

SmartBox: An IoT-Enabled Locker System for Secure and Efficient Package Handling

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Abstract

Cambodia's e-commerce is growing rapidly, but last-mile delivery remains inefficient. Issues such as missed deliveries, limited courier availability, poor coordination, and lack of real-time updates continue to affect customer satisfaction and reduce trust in online shopping. Despite increasing digital adoption, the country's logistics infrastructure still faces challenges in meeting delivery demands. This paper presents SmartBox, an IoT-enabled locker that improves last-mile delivery by adding flexibility, reliability, and control. Instead of relying on traditional door-to-door delivery, SmartBox enables customers to receive packages at designated lockers. The system features real-time pickup notifications and PIN-based access to ensure security and convenience. SmartBox was developed using Telegram and the python-telegram-bot library for user interaction, Laravel and MySQL for backend development, and tools such as AWS, Cloudflare, ApexCharts.js, GitHub, and Gmail SMTP for deployment and communication. Locker control is managed by an ESP32 microcontroller, integrated via the MQTT protocol for remote activation. Testing showed all twelve features worked reliably across browsers and mobile devices. A UTAUT survey of 14 users showed high performance and behavioral-intention scores. The system is scalable, cost-effective, and suitable for deployment in universities, offices, and residential areas.

Keywords: Last-mile delivery, Smart Locker, IoT

Introduction

Cambodia's economy has demonstrated steady growth, with e-commerce revenue projected to reach \$1.78 billion by 2025 (Digital Economy and Business Committee - DEBC, n.d.). Alongside this growth, consumer activity has surged, with 29.97% of Cambodians engaging in online shopping multiple times per month (Standard Insights, 2023), driven by increasing consumer expectations for convenience, flexibility, and a wide range of options (Kiripost, 2024). E-commerce offers convenience to consumers, enabling them to browse, compare, and purchase products whether from the comfort of their home or on the go (Tamm, 2023). However, late deliveries remain a persistent issue, with 32.07% of orders being delayed (Standard Insights, 2023). These challenges underscore the limitations of current delivery methods in addressing consumer demands for speed and reliability. The increasing demand for e-commerce and consumer preferences for same-day delivery present significant opportunities for innovation. This gap between technological advancement and operational readiness highlights the pressing need for more comprehensive and sustainable solutions to support the rapid expansion of Cambodia's logistics sector.

This paper introduces "SmartBox", an IoT-based e-logistics platform that connects online buyers and sellers through secure and convenient package storage. By using smart lockers, SmartBox enables same-day delivery, real-time updates, and flexible pickup, reducing missed deliveries and



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improving reliability for both senders and receivers. The main objective of SmartBox is to provide an additional option for the current last-mile delivery in Cambodia. It seeks to improve delivery success rates, ease courier workloads, and enhance user convenience.

Related Work

Last-mile delivery plays a critical role in e-commerce logistics, representing the final stage of transporting goods from distribution centers to consumers. Its importance continues to grow alongside consumer demand for speed, convenience, and reliability. Group (2023) noted that logistics providers are now evaluated largely on their ability to offer flexible, consumer-focused services. One promising solution to last-mile inefficiencies is the use of smart lockers, which provide a convenient alternative for both courier and customer interactions. These lockers support diverse logistics scenarios, including secure parcel drop-offs, returns, and pick-ups, while also improving operational efficiency (Group, 2023). A case study conducted in Jabodetabek, Indonesia, analyzed the smart locker system's impact on last-mile delivery performance (Refaningati et al., 2020). The study identified key problems such as untimely deliveries, where recipients are not present during delivery, and order fragmentation due to mixed rural and urban logistics routes. Findings revealed that smart lockers reduced total delivery trip lengths by 30.65% compared to conventional delivery, while also enabling flexible pickup times for customers. This improves service reliability and reduces missed delivery attempts, particularly in congested urban areas or remote locations.

Literature review further emphasizes the value of IoT-based smart locker systems. Sa-ngiampak et al. (2019) introduced LockerSwarm, a system designed for university campuses, combining portable smart locks, a LINE chatbot interface, and a centralized backend for monitoring and control. Users can find, reserve, and unlock lockers via QR code through the LINE app, with the added ability to share locker access with others. This system improves convenience for students carrying heavy items and introduces a collaborative, tech-enabled solution for storage needs on campus. Similarly, Naik et al. (2020) proposed an IoT smart locker system using facial recognition and image encryption to enhance security. The system monitors intrusions, verifying whether individuals attempting to access the locker are authorized. If unauthorized, the system captures their image and alerts the legitimate user, who can then remotely approve or deny access. This innovation improves locker safety while maintaining ease of use.

Research Design and Methods

The research process was guided by the conceptual framework shown in Figure 1, which maps the core challenges faced by online buyers and sellers. The development of these solutions was conducted using the Rapid Application Development (RAD) model (Digital Policy Office, 2024), incorporating the integration of a Telegram Bot and locker system as shown in Figure 2. After development, the platform was deployed on an AWS EC2 instance, while the ESP32 microcontroller was connected to AWS IoT Core for MQTT communication between the backend and the device. To complete the study, the platform's effectiveness was evaluated using the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Marikyan & Papagiannidis, 2023), with data gathered from testing in a public setting.

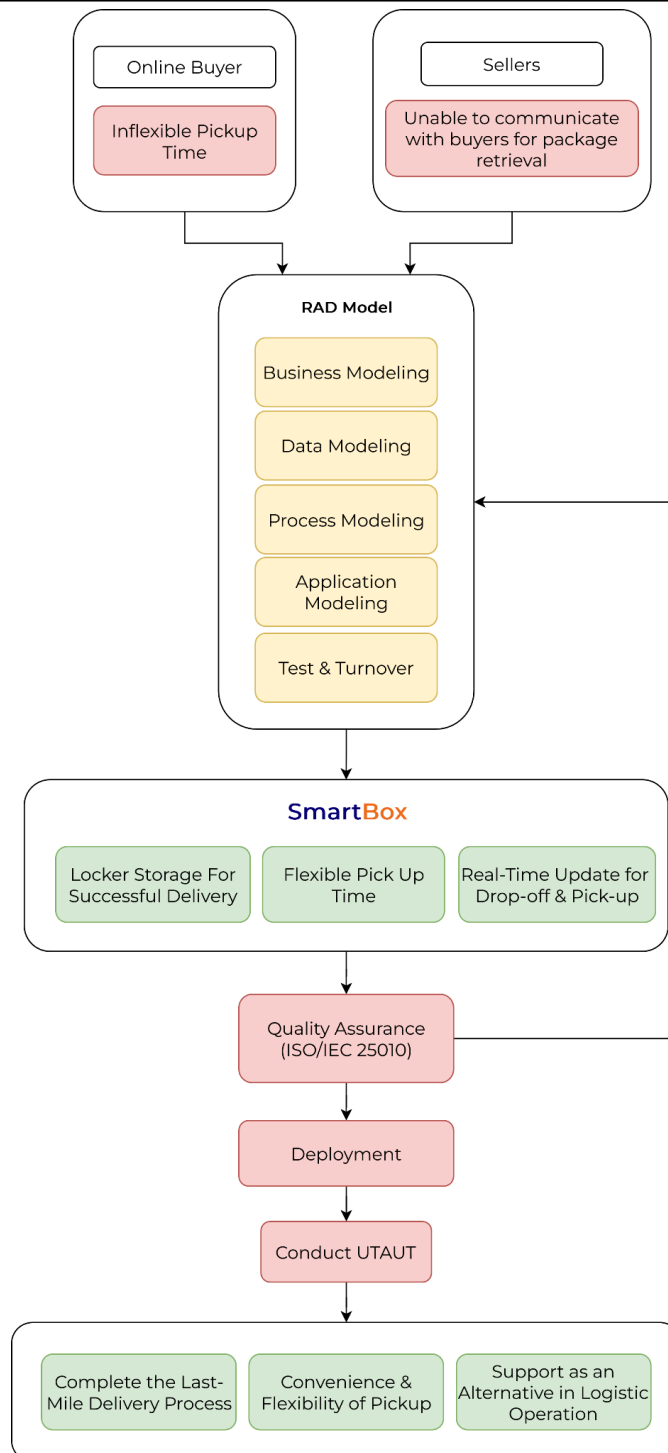


Figure 1 :Conceptual Framework of SmartBox

Note. This framework illustrates the key challenges identified in Cambodia's e-commerce logistics system for buyers and sellers, the proposed SmartBox solution designed to address package delivery and retrieval issues, and the overall development process utilizing the UTAUT framework to ensure successful implementation and user adoption.

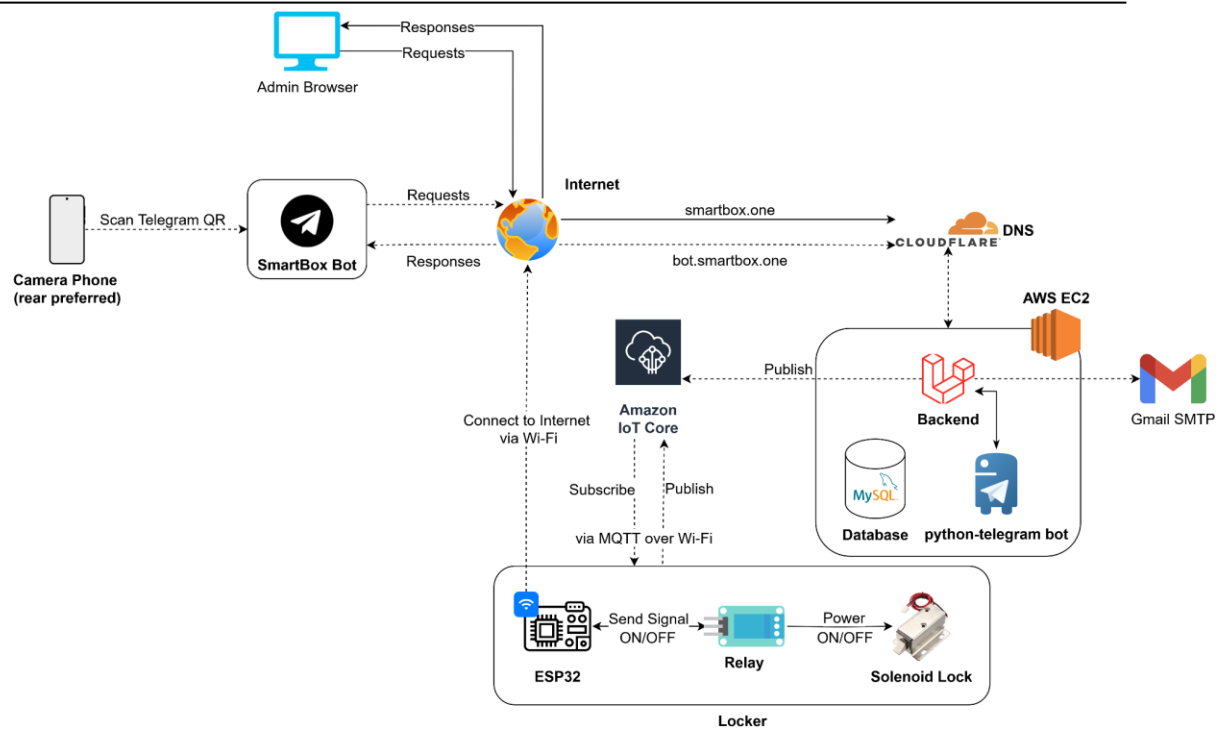


Figure 2: SmartBox System Architecture

Note. This diagram illustrates the key technical components of the SmartBox system and the flow of information between the Telegram Bot, the backend, the APIs, the microcontroller, and the locker components.

Results

After the successful deployment of the SmartBox system, a comprehensive user acceptance testing was conducted using the UTAUT framework, alongside performance testing to evaluate technical robustness. The UTAUT-based survey was administered to participants at the National Incubation Center of Cambodia (NICC) and the Cambodia-Japan Cooperation Center (CJCC), allowing users to interact with the system as both senders and receivers. Responses were collected using a 5-point Likert scale, where 1 indicates a strongly negative experience and 5 indicates a strongly positive experience. The results, summarized in Table 1, demonstrate a high level of acceptance among SmartBox users, with mean scores across all key UTAUT constructs consistently above 4.0.

Table 1: Summary of Mean Scores for Key UTAUT Constructs for SmartBox Users

UTAUT Constructs	Indicator Measured	Average Rating
Performance Expectancy	Ability to improve delivery & pickup efficiency	4.53/5
Effort Expectancy	Ease of using SmartBox via Telegram and lockers	4.19/5
Social Influence	Encouragement from peers to use SmartBox	4.14/5
Facilitating Conditions	Access to tools (Telegram, phone, internet, lockers)	4.42/5
Behavioral Intention	Intention to continue use, recommend, and prefer	4.61/5

Note. This table presents UTAUT-based user acceptance testing results from participants at NICC and CJCC using a 5-point Likert scale (1 = strongly negative, 5 = strongly positive).

Among all constructs, Behavioral Intention received the highest average rating (mean = 4.61), suggesting a strong likelihood of continued usage and recommendation. This was followed by Performance Expectancy (mean = 4.53), indicating user confidence in the system's ability to improve delivery efficiency. Notably, Effort Expectancy received a slightly lower score (mean = 4.19), indicating potential areas for further improvement in user experience. In addition to user acceptance, performance testing validated the system's technical reliability. Load testing with 9,000 concurrent users and stress testing with 30,000 concurrent users confirmed SmartBox's resilience, scalability, and responsiveness, reinforcing its readiness for wider deployment in real-world settings.

Discussion

The findings from this study confirm that SmartBox is an effective and highly accepted last-mile delivery solution that could achieve a higher rate of same-day delivery, based on strong performance and usability ratings from users acting as both senders and receivers at NICC and CJCC. The most significant insight is how key adoption factors emerged from the user feedback. Behavioral Intention received the highest rating, indicating a strong willingness to continue using and recommending the system. Performance Expectancy also ranked highly, reflecting user confidence in SmartBox's ability to reduce delays and improve delivery efficiency. The slightly lower rating in Effort Expectancy suggests room for further enhancing ease of use.

Despite these positive results, certain limitations remain. While the UTAUT-based evaluation provided valuable insights, a much larger sample of 100 participants or more is needed to have broader user acceptance and adoption trends. Additionally, while the system performed well under stress, future improvements are needed to maintain low error rates at scale. The current version also lacks integrated payment features, which could enhance convenience and support expanded functionality. By integrating Cambodia's robust digital payment method KHQR, SmartBox could allow users to pay for locker usage instantly via payment links streamlining transactions and making the system more accessible for local e-commerce logistics. Finally, while SmartBox can enhance delivery efficiency, future adoption should consider its implications on courier employment patterns, digital literacy gaps, and accessibility for non-smartphone users. By partnering with local logistics providers, it could help reduce this effect.

Conclusion

This study demonstrates the successful development and deployment of SmartBox, a secure IoT-based locker system that effectively addresses key last-mile delivery challenges in Cambodia's e-commerce sector. By validating the system's technical performance, user acceptance, and economic sustainability, this research provides a proven model for future logistics solutions in similar emerging markets. The primary contribution of this work lies in showing how technology adoption is influenced by user experience and expectations, offering valuable insights for the future design of user-centered, digitally enabled delivery infrastructure.

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