural model

4.3.1. Explanation of independent variables for dependencies (R^2)

R^2 is also known as the determination factor, which measures the size of the influence on the overall structural model. According to Table 6, the corrected R^2 for the "Perceived Value" factor is 0.450, indicating that the model explains 45% of the variation in this variable. This suggests that the model provides an average explanation for the "Perceived Value." For the

"Intention to use smart-lockers" factor, the corrected R^2 is 0.514, indicating that the model explains 51.4% of the variation in that variable. This result shows that the model has a reasonably good explanation for "Intention to use smart-lockers."

Table 5: Standardized R^2

	Standardized R^2
Perceived value	0,450
Intention to use	0,514

Comparing the two corrected R^2 indicators, we find that the model explains "Smart Lockers Intent" better than 'Perceived Value'. However, both indicators are moderate, suggesting that factors beyond the model may influence them.

4.3.2. Evaluating impact relationships

To assess the influence of model variables, the study employed the Bootstrap method. It is a statistical technique based on repeated sampling from the original data, enabling the estimation of standard errors without assuming the data's distribution. The results of the Bootstrap process are presented in Table 6, which includes key parameters related to path coefficients in the structural model.

Table 6: Results of relationships between structures in the model.

Hypothesis	**Original sample (O)**	**Sample mean (M)**	**Standard deviation (STDEV)**	**P values**	**Result**
H1: Convenience → perceived value	0,472	0,474	0,055	0,000	Accept
H2: Convenience → Intention to use	0,238	0,240	0,074	0,001	Accept
H3: Perceived security → perceived value	0,236	0,236	0,067	0,000	Accept
H4: Reliabily → perceived value	**0,119**	**0,120**	**0,073**	**0,103**	**Reject**
H5: Reliabily → Intention to use	0,143	0,144	0,050	0,004	Accept
H6: perceived value → Intention to use	0,474	0,474	0,068	0,000	Accept

The results of the Bootstrap analysis show that, except for the H4 hypothesis, which states that reliability affects perceived value, all the remaining hypotheses are acceptable and statistically significant. The standardized research model is presented as shown in Figure 2.

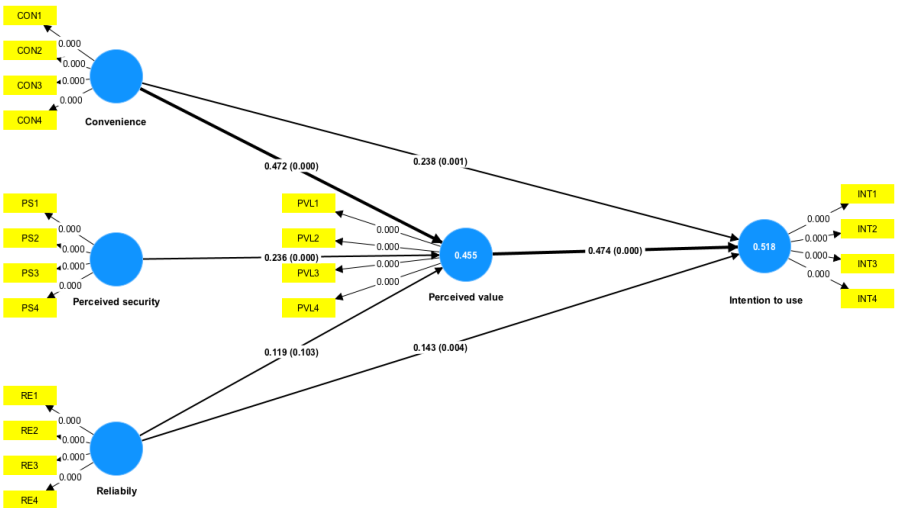

Fig. 2. Standardized research model.

4.3.4. Discussion

Convenience significantly impacts perceived value ($\beta = 0.472$, $p < 0.001$), aligning with self-service tech studies [13]. In sustainable urban logistics, convenience benefits both individuals and the environment. It allows individuals to pick up goods 24/7 at convenient locations, saving time and reducing costs, especially for those with irregular schedules [13]. For businesses, accepting lockers streamlines deliveries, cutting last-mile costs by 15-25% and increasing success from 80% to 95% [7]. Societally, fewer deliveries and optimized routes cut CO_2 emissions by 30-40%, traffic congestion by 20-25%, and noise pollution. Promoting sustainable logistics relies on offering genuine convenience, which naturally yields environmental benefits. This approach suits Vietnam, where awareness of sustainability is growing. When convenience hits the optimal level, a network effect will benefit both businesses and the environment.

Perceived security is crucial, with concerns about data safety rising among Vietnamese consumers, especially following Decree 13/2023. Unlike home delivery, lockers require data encryption and multi-factor authentication, as users worry about both digital and physical safety of their goods. Adequate security boosts trust, reduces lost goods claims by 60-70%, increases the number of high-value items sent via lockers to 70%, and lowers insurance costs. Trust in security also promotes locker adoption, enhancing delivery efficiency and reducing environmental impact. Security is essential for trust and sustainable last-mile logistics. The model also shows that both convenience and reliability have a significant direct effect on the intention to use a smart closet, with coefficients of 0.238 and 0.143, respectively. This indicates that, even without considering perceived value, these two factors are still likely to motivate users to choose the service. This finding aligns with previous studies on the impact of convenience on usage intent.

Perceived value plays a crucial role in shaping the intention to use, with an impact factor of 0.474. This confirms the mediating role of perceived value in the relationship between independent factors and the intention to use, consistent with perceived value theory [11]. This finding highlights the importance of not only offering useful features but also clearly communicating their value to potential users.

A notable finding from the study results was the statistically insignificant impact of the Reliability factor on Perceived Value ($\beta = 0.119$, $p = 0.103$), although Reliability directly influenced Intent ($\beta = 0.143$, $p = 0.004$). This contrasts with previous research in developed countries. The explanation lies in Vietnam's specific context. First, in Ho Chi Minh City, smart lockers are still a new technology, with only 5% of logistics companies using them. Early adopters tend to focus on obvious benefits, such as convenience and security, rather than on abstract qualities like reliability. Research suggests that reliability becomes important only after the technology is widely adopted. Second, unlike in developed markets where locker systems have been standard for decades [9], students in Ho Chi Minh City lack experience with similar services and thus have no basis for forming specific reliability expectations. Inexperienced consumers tend to rely on more easily observable attributes

rather than long-term quality indicators. Third, students with flexible schedules look for solutions to receiving goods that do not depend on fixed times. They prioritize factors that directly address this need, such as 24/7 convenience and security, over reliability, which becomes evident only over the long term.

5 CONCLUSION

This study examined factors influencing students' intention to use smart lockers in Ho Chi Minh City, a sustainable last-mile logistics solution. Convenience (β=0.472), perceived security (β=0.236), and reliability (β=0.143) primarily impacted usage, with perceived value

serving as a key intermediary (β=0.474). Reliability did not significantly affect perceived value in Vietnam's emerging tech market, reflecting early-stage adoption.

Academically, this research advances the theory of self-service technology in sustainable urban logistics by: (1) broadening Resource Matching Theory and perceived value theory to include sustainability and social responsibility perspectives; (2) demonstrating that the importance of technological attributes, such as reliability, varies depending on market development and cultural context; (3) clarifying the "win-win" mechanism between personal benefits (convenience) and collective environmental gains (emission reduction, congestion alleviation).

Practically, the study provides a valuable database for developing a sustainable urban logistics ecosystem in Vietnam, especially as major cities confront air pollution, traffic congestion, and the rapid growth of e-commerce. By identifying key factors that influence young users' willingness to adopt these solutions, the research supports the development of more effective implementation strategies.

Based on the findings, recommendations for service providers include increasing locker density within 500 meters of schools, dorms, and student housing, ensuring 24/7 operation with transactions completed in under 2 minutes. Integration with platforms like Shopee, Lazada, and TikTok Shop can reduce barriers to usage. Units should implement two-factor authentication, maintain transparent privacy policies in accordance with Decree 13/2023/ND-CP, and install surveillance cameras and warning systems. Providers should initially promote convenience and security benefits, emphasizing personal advantages and environmental impacts such as CO_2 reduction and congestion mitigation to attract eco-conscious youth. Policymakers should offer tax incentives and support the installation costs in dense areas. Urban planners should reserve space for smart lockers in new developments. Smart cabinets should be incorporated into city emission reduction strategies, prioritizing licensing for locker-enabled logistics firms and e-vehicles.

The study has some limitations: First, the survey sample only includes students from Ho Chi Minh City, which may not represent all potential users, such as office workers, housewives, and the elderly. Second, it did not consider perceived environmental benefits as an independent factor influencing usage intent. Third, cross-sectional research cannot capture changes in behavior and thinking over time. Future research could: (1) broaden the geographic scope and participant pool for a more comprehensive understanding; (2) include factors like cost, interface design, and perceived environmental benefits in the model; (3) conduct longitudinal studies to see if the role of reliability shifts as the market matures; and (4) compare user groups with different experience levels (early adopters versus late majority) to better understand how the technology adoption stage impacts user behavior.

6 ACKNOWLEDGMENTS

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