

Parcel lockers as an instrument of the sharing economy in package delivery

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Abstract

The development of e-commerce has influenced the increase in the number of delivery vehicles in urban areas, resulting in environmental pollution, noise pollution, and traffic congestion. Operators also face various challenges in last-mile delivery, resulting in high transportation costs and prolonged delivery times. These problems require efficient management strategies to reduce the negative impact on the environment and improve the quality of life in cities. Today, with the sharing economy becoming a key element of business models, particularly in the transportation industry, the solution can be found in the implementation of parcel lockers. The sharing economy represents an economic model in which individuals or organizations share access to resources, services, or infrastructure through collaborative consumption, usually through online platforms or applications. This model enables cost reduction and increased service availability, contributing to a more sustainable and efficient use of resources. Therefore, this paper analyzes the implementation of the sharing economy in last-mile delivery, with a specific focus on the role of parcel lockers as an innovative solution. The authors investigate the functionality of parcel lockers, highlighting their advantages and their impact on last-mile delivery.

Keywords: parcel lockers, sharing economy, last-mile delivery

1 Introduction

Before online shopping became the norm, consumers handled transportation and all other aspects associated with the last mile, transporting purchased products from the point of purchase to their destination. Today, with online shopping and home delivery becoming extremely popular, consumers are less likely to shop in traditional ways by going to retail stores. Consumers purchase various items online, and advanced technologies drive the growing trend of e-commerce and associated processes.

Last-Mile Delivery is a term used in supply chain management and transportation planning to describe the movement of people and goods from a transportation hub to the final destination at a household [1]. One of the largest and fastest-growing segments of last-mile delivery operations is package delivery. The importance of this type of delivery is increasing with the growing interest in distance shopping. E-commerce significantly contributes to the global parcel delivery market and is one of the fastest-growing business sectors worldwide [2]. According to projections, the

annual revenue growth rate of e-commerce from 2024 to 2029 will be 9.79% [3].

With the rise of online shopping, new delivery problems arise. A huge number of delivery vehicles have become a significant factor in urban traffic congestion. These vehicles, besides moving, often have to stop multiple times in busy streets, creating problems for both the drivers of these vehicles and the residents. The high number of vehicles also contributes to environmental pollution, excessive noise, and problems such as high delivery costs and long delivery times. Because of all the above, numerous ideas and technological solutions are flourishing lately, aiming to solve the issue of efficient delivery while respecting environmental guidelines. Today, as the sharing economy becomes a key element of business models, especially in the transportation industry, the solution can be found in the implementation of parcel lockers.

Within this paper, the effects of parcel lockers implementation were analyzed, with the aim of determining whether the use of parcel lockers, as a tool of the sharing economy, can reduce the negative impact on the environment caused by a

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large number of deliveries in the city, as well as determining the advantages of using this system.

The paper is structured into six chapters. The next chapter defines the concept of the sharing economy and its connection to transportation and last-mile delivery. The third chapter defines the role and lists the most significant advantages of using parcel lockers. Examples of best practices, or the effects achieved by implementing these systems in some cities around the world, are provided in the fourth chapter. The fifth chapter analyzes the possibilities of integrating crowd-sourced delivery and parcel lockers. Finally, the conclusions are provided at the end of the paper.

2 Sharing economy

The concept of the sharing economy is difficult to define, as the term is used differently in practice and the meaning of "sharing" can vary [4]. Liu Weili and Khan Hayat conducted a literature review to identify the most relevant definitions of the sharing economy offered by various authors. Generally, the sharing economy refers to the efficient sharing of resources, but it should be noted that there is no universally accepted definition. For example, Ter Huurne and associates define the sharing economy as an economic model that consists of sharing unused resources among people without transferring ownership. This includes sharing space, skills, and items through online platforms. Similarly, Botsman defines the sharing economy as a system that facilitates the sharing of unused resources and services for monetary or free exchange between individuals or organizations [5].

Some authors consider that the sharing economy is a relatively new concept whose emergence was crucially influenced by the development of the internet and modern information and communication technologies [4]. On the other hand, there are authors who emphasize that some forms of sharing existed long before the internet, such as carpooling, which was organized through bulletin boards or word-of-mouth recommendations. However, the development of information and communication technologies has allowed these models to reach a higher level, providing greater convenience and efficiency in their implementation [6].

Based on the above, the sharing economy can be defined as an economic model in which individuals or organizations share access to

resources, services, or infrastructure through collaborative consumption, typically facilitated by online platforms or applications. This model enables cost reduction and increased service availability, contributing to a more sustainable and efficient use of resources.

The most intensive development of sharing economy examples is currently observed in the hospitality and transportation sectors, with the most well-known representatives being Airbnb and Uber. These platforms enable the sharing of accommodation and transportation among individuals, resulting in significant changes in these industries. However, it is important to note that the sharing economy includes other segments of the economy and society such as food, fashion, tools, and many others, with platforms such as EatWith, Rent the Runway, ToolShare, and similar ones.

In traffic, the sharing economy dominates in the area of shared mobility, but in recent years, there has been increasing interest in sharing freight and applying the sharing economy in last-mile delivery. This can include sharing cargo space or the possibility for passengers traveling to deliver or transport something for other users on the same journey. One example of the application of the sharing economy in last-mile delivery is parcel lockers. Parcel lockers allow for the sharing of cargo space by different users in a short period. Necati Oguz Duman and his associates have researched existing and potential business models of the sharing economy in last-mile delivery, among which one of the models they highlight is the use of parcel lockers [2].

3 Parcel lockers

The rise of e-commerce has resulted in increased demand for postal services. Customers can search for products and place orders anytime and anywhere. Due to the circumstances arising from modern lifestyles and business practices, one of the key parameters of postal service quality – accessibility, is becoming increasingly difficult to maintain at an appropriate level. Customers are finding it increasingly challenging to use postal services because their business and personal obligations often overlap with postal company working hours, leading to growing demands [7]. Customers not only want to receive their orders quickly and benefit from free or low-cost shipping but also to collect their shipment/package at a location and time that suits them. One solution

that companies can offer is "out-of-home delivery," i.e., delivering parcels outside the recipient's home, with one of the most advanced solutions in this area being the use of parcel lockers [7,8].

Parcel lockers are self-service terminals that function for both sending and receiving parcel shipments. They can efficiently replace traditional courier door-to-door delivery and improve the delivery of parcel shipments [9].

To use the parcel locker delivery service, customers choose the locker location as the delivery address. The delivery company sends the package to that location, and once the package is placed in the locker, the customer receives a one-time code to open the locker and retrieve their order. After the customer picks up the packages, the locker is assigned to other deliveries. Generally, lockers are allocated for short-term use, usually up to several days [2].

Parcel lockers offer numerous advantages for delivery companies, customers, and sellers. For delivery companies, one of the most significant advantages is the ability to consolidate a larger number of deliveries, eliminating the need for workers to visit each customer individually. This primary reduces traffic congestion and negative environmental impact, while operators have lower costs, requiring fewer vehicles and fewer drivers for parcel delivery [10].

One of the main advantages of using parcel lockers for customers is the convenience and flexibility of access. Instead of waiting for delivery for several hours, customers can go to the nearest parcel locker and pick up their package at a time that suits them. Parcel lockers allow package pickup 24 hours a day, 7 days a week. Another significant convenience is quick and easy use, and parcel lockers are generally located in places with easy access and parking [7,10].

From the seller's perspective, parcel lockers provide a secure location for packages, reducing the risk of shipment damage. The implementation of this delivery method has led a high rate of first-time delivery success and easy returns at low costs [7].

4 Examples of good practices

This chapter analyzes relevant research on the application of parcel lockers. The first part will present the effects of parcel lockers implementation as documented by Poland in its research, followed by the results of research

conducted in Norway, the Netherlands, and research by scientists from Loughborough University in the United Kingdom.

4.1 Poland

As in other cities around the world, last-mile deliveries are a major factor in traffic congestion in Polish cities. With the increase in online sales, the number of home deliveries has also increased. Individuals typically purchase small quantities of products expecting fast delivery, so delivery companies provide their services regardless of the utilization of cargo space. A large number of smaller orders also requires a greater number of delivery vehicles. On the other hand, there is an issue with inadequate vehicle fleets, often not tailored to the needs of e-commerce, especially in terms of vehicle size compare to delivery volume. Local authorities often apply inefficient measures to reduce the negative impact of urban freight traffic. In Poland, these measures mainly focus on access restrictions, leading to many issues in home deliveries [11].

Poland has recognized significant potential in alternative parcel delivery solutions and has initiating the implementation process of parcel lockers to overcome the mentioned problems. The concept of using parcel lockers in Poland was realized by the Polish company InPost, which implemented its parcel lockers not only in Poland but also in other countries worldwide. According to data from 2014, InPost had implemented over 3,000 parcel lockers in 20 different countries [11].

To assess the efficiency of parcel locker implementation, a research was conducted in Poland in 2013, and some of the results of that research are presented in Table 1.

Table 1. Results of researches - Poland [11]

	Courier	Parcel lockers
Number of km during a day	150	70
Number of parcels delivered per day	60	600
CO₂ emission (tons per annum)	32.500	1.516
Fuel consumption l/year	22.500.000	1.050.000

According to the research conducted by the Department of Robotics and Mechatronics at the University of Krakow, a courier from the company InPost delivering packages to parcel lockers is able to deliver 600 packages in one day, covering a distance of approximately 70 km. This means he can deliver 540 more parcels compared to traditional delivery method, while traveling 80 km less [11].

The research also indicates that the implementation of parcel lockers significantly reduces the negative impact on the environment. CO₂ emissions decrease by over 95% with the use of parcel lockers. Additionally, the implementation of parcel lockers results in a reduction in fuel consumption by enabling the delivery of a greater number of parcels in a single trip, thus reducing the need for multiple trips to individual recipient addresses. This directly contributes to reducing the costs for delivery companies, such as InPost in this case [11].

4.2 Norway

PostNord, as one of the leading parcel delivery companies in Norway, recognized the need for innovations in its delivery model to remain competitive in the market. To improve its delivery model, the company initiated a pilot project by installing parcel lockers in several regions of Norway.

In order to expand the parcel locker network, a study was conducted with the primary goal of proposing alternative scenarios for expanding the parcel locker network, as well as comparing them with the current delivery model. The study was conducted in the Greater Oslo region, located on the southern coast of Norway, consisting of the city of Oslo and several municipalities.

Donga and colleagues proposed four alternative delivery models in their work, depending on where and how packages are delivered. The basic scenario (S1) reflects the current situation in which there are two delivery options: standard home delivery and delivery to parcel lockers. Home delivery originates from the "Lorenskog" terminal, while deliveries to parcel lockers come from the "Alfaset" terminal. In the second scenario (S2), both home deliveries and deliveries to parcel lockers originate from the same terminal - the "Lorenskog" terminal. In the third scenario (S3), packages intended for home delivery that require the recipient's presence are

redirected to parcel lockers (if their dimensions are suitable for parcel lockers and if the distance to the nearest parcel lockers is less than 2 km). Scenario four (S4) involves that all home deliveries from scenarios 1 and 2 are sent to parcel lockers (if they meet the size requirements and if the distance is less than 2 km), in this case assuming that the capacity of the pilot parcel locker network is not enough, so it is planned to use an expanded parcel locker network.

At the time of the study, there were 198 parcel lockers in the Greater Oslo region. With this network, the average walking distance between customers' homes and the nearest parcel locker was about 2.1 km. The expanded network, adopted in scenario 4, included 506 parcel lockers, reducing the average walking distance between customers' homes and the nearest parcel locker from 2.1 km to 0.75 km [12].

To select the optimal variant, a comparison of scenarios was conducted using several indicators. For the analysis, one day of PostNord's deliveries in the Greater Oslo region was taken into account, selecting the date with the highest number of parcel deliveries in 2021.

The results of this study show that using parcel lockers can bring significant cost savings for the company while reducing negative environmental impact. Only sharing a delivery terminal (in this case, the "Lorenskog" terminal in scenario 2) reduces daily delivery costs by about 1.6%, with daily delivery costs further reduced as the share of deliveries to parcel lockers increases. By replacing home deliveries with deliveries to parcel lockers, savings of up to 7.4% can be achieved, which on an annual basis, in this specific case, amounts to around 11.03 million NOK (1 NOK $\approx$ 0.086€). Additionally, as the share of deliveries to parcel lockers increases, the average vehicle capacity utilization rate increases from 16.0% to 41.8%.

Regarding the environmental impact, there is a noticeable reduction in all analyzed pollutant emissions. By converting parts or all of the home deliveries to deliveries to parcel lockers, up to 32.68% of all listed emissions can be saved [12].

4.3 Loughborough University (United Kingdom)

As previously mentioned, parcel lockers increase delivery consolidation, reducing the number of delivery points and vehicle kilometers traveled. They are also considered an optimal solution for failed deliveries, address finding issues, and return deliveries. Many authors emphasize that parcel lockers have a positive impact on the environment, reducing exhaust emissions, noise, and traffic congestion. However, most of these authors or studies ignore the external effects of parcel pickup.

In contrast to most published studies, research conducted by Schneider and associates from Loughborough University considers emissions from delivery vehicles as well as emissions from customers. HBEFA handbook, which provides emission factors for road vehicles in grams per vehicle/kilometer, for different vehicle categories, engines, traffic conditions, and climatic conditions, was used to assess emissions. The factors considered in the study were carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC), nitrogen oxides (NO_x), and particles (PM₁₀) [13].

The study showed that the reduction in emission factors largely depends on the number of users who pick up their parcels by car. When comparing emissions from home delivery and delivery to parcel lockers, the proportion of customers who pick up their parcels from lockers by car must be low because otherwise home delivery would result in lower emissions. For example, to reduce CO₂ emissions for delivery to parcel lockers, the proportion of users who pick up parcels from lockers by car must be less than 20%. The share of NO_x would be lower for delivery to parcel lockers if the proportion of

users who go to lockers by car is between 20% and 40% [13].

Although it is vital to minimize CO₂ emissions, it is also crucial to reduce other emissions. The European Environment Agency (EEA) identifies PM₁₀ and NO_x as the most harmful pollutants to human life. PM₁₀ and NO_x emissions are 4 and 2 times higher for delivery vehicles than for passenger cars, respectively. Therefore, reducing the number of kilometers traveled by delivery vehicles by delivering to parcel lockers has a much greater effect on PM₁₀ and NO_x emissions compared to other emissions. That is, emissions of these pollutants can be reduced by delivering to parcel lockers even if half of the customers pick up their parcels by car. To reduce CO₂ and other pollutant emissions (CO, HC, etc.), almost no customers should use a car to pick up parcels. The maximum proportion of customers who can pick up parcels by car while significantly reducing pollutant emissions varies depending on the type of delivery vehicle, age, cold/hot start after pickup, and temperature [13].

4.4 The Netherlands

An increasing number of countries recognize the positive effects of implementing parcel lockers, and another country that has conducted research in this area is the Netherlands. PostNL, the leading parcel delivery company in the Netherlands with approximately 70% market share, actively explores innovative solutions to remain a market leader. Given the growing number of delivered and returned parcels, increasing customer expectations, and intensified competition in the market, PostNL has identified the need to adapt to new trends. Accordingly, the company has installed several parcel lockers across the Netherlands to improve parcel delivery. PostNL's primary goal is to reduce delivery costs

Table 2. Environmental impact depending on the applied scenario [12]

	S1	S2	S3	S4
Fuel per parcel (kg)	0,07	0,06	0,06	0,05
CO₂ emission per parcel (kg)	0,22	0,20	0,19	0,15
NO_x emission per parcel (g)	0,25	0,23	0,22	0,17
PM₁₀ emission per parcel (hg)	1,04	0,95	0,89	0,70
Emission saving per parcel (%)	-	8,22	14,48	32,68

and improve service quality, for which purpose a study was conducted in the "De Pijp" district in Amsterdam. The focus of the study was on the question: "How to conduct parcel delivery in a more sustainable and financially efficient way using parcel lockers?"

The study analyzed the existing parcel delivery model and proposed three new alternatives. These alternatives differ depending on the distribution and collection options for parcels. All three alternatives have three variants that are the same for each of them. These variants differ in the size of the parcel lockers: variant 1 uses XS lockers, variant 2 uses S lockers, while variant 3 uses M, L, and XL lockers [14].

In the existing delivery model, all parcels are delivered to the home address, while parcel collection is exclusively done at retail stores. Alternative 1 involves redirecting failed delivery attempts to home addresses to parcel lockers on the same day, with parcels being collected exclusively from parcel lockers. In alternative 2, parcel lockers are used as the first delivery option, and parcels are delivered to the home address only for parcels that do not fit in the dimensions of the parcel lockers. In this case, parcels are collected both at retail stores and from parcel lockers. Alternative 3 covers only parcel distribution, without collection. Parcels are first delivered to parcel lockers, and parcels that do not fit in the dimensions of the parcel lockers are sorted and delivered through the standard route to the home address. If the lockers are full or there is no one at home, parcels are delivered to a retail store [15].

The results of this study show that replacing home delivery with parcel lockers is a successful strategy that can result in cost savings and increased delivery sustainability. Since this research aimed to design a delivery model that could operate more efficiently and sustainably than the current delivery model, alternative 2 with S-sized parcel lockers proved to be the best [14].

Instead of a total of 1,475 stops during delivery, this alternative model would have 430 stops for home deliveries and only 47 stops for deliveries to parcel lockers. This approach would ensure that a larger part of parcels is delivered to parcel lockers, but there would also be an option to pick up parcels at home or at a retail. Implementing this delivery model could significantly reduce the number of drivers and delivery vehicles, while increasing delivery efficiency. According to the analysis, this would

result in savings of around 121,356.00 euros annually in this specific case [15].

This study once again confirms the advantages of using parcel lockers, which not only significantly reduce delivery costs for delivery companies but also make it easier for customers to pick up parcels.

Y.A. van Amstel concludes that the proposed alternative model will reduce the number of delivery vehicles in the city, which will directly contribute to reducing traffic congestion. Additionally, the parcel locker route has fewer stops compared to the normal delivery route, enabling more efficient driving [15].

5 Crowdsourced delivery

Crowdshipping, as a sharing economy concept, is becoming an interesting solution for last-mile delivery challenges. Crowdsourced delivery is a shared delivery model in which individuals deliver packages on behalf of an organization for a fee [9]. As crowdshipping is gaining popularity and parcel lockers are becoming a flexible and widely accepted solution for last-mile delivery challenges, an increasing number of studies are focusing on analyzing the integration of these two models.

Research conducted by Hadi Ghaderi and colleagues in 2022 represents one of the first studies examining the integration of crowdshipping (parcel delivery by occasional couriers) and parcel lockers. Their research focuses on developing a model that uses parcel lockers as transfer points. In such a system, one delivery task can be performed by multiple couriers together, which is called share delivery. This approach aims to develop an efficient model that will improve delivery services, increase delivery success rates, and reduce delivery costs in urban areas. Although group delivery seems to be a commercially attractive and environmentally friendly way of delivering parcels, it is promising only when a new generation of travel is not needed. Numerical analyses have shown that shared delivery can improve the delivery success rate by up to 5%, which can be achieved by implementing a small number of parcel lockers at 'critical' locations. The authors found that despite involving more than one crowdshipper for delivery and the costs of implementing and maintaining parcel lockers, the system generates significant profits [16].

Aleksandar Vajrovski and his colleagues researched a specific form of group delivery known as crowdshipping in public transport. This model involves public transport users using a mobile application to pick up parcels from parcel lockers, carrying them during their journey, and then delivering them to other lockers. Public transport users can register on a central group delivery platform and publish their regular routes, such as daily commutes to and from work. When they arrive at their destination, users place parcels in lockers recommended by the application, then confirm delivery by scanning the barcodes of the parcel and the locker. Lockers can serve as parcel endpoints, where actual recipients pick them up, or as transfer points, where parcels wait for other crowdshippers to pick them up. The authors state that the key to the success of this concept is recruiting a large base of crowdshippers, voluntary public transport users, which is significantly larger than the number of parcels to be delivered. They also emphasize that the ability to transfer parcels across multiple travel segments with multiple crowdshippers significantly increases planning flexibility and promises a higher number of delivered parcels, resulting in greater profit for the platform compared to the current practice of having only one crowdshipper per parcel. This innovative concept represents an efficient and environmentally friendly delivery method and opens up new possibilities for improving parcel delivery business [17].

Considering the significant success of newly established sharing economy giants such as Airbnb and Uber, it is not surprising that postal service providers are increasingly trying to apply the sharing concept to their last-mile delivery services. The mentioned studies show that these models have the potential to significantly improve last-mile delivery, reduce costs, and enhance efficiency, making them an interesting solution for the future of delivery. However, there are still no concrete results from practice.

6 Conclusion

This paper explores the application of the sharing economy concept in parcel delivery, focusing primarily on the use of parcel locker systems instead of traditional home delivery.

The sharing economy concept refers to a model in which individuals or organizations share access to resources, services, or infrastructure through collaborative consumption, usually facilitated by online platforms. Parcel lockers, as

systems that enable the sharing of storage space by different users, represent an excellent example of the sharing economy applied to parcel delivery.

Through the analysis of various studies and best practices examples, this paper highlights that the implementation of parcel lockers as a tool of the sharing economy is an efficient alternative to traditional parcel delivery. The use of parcel lockers enables the delivery of a larger number of parcels in a single trip, thus reducing fuel consumption and delivery costs. Additionally, this approach contributes to reducing the negative impact on the environment and traffic congestion in cities. The flexibility of access further improves the customer experience, making this model even more attractive to all involved participants.

Recognizing the advantages of parcel lockers, postal service providers are increasingly attempting to transfer the sharing concept to their services. Crowdshipping, as part of the sharing economy, has proven to be an interesting solution for the challenges of last-mile delivery, especially in combination with the increasingly popular parcel lockers. Although studies show that the integration of parcel lockers and crowdshipping is not only possible but also an effective alternative to traditional parcel delivery, further research and implementation in practice are needed to confirm their efficiency, sustainability, and benefits for all participants in the delivery process.

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