

REVOLUTIONIZING URBAN LAST-MILE DELIVERY WITH AUTOMATED PARCEL LOCKERS: AN OVERVIEW

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Abstract: *With last-mile logistics being the most important component of delivery, the rapid growth of electronic commerce has also led to a surge in logistical complexity. Because users prefer to have their purchases delivered to their homes, this is one of the biggest challenges facing e-commerce. Many times, deliveries cannot happen because the recipients are not at the agreed delivery point. This causes the quality of service to decrease and distribution costs to increase. Based on this information, the present paper studies the role which Automated Parcel Lockers (APLs) have in addressing flaws in the urban last-mile delivery system. It is clear that e-commerce is on an ascending path, continuously developing, while traditional methods of delivery often encounter challenges such as high costs, increased impact on the environment, or customer dissatisfaction. APLs are part of a promising solution offering advantages such as improved delivery efficiency and customer satisfaction while reducing carbon emissions. The research methodology included a review of the literature on the subject, examination of industry reports and various case studies. The results provided an ambivalent perspective of both advantages and challenges which this system of delivery provides. Among the benefits, operational cost savings and reduced environmental impact are worth mentioning, while the challenges bring forward matter such as high installation costs or accessibility concerns. The findings also suggest that APLs require, for a successful integration in logistic operations, overcoming barriers of a technical and financial nature. The paper concludes with a broad perspective on the future development of APLs and necessary research directions. The importance of investigating further technological integration of these means, while adapting to both urban and rural conditions is also emphasized.*

Keywords: Automated Parcel Lockers; Last-mile Delivery; Urban Logistics; E-commerce; Sustainability.

JEL Classification: R41; L87; L81; Q56

1. Introduction

Home deliveries have gone through many changes, especially when it comes to last-mile delivery, which has faced various challenges and inefficiencies. As customer preferences and market demands have evolved, new solutions have emerged to make deliveries more efficient (Escudero-Santana et al., 2022). Next,

we will discuss how home delivery has developed, from the issues encountered with traditional methods to new solutions like smart lockers.

Storage lockers have evolved significantly over time. Initially, they were simple wooden boxes secured with padlocks, primarily used for storing valuables or important documents. These versions offered minimal protection and were easy to tamper (Kizhner, 2022).

The Industrial Revolution changed how lockers were made. This made them stronger and easier to produce, so they started showing up in more places like schools and factories. In the early 1900s, combination locks were introduced, which was a big improvement. These new locks made lockers safer and more convenient because people no longer had to worry about losing keys. This development made lockers more secure and user-friendly, setting the stage for today's advanced automated systems (Fadat, 2023).

The way packages are delivered has changed with the rise of online shopping. Many people are now using Automated Parcel Lockers (APLs) to securely store and retrieve their packages. This has been especially helpful in busy areas.

During the COVID-19 pandemic, online shopping and home deliveries saw a significant increase in sales. While the growth has slowed down, online shopping is still expected to remain popular. Customers now expect faster and more reliable delivery times (Genevieve et al., 2022).

Nowadays, automated parcel lockers (APLs) have advanced features such as automated locks, digital screens, and real-time messages to notify you when your package is ready for pickup. They not only make the process of getting your stuff easier and more secure, but they also cut down on the number of delivery attempts, which is good for the environment (Sawik, 2024).

Research on last-mile delivery options, in particular Automated Parcel Lockers (APLs), has shown that companies still require assistance in order to optimise their integration into larger logistical systems, even though the use of APLs is increasing. The features and potential advantages of APLs are widely known, however, there is still a discrepancy between the expected efficiencies and the results that businesses really attain (Aljohani, 2024).

The aim of this study was to demonstrate the significance and possible influence of APLs on improving last-mile delivery, especially in urban settings. The efficiency of APLs in lowering delivery times, costs, and environmental effects was the main emphasis of this study, in which a systematic evaluation of the literature together with industry reports and case studies were used. The main goal was to show that APLs could be a practical way to address the inefficiencies of conventional distribution techniques.

The data used in this research came from academic journals, market analysis papers, logistics businesses, and other sources.

2. Theoretical framework

2.1. Smart locker technology

Before the pandemic, home deliveries made up just a small portion of the market, and recipients would often pay extra to get their packages "in hand," either directly

at their door (attended home deliveries) or left on the doorstep or in the mailbox (unattended home deliveries), including in apartment buildings. However, during the pandemic, the volume of home deliveries more than doubled and has remained high ever since, even though the majority of packages are still delivered to collection points (Pinchasik et al., 2023).

Home delivery has long been preferred by most buyers. However, home delivery has had, and continues to have, a significant drawback: most of the time, when the courier arrives at the buyer's home with the package, it is very likely that they are at work, which often leads to a negative reaction from customers. This was the reason why many buyers chose to provide their workplace address for delivery. This way, they ensured they could receive the package on the day and time the courier arrived. However, this practice was not well-received by employers, who often prohibited employees from receiving personal deliveries at the workplace (Allen et al., 2018). Last-mile delivery, which is the final step in getting products to customers, often proves to be quite inefficient for several reasons (Deutsch and Golany, 2018). First, dealing with small packages or multiple stops makes it hard to use the space in delivery vehicles efficiently, leading to higher costs and longer delivery times (Visser et al., 2014). Another issue is missed deliveries when customers are not home, which results in extra costs and additional CO₂ emissions—each extra delivery attempt increases emissions by about 15% (Gevaers et al., 2011). Moreover, the high demand for deliveries, especially during holiday periods like Christmas, Easter, or back-to-school season, puts a lot of pressure on couriers, who have to handle a large number of deliveries which can also contribute to traffic congestion (Yuen et al., 2018).

The smart locker, also known by other names such as automated locker or delivery box, is seen as a sustainable solution for home delivery, offering an alternative to common problems (Lemke et al., 2016). These lockers are automated, unstaffed, and are placed in secure locations such as the ground floors of buildings or train stations. They can be accessed with a key or an electronic code, and customers are notified about the delivery via phone or email (Okholm et al., 2013). The smart locker is mainly used for parcels, but it can also store food with temperature control. This solution helps improve vehicle routes, reduces delivery costs, and minimizes issues related to incorrect addresses or missed deliveries (Zenezini et al., 2018). Customers appreciate the smart locker for its lower shipping costs and the convenience it offers, and its use can reduce gas emissions by up to two-thirds compared to traditional home delivery (Van Duin et al., 2020).

Parcel lockers are unattended collection points placed in public or private locations, where parcels are stored temporarily until customers retrieve them using a reference code provided with their order (Augereau and Dabanc, 2008).

The first Automated Parcel Locks (APL) were introduced in the early 2000s and emerged to counter the logistical challenges arising from the rapid growth of online commerce. With the help of these systems, it was possible to reduce the number of failed deliveries, especially in cities, where recipients were often not at home when the courier arrived. Generally, APLs have been placed in public places such as shopping malls and transport stations, thus giving consumers the ability to collect their parcels safely and conveniently using a unique access code at any time of the day or night.

These initial implementations brought significant improvements in delivery efficiency and customer satisfaction. The ability to pick up packages at any time without worrying about missed deliveries greatly changed how deliveries were handled, especially in busy urban areas (Sawik, 2024).

2.2. Advantages and benefits associated with smart lockers

Smart lockers have really changed the way packages are delivered and picked up. They provide great benefits for both customers and companies. These high-tech lockers use advanced security and digital technology to offer a simple and efficient solution to the challenges of parcel delivery.

Customers love these smart lockers because they are super convenient and flexible. They can grab their packages at any time without having to deal with delivery personnel directly.

- Convenience and flexibility

Smart lockers allow customers to pick up their packages at any time, day or night, without worrying about missing a delivery. This is particularly useful for those with busy schedules or who are not home during regular delivery hours (Golinska-Dawson and Sethanan, 2023).

- Enhanced security

Smart lockers offer a safe place to store parcels, lowering the risk of theft or damage. Customers receive a unique code to access the locker, ensuring that only they can retrieve their package (Pitney Bowers, 2021).

- Contactless and efficient

Since the COVID-19 pandemic, the demand for contactless delivery options has grown. Smart lockers provide a completely contactless solution, allowing customers to pick up their parcels without any physical interaction, making the delivery process safer and more efficient.

Many companies have adopted smart locker systems and have seen the advantages they offer firsthand (Gutenschwager et al., 2024).

- Cost savings and efficiency

Smart lockers help companies reduce the costs associated with last-mile delivery by minimizing the need for multiple delivery attempts and optimizing delivery routes. By consolidating deliveries to a single location, logistics companies can save on fuel and labor costs, making the process more efficient and cost-effective (Coates, 2023; DHL, 2023).

- Improved operational efficiency

The automation provided by smart lockers streamlines the package handling process, reducing human error and freeing up resources. Companies can manage a higher volume of deliveries without requiring additional staff, thus improving operational efficiency (DHL, 2024).

- Sustainability

Smart lockers contribute to reducing the environmental impact of deliveries by lowering the number of delivery vehicles on the road. This reduction in traffic not only cuts down on fuel consumption and emissions but also helps in alleviating congestion in urban areas, aligning with the growing focus on sustainable logistics practices (FedEx, 2023; Sawik, 2024).

Smart lockers are becoming increasingly important in modern logistics as more companies realize their benefits. These systems make deliveries easier, cut costs, and make customers happier. They also provide users with more flexibility and security. By integrating smart lockers into their current logistics setup, companies can address immediate needs and prepare for future demands. As technology continues to advance, smart lockers will become even more essential in the supply chain.

2.3. Disadvantages and challenges associated with smart lockers

Although smart lockers have brought efficiency, security, and convenience to package delivery, they are not without challenges. The implementation and use of these technologies present various difficulties for both companies and consumers. Obstacles such as high installation costs, accessibility issues, and negative user perceptions can hinder the adoption of automated lockers and affect user satisfaction. To successfully implement these systems and ensure that users have realistic expectations, it is crucial to understand and address these challenges.

- **Technical issues and complex logistics**

Although automated lockers offer many advantages, there are several technological issues that may complicate matters. These lockers are highly dependent on technology, including network connections and software, which can occasionally have problems. Issues such as network problems or system errors might cause delays in receiving your items and can be rather inconvenient. Additionally, it might be challenging to get these lockers to function properly with the current logistical systems, and it requires constant technological maintenance and upgrades. For companies, this means investing in specialized IT support and dealing with the potential for technical downtime (Smiota, 2024).

- **High initial costs and maintenance**

The deployment of automated lockers involves significant initial costs. The main costs are buying, installing, and connecting the lockers with current logistics systems. Along with the initial investment, maintenance and system upgrades are ongoing expenses. Regular maintenance is necessary to keep the lockers working well, which can be expensive and time-consuming. It is also important to consider the cost of fixing or replacing damaged or outdated lockers. These high costs can be a barrier, particularly for smaller businesses or those operating in regions with lower adoption rates of such technology (Luis et al., 2022).

- **Limitations in accessibility and adaptability**

Automated lockers are not always accessible to everyone. For instance, they may be difficult to use for individuals with disabilities or those who are not tech-savvy (Malyack et al., 2022). Additionally, the placement of these lockers is typically in urban areas, which can limit their accessibility for people living in rural locations. The one-size-fits-all approach of many locker systems also means they may not be adaptable to the varying needs of different businesses or consumers. This lack of flexibility can limit their effectiveness in serving a diverse customer base (DHL, 2024).

- **Negative consumer perceptions**

Despite their advantages, not all consumers are comfortable with using automated lockers (Quan et al., 2022). Some people might feel that the technology is too

complicated or inconvenient and prefer traditional delivery methods. Others might worry about the safety of their packages, especially if the lockers are in unmonitored areas. Additionally, if a customer has a negative experience with an automated locker—such as difficulty retrieving a package or encountering a technical issue—it can lead to dissatisfaction and a reluctance to use the service again. Overcoming these negative perceptions requires companies to invest in customer education and ensure a reliable user experience (Pitney Bowes, 2021).

As we have seen, automated lockers provide a lot of advantages, but they also have drawbacks. Addressing these challenges is important to ensure they work well for businesses and customers. As technology advances, new opportunities for developing and using automated lockers are emerging.

3. Future prospects of automated lockers

The future of automated lockers is bright, with many interesting advancements looming as technology continues to advance. The efficiency, accessibility, and scalability of automated locker systems are anticipated to be significantly improved by these developments, making them even more crucial to the retail and logistics sectors.

■ Predictions for technological development

Significant technical developments in automated lockers are anticipated in the upcoming years. Improved user interfaces that make the systems more user-friendly for both customers and logistics operators are expected to be among these advances, as will increased security features like biometric verification and AI-driven predictive analytics to maximise locker utilisation.

Additionally, the integration of Internet of Things (IoT) technology will allow for real-time tracking of parcels and better management of locker systems, ensuring higher efficiency and reducing the risk of technical issues (Korczak and Kijewska, 2019).

Furthermore, automated lockers should become more smoothly incorporated into urban infrastructures as smart cities expand. Better locker location and accessibility are only one aspect of this integration; lockers will also be connected to other smart systems, such as public transit and traffic control. This will make parcel deliveries more efficient and contribute to the overall goal of creating smarter, more connected cities (Coates, 2023).

■ Integration with other systems and services

Increased system and service integration is another aspect of automated lockers' future. This can entail integrating lockers with payment processors, CRM software, and online shopping portals. With this kind of connectivity, clients might select particular lockers according to their preferences, get real-time information, and even handle returns more effectively, resulting in more personalised delivery experiences. Another area with potential expansion is integration with last-mile delivery services like autonomous cars or drones (Openvia). By connecting automated lockers with these innovative delivery methods, the logistics industry can further streamline operations, reduce costs, and minimize the environmental impact of parcel deliveries (Pitney Bowes, 2021).

■ Expansion of lockers network

Continuous innovation is vital for the future of automated lockers, particularly in expanding their networks to rural and underserved areas (Parcel and Postal Technology International, 2024). This could involve developing modular or mobile lockers that can be easily relocated based on demand.

The smart parcel locker network is set to grow significantly, with the global market expected to increase from USD 736 million in 2020 to USD 1,438 million by 2025, driven by the rise in e-commerce and the demand for contactless delivery solutions, according to a report by MarketsandMarkets (2023).

- Sustainability of automated lockers

Improvements in the sustainability of automated lockers are likely to be observed in the future. Future designs could focus on using renewable energy sources, such as solar power, to operate lockers, further reducing their carbon footprint and aligning with global sustainability goals (Parcel Hive, 2024).

Additionally, as e-commerce continues to grow worldwide, particularly in developing markets, the demand for efficient last-mile delivery solutions such as automated lockers will increase. Companies that can use and adapt these systems to local conditions and preferences will be in a position to benefit from this growing market.

4. Conclusions and recommendations

This investigation of data on automated lockers showed several important discoveries. Automated lockers are an invaluable resource in contemporary logistics, providing substantial advantages, including efficiency, security, and convenience for customers and organizations. Their capacity to optimize last-mile delivery procedures, save operating expenses, and improve customer contentment has established them as an important part of the logistics network. Nevertheless, in order to guarantee the effective deployment and broad acceptance of automated lockers, certain obstacles must be overcome. Obstacles include technical problems, expensive startup expenses, and maintenance needs, especially for smaller enterprises.

Furthermore, barriers to accessibility and adaptability and possible unfavourable customer impressions highlight the necessity for continuous advancements and innovations (Mohri et al., 2024; Jang et al., 2024).

Automated lockers have a bright future ahead of them, as technological developments should only expand their functionality. Their continuous progress is fuelled by their integration with other systems, like e-commerce platforms and last-mile delivery services, or the expansion into new international markets. In order to overcome present constraints and broaden their application, the creation of more flexible and long-lasting locker systems will be essential (Falcone et al., 2019).

Given the rapid development of automated lockers and their increasing importance in logistics, several areas are suitable for further research:

- Growing accessibility and inclusivity

Future studies should focus on developing automated locker systems that are more accessible to a broader range of users, including those with disabilities and located in rural areas. Research should explore how these systems can be designed and

implemented to serve populations with different needs more effectively (Ciesla, 2023).

- Long-term cost analysis

While the initial costs of automated lockers are known and documented, there is a need for more detailed research into the effects of financial implications over time, such as maintenance costs, technological upgrades and potential savings from operational effectiveness. Such research can provide valuable insights for businesses which are considering investing in these systems (Villa et al., 2021).

- Sustainability and environmental impact

As sustainability becomes a priority in logistics, studies should explore the environmental benefits which automated lockers bring, particularly in reducing carbon emissions and traffic congestion. Additionally, studies should investigate ways to make these systems more efficient from the energy consumption point of view, potentially through the use of renewable energy sources (Sawik, 2024).

- Consumer behaviour and adoption

Understanding consumer attitudes towards usage of automated lockers is essential for their success. The factors that influence consumer adoption, satisfaction and loyalty, as well as strategies for overcoming any negative perceptions should be examined (Rosca et al., 2024).

- Global expansion strategies

With the expansion of automated lockers worldwide, there is a need to investigate how these systems can be adapted to different cultural and economic contexts. This includes studying the challenges and opportunities associated with deploying lockers in developing markets and creating solutions to meet local needs (Dissauer et al., 2024).

By addressing these research areas, stakeholders can ensure that automated lockers continue to evolve in ways that maximize their benefits and minimize their challenges, ultimately enhancing their role in the future of logistics and e-commerce.

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