

Parcel lockers as delivery solution

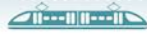
Usage patterns, experiences and effects of network expansions

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- Parcel lockers are secure, flexible delivery solutions, primarily intended to replace home deliveries. Advantages include that distributors can deliver multiple parcels simultaneously, to a location near customers, rather than servicing many individual locations. Parcel lockers also increase flexibility as customers can pick up deliveries 24/7.
- Following a pilot in 2021, both network coverage of PostNord's parcel locker network and delivery volumes have increased strongly, reaching regions across Norway. Most lockers are located near grocery stores and housing cooperatives. Although network density varies between regions, customer coverage is becoming satisfactory many places, particularly in Oslo.
- Customers collect their parcels somewhat faster than during the pilot phase in 2021. Pickup patterns exhibit some differences between geographical locations and location types, amongst others driven by the time-of-day of deliveries vs. when visiting different types of delivery locations is convenient for recipients.
- In 2022, delivery times have gone down, both per location and per parcel. Nevertheless, the number of parcels delivered per location remains relatively low, except during certain peak-periods. This suggests a potential for efficiency improvements. Also, economies of scale in other stages of the delivery process could likely be exploited better.
- Increased use of parcel lockers as alternative to home deliveries has a potential to reduce traffic, environmental emissions, and other external costs to society – also when considering recipients' collection trips that parcel lockers necessitate. Even if the logistics operator's last-mile distribution is fully electrified, increased use of parcel lockers will remain economically beneficial for society by reducing total traffic.

Background

Although e-commerce has been increasing over time, this growth was strongly amplified during the COVID-19 pandemic, which also increased demand for home deliveries and put a strain on parcel delivery capacity. While society seems to have normalized post-pandemic, online shopping is expected to remain at high levels. This has increased the need for more flexible delivery solutions, as time windows for home deliveries often are too broad for customers, particularly after people started returning to their workplaces, rather than working from home. The above formed the underlying motivation for KONTAKTFRI, a Pilot-T project



financed by the Research Council of Norway and with PostNord as project leader. The KONTAKTFRI project revolves around pilots of two new delivery alternatives: contactless home deliveries and parcel lockers.

Parcel lockers allow recipients to collect their parcels 24/7. PostNord's objective is to create a parcel locker network where lockers are conveniently located, and within 'slipper distance' (up to 300 meters) from recipients.

Development of PostNord's parcel locker network

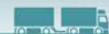
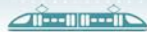
PostNord established its first parcel lockers in the fall of 2020. After a pilot phase in 2021, the network increased to nearly 2 150 lockers across 941 locations by March 2023. While the pilot phase primarily targeted Oslo and Viken county, and particularly locations near housing cooperatives, the network has now expanded to many different Norwegian regions, particularly including cities and larger towns, but also smaller municipalities. Expansions have been largest for locations near grocery stores, which constitute the predominant location type in most counties. In some counties, however, particularly in Oslo, housing cooperatives remain the primary location type. Other locations, such as transportation hubs, educational institutions, and workplaces, so far only make up smaller shares. Most locations have either 2 or 3 parcel lockers, with an overall average of 2,3 lockers per location. On average, grocery store locations have a slightly higher average (2,5 lockers per location) than housing cooperatives (2,0).

Population coverage

By dividing the number of locations and lockers by respective populations, we find that by mid-March 2023, there were on average 5 800 people per locker *location*, and 2 500 people per locker (nationwide). These figures, however, vary considerably both between counties and municipalities. For the ten largest Norwegian municipalities, each location is on average shared by 4 500 individuals, while each locker is shared by about 1 980 people. Coverage is best in Drammen, followed by Kristiansand, Trondheim, Oslo and Lillestrøm.

Further analyses, where we relate parcel lockers' detailed locations to where people live, show that Oslo clearly has the highest share of residents living within relative short distances from their nearest locker (11% within 125 meters aerial distance, increasing to 28% within 250 meters, 64% within 500 meters, and 91% within 1 km). In all other Norwegian counties, fewer than 10% of residents live within 250 meters and the proportion of the population living within 500 meters from their nearest PostNord locker is roughly half to one-third compared to Oslo. While only 9% of Oslo's population lives more than 1 km away from their nearest parcel locker (aerial distance), this share lies between 44% to roughly 80% in other counties.

Most parcel lockers is located in municipalities with larger populations. This also explains some of the variation between counties. For example, counties like Viken and Vestland have more residents living over 1 km from their nearest locker (particularly in rural areas), but also areas (particularly the cities) where many people live within relative short distance of their nearest parcel locker. Our analyses and underlying data allow identification of areas with relatively good coverage relative to their population, and areas it might be beneficial to prioritize in further network expansions.



Delivery pattern

Compared to 2021, the number of shipments delivered to PostNord's parcel lockers increased more than tenfold in 2022. This growth primarily took place during the second half of the year, particularly related to Black Week and Christmas shopping. For 2021-2022 overall, around 45% of shipments were delivered to parcel lockers located near grocery stores, and another 45% to locations near housing cooperatives.

Nearly all deliveries to parcel lockers take place on working days, most on Wednesdays, followed by Thursdays and Tuesdays (with each day representing ca. 20-22% of weekly deliveries). Almost all deliveries take place during daytime, starting from 9 AM and with little activity during morning rush hours. Overall, around a third of all parcels is delivered between 9 AM-12 PM and another 39% between 12PM and 3PM, making this the main delivery window. Of all parcels, 18% were delivered during the afternoon rush (3 PM-6 PM), but also evening deliveries (6 PM-12 AM) make up a significant part of parcel locker deliveries (9%).

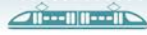
Time use for deliveries

Time calculations indicate that deliveries on average take approximately 2,5 minutes per location, while the average delivery time per parcel is 25 seconds, for 2021-2022. These figures are estimated based on deliveries consisting of 2 or more parcels to the same location during the same round, and calculated using time stamps registered for the first and last parcel put into the parcel locker. Compared to the pilot phase in 2021, average delivery times per location have gone down from nearly 3,5 minutes. Delivery times per parcel have also slightly decreased, from 32 to 25 seconds on average. This is due to an increase in the number of parcels per delivery compared to the 2021 pilot phase, with few locker locations.

As for 2021-deliveries, we find efficiency gains when multiple parcels are delivered simultaneously. However, when more than 5-6 parcels are delivered simultaneously, efficiency gains per extra parcel become smaller, and when the number of parcels becomes large, delivery times may be negatively affected. After a period with higher time use per parcel in 2021 (and larger variation), delivery times per parcel have gradually been reduced and converged to approximately 20 seconds. This can be due to economies of scale as well as learning effects and general efficiency improvements. Our delivery time estimates do not capture those stages of the delivery process where the largest efficiency gains are expected (driving to a suitable spot for parking, time drivers spend inside and outside their vehicles, walking time, etc). For the majority of shipments (95%), locker locations are only serviced with one round per day. Locker locations are only very rarely serviced more than twice a day.

Collection patterns

Also, recipients primarily collect their parcels during weekdays, but to some extent also during weekends (11%, of which most on Saturdays). Most parcels are collected on Wednesdays and Thursdays, followed by Tuesdays and Fridays. This pattern is closely related to the time of delivery. We also observe some variation between location types, both regarding what day parcels are collected, and the time of day. These differences can largely be explained by recipients' availability and travel patterns, e.g., when they are at work, at home, tend to visit grocery stores, etc.



Pick-up times

Around 60% of parcels are collected within a day after delivery. On average, parcels are collected 31,6 hours after delivery, which is nearly 4 hours faster than during the pilot phase in 2021. Although the shares of parcels collected within a day is similar between location types, there is some variation in average pick-up times, which range from an average of 30,5 hours for locations near grocery stores, to 34,5 hours for transportation hub locations. For some parcels, collection takes considerably longer, again with slight differences between locations. Collection times are affected by what time of day parcels are delivered, and when recipients conveniently or naturally visit different types of locations. Few parcels are collected at night and some location types are visited less frequently during weekends. Average times to collection are higher for parcels delivered towards the end of the working week and later in the day.

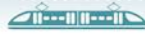
Pick-up times also vary somewhat geographically. For example, pick-up times are shortest in Porsgrunn, Moss, Haugesund, and Hamar (28-30 hours on average), which are also some of the municipalities with best network coverage in terms of the number of locations and parcel lockers. Areas with the longest pick-up times include Majorstuen (39 hours) and Vinderen/Holmenkollen (37 hours) in Oslo. We also observe several hours' difference between different parts of Oslo more generally. Overall, pick-up times have fallen since 2021, with larger decreases in some places. There are small differences in pick-up times between small- and medium-sized parcels, which constitute the majority of deliveries to parcel lockers, and slightly shorter pick-up times for larger parcels (but making up only a fraction of parcel locker deliveries).

Products delivered to parcel lockers

Based on industry classification codes of parcel senders, we estimate that half of the shipments delivered to parcel lockers contain clothing, textiles, shoes, etc., while other categories, such as books and music, electronics, and interior and building materials each account for around 4%. Around 20% of shipments consist of various consumer products, while the remaining parcels either lack information that allow classification, or belong to product categories with minor shares. There are slight differences in pick-up times for different product categories, with averages varying from 26,7 hours (books and music) to 36 hours (cosmetics and pharmacy products).

Experiences from Denmark

In Denmark, Nærboкс started rolling out its parcel network in 2019, using the same type of parcel lockers common in Norway. Nærboкс' network is semi-open, allowing deliveries from multiple distributors, with PostNord, Bring and DHL being the largest actors. Open or white-label parcel locker networks are also discussed in some regions in Norway, as they could entail some advantages for society, e.g., related to distribution efficiency. However, open networks also require solutions to different implementation barriers. Nærboкс participated in interviews and shared experiences and data. In this regard, Norway and Denmark exhibit both similarities (e.g., objectives to establish parcel lockers within 'slipper distance' of recipients), and differences. Geographically, Norway and Denmark differ considerably, but population-wise, they are reasonably comparable, as the Copenhagen metropolitan area has a similar population as Oslo and Viken county, while also populations at the country level are notably similar.



Comparisons with Norway

Denmark was one of the first countries in Europe to establish a comprehensive network of parcel lockers. In the case of Nærboks, most lockers are strategically placed in or near stores (47%), followed by residential areas (28%). While lockers in residential areas for PostNord in Norway largely entail locations near housing cooperatives, Nærboks has chosen to also establish lockers in residential areas with lower population densities. Compared to PostNord's network in Norway, Nærboks has a higher average number of lockers per location and a considerably higher maximum number of lockers per location. This discrepancy is due to restrictions on the placement of lockers in Denmark and yields longer collection distances for recipients than the objective of 500-700 meters.

Part of Nærboks' strategy is to ensure capacity for all parcels most of the time, and a choice has been made not to pre-allocate the number of locker compartments to different operators. Nærboks reports that this decision has enhanced capacity utilization. While distributors typically need to reserve capacity in advance, they also have the flexibility to utilize any available compartments upon arrival. On average, 50% of locker capacity is utilized, and during normal periods, only a small fraction of parcels is rejected due to capacity constraints. Challenges are primarily observed during specific peak periods. Further, collection and delivery patterns exhibit substantial similarities to those observed in Norway.

In Denmark, deliveries to parcel lockers are carried out by the respective distributors themselves. One alternative approach would be to use consolidation terminals where distributors deliver their shipments for collective distribution to the lockers. This approach can potentially reduce last-mile traffic to the lockers. Nevertheless, analyses for PostNord in Norway show that the majority of shipments (95%) are delivered to the same locker with one delivery round per day (see chapter 4.4), including in Oslo. If this is similar for other distributors, benefits from consolidating shipments for coordinated delivery to lockers would be marginal.

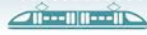
Customer evaluations indicate that recipients using Nærboks' lockers are generally quite satisfied. On average, customers in Copenhagen are most satisfied, although differences between location types and geographical areas are small. Overall, Nærboks' customer evaluations and similar consumer surveys conducted in Norway (which highlight a particular acceptance of parcel lockers in Oslo), suggest higher acceptance in urban areas.

Among challenges reported by Nærboks are the development of technological solutions that satisfy branding preferences of individual distributor firms. Further, efforts are undertaken to attract actors with atypical delivery requirements (e.g., morning, evening, or weekend deliveries) as a means to increase capacity utilization.

Effects of network expansion and increased use

We also carried out analyses of different effects of network changes and increases in the number of deliveries to parcel lockers. These analyses examine changes resulting from different network expansions compared to the pilot phase, and effects of rerouting home deliveries to parcel lockers in the vicinity of the recipient. Effects analysed include efficiency, hereunder distribution costs, traffic, environmental emissions and external damage costs of society, from the distributor's last-mile transports. Additionally, we analyse effects of recipients having to collect their parcels from lockers rather than receiving them at home, under different assumptions.

Results indicate that expanding the parcel locker network can considerably reduce pick-up distances for recipients and that increased use of parcel lockers can make the distributor's last-mile transports more efficient and reduce costs, while also reducing traffic and emissions. In



scenarios where home deliveries are redirected to parcel lockers and the parcel locker network is expanded, we find that fuel consumption, CO₂-emissions, and local emissions from the distributor's last-mile can be reduced by 30-33%. Simultaneously, customer pick-up trips generate traffic and emissions. Here, the level is highly dependent on distance and modal choice (especially the share of fossil fuel-driven cars) and the extent to which parcel collection is combined with other errands. Nevertheless, we find a potential of 13-32% reductions in emissions (distributor and recipients in total), even with conservative consumptions. Similarly, we find a potential for decreasing external damage costs by 12-25%.

Our analyses reveal interesting dynamics regarding network expansions. For example, some strategies overlap or reduce pick-up distances for recipients already living near a parcel locker, while other expansion strategies make parcel lockers a viable option for 'new' recipients in more rural areas. There also appears to be a 'saturation point', where additional network expansions only marginally increase the number of parcels that can viably be delivered to parcel lockers, but simultaneously fragment existing deliveries and reduce distribution efficiency.

While electrification of delivery vehicles will eventually reduce emission *benefits* from increased parcel locker usage, reductions in traffic remain unaffected, and so are reductions to the main drivers of societal damage costs and the majority of the distributor's operational expenses. Increased use of parcel lockers therefore has several positive effects, even when the distributor's transports become zero-emission, and will be economically beneficial for society.

Conclusion

Overall, the use of parcel lockers as delivery solution has increased rapidly, even though locker deliveries still constitute a small share of parcel deliveries to consumers. PostNord's network coverage is starting to become substantial, also in a European context. By mid-March 2023, the network constitutes nearly 4 parcel lockers and close to 1,75 locations per 10 000 inhabitants, with lockers from other actors (particularly the larger network operated by Posten) coming on top.

Parcel lockers have a number of advantages, but also disadvantages. The potential for more effective, cheaper and more flexible deliveries can benefit both the distributor, recipient and society at large. At the same time, several trade-offs exist where different interests are partially compatible and partially diverge. Examples include themes like distributor-specific vs. open networks and implications for efficiency, traffic, environment and effective use of scarcely available land. Both for the distributor, recipients and society, there are trade-offs between location choices, network density and population coverage on the one hand, and efficiency, convenience, pick-up distances and emissions on the other. Network density beyond a 'saturation point' can for example yield delivery fragmentation and negative traffic effects, even though it may yield more convenient collection for recipients. Similarly, locations with good (vehicle-based) accessibility for the distributor are not necessarily the best locations for recipients, or reduce incentives for collecting parcels using environmentally friendly modes (walking, cycling, public transport) or in combination with other errands. Our analyses also showed that it is important to understand which network expansion strategies might complement each other, and which strategies overlap.

Regarding delivery efficiency, improved information on time use would be desirable, especially on delivery stages before the first parcel is put into a locker, and after the last parcel is delivered. These stages could not be analysed based on data available in the current project, but are stages where larger economies of scale may be expected. Our analyses indicate a potential for efficiency improvements and increased exploitation of economies of scale, as we



observe that the average number of parcels delivered per distribution round and per parcel locker, remains relatively low. However, this varies throughout the year, e.g., with higher delivery volumes in the period leading up to Christmas.

Regarding capacity and efficiency, analyses of parcel pick-up times have provided insights into when recipients tend to collect parcels from different locations. These insights can be used to optimize delivery schedules and can potentially induce shorter pick-up times and better capacity utilization.

Overall, we found that parcel lockers have a potential to reduce both emissions and other damages to society, when they replace home deliveries. Even though CO₂-reduction *benefits* are reduced when distribution transports shift to zero-emission vehicles, efficiency gains, cost savings and reductions of other negative impacts for society, will remain.