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From home delivery to parcel lockers: a case study in Amsterdam

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Abstract

E-commerce is still a strong growing segment with fierce competition among parcel delivery service providers. To stay ahead of the competitors innovation is necessary. Currently, parcels are being delivered with large delivery vans which will usually deliver single parcels to doorsteps of their customers. This so called 'last mile delivery' is the most expensive logistics activity. In the literature it is proposed that parcel lockers have high potential to save cost. In our paper a literature review on parcel lockers, 3 methods for analysis are described and the results of a case study are provided.

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Keywords: Parcel delivery; Parcel lockers; Modelling; Implementation.

1. Introduction

PostNL is the market leader (70%) in The Netherlands for parcel delivery. With the growing competition in parcel delivery it is important to stay ahead of the competitors, and innovation is necessary. Currently, parcels are being delivered with large delivery vans which will usually deliver single parcels to the doorsteps of consumers or to retail locations. The critical point of parcel delivery is the last mile delivery because the related costs are relatively high. Most important reason for these high costs is the fact that the First Right Time Delivery is only 75% (van Duin et al., 2014).

For this reason PostNL seeks various ways to reduce costs and improve service at this point. The literature mentions several innovative methods to deliver parcels for the last mile leg, such as drones, AGV's and bikes (van Kaauwen &

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van Duin, 2018). One of the concepts with the highest potential is delivery to a parcel locker. To deal with the growing volumes of delivered and returned parcels, increasing customer expectations, and toughening market competition, retailers and logistics service providers are exploring and implementing innovative tools such as self-service technologies (SSTs). In the last mile delivery context, SSTs are presented in the form of parcel lockers, which are commonly used for self-service collection and return of goods purchased online (Vakulenko et al., 2018). Also PostNL has installed several parcel lockers in The Netherlands to adapt to the growing parcel market. These standalone parcel lockers are a solution for last mile delivery, replacing delivery to houses and reducing the chances of missed delivery. More and more parcels are being delivered to collection points due the fact that people are not at home during delivery (Blanquart et al., 2014). In order to come up with a solution using parcel lockers for last mile logistics, the following research question is formulated:

'*How can last-mile parcel delivery be conducted in a more sustainable and financially cost efficient way using parcel lockers?*

This paper is structured in five sections. The Introduction provides information on the research topic, followed by the problem definition and research question. A literature review on using parcel lockers in the last mile is given. A pilot project is described in terms of the current logistical processes and the new alternatives for future delivery. The evaluation methodology is explained as an integrated set of three methods: cost effectiveness analysis, multi-criteria analysis and simulation. The conclusion explains the best alternative design.

2. Literature review on parcel lockers in the last mile

According to the literature the last mile can be defined as: 'The final leg in a business-to-consumer delivery service whereby the consignment is delivered to the recipient, either at the recipient's home or at a collection point' (Gevaers et al., 2011). The final leg starts at the moment the consignment leaves the last distribution centre before being delivered to the recipient's home. The scientific literature on parcel lockers is rather scarce. Based on our literature review (searching words 'parcel lockers' in Scopus) the following four important aspects can be distinguished:

1. Customer perspective of parcel locker use,
2. Location of parcel lockers,
3. Cost (perspective) of parcel lockers,
4. Environmental economics.

2.1. Customer perspective of parcel locker use

The research of Iwan et al. (2016a) investigated the customer perspective of using parcel lockers. The research shows that with a 95% probability the parcel lockers users are satisfied with the service, the average grade was between an 8.7 and 8.9. Also 89% of the population values parcel lockers better than using Polish Post normal services. An important side note is the fact that the respondents of the survey in the research do NOT make use of the parcel lockers service that often or not all. Reasons are that the services are not being offered by online retailers, and therefore customers aren't able to select a parcel locker as a serious delivery option. Both price of the service and the parcel locker location are two important aspects for using the parcel locker service. Speed of the service and 24-hour availability are mentioned as well as important characteristics, though they are related to the price of the service. Cherret et al., (2009) mention that parcel lockers are the independent and 24/7 accessible solution to the current collection points. Collection points are mostly located at a supermarket, gas station or any other commercial establishment. This means limited opening hours. Safety of a locker has been valued as a characteristic as well, although people perceive home delivery as being safer than delivery to a locker. Vakulenko et al. (2018) showed in their consumer review of four value propositions how the self-service tool provides value to consumers and the way this value is created. They conclude that the value of parcel lockers is sufficient enough to allow logistics service providers to improve and optimize the performance of their parcel locker networks.

2.2. Location of parcel lockers

Regarding the important aspect of location, the average grade was valued at 8.25 and 15% of the respondents would have used parcel lockers more often if their location was more close (Iwan et al., 2016a). The most favoured locations according to the respondents are nearby home addresses and on the way back from work. The least favoured locations are locations nearby shopping centres and bus/tram stops. Respondents picking up at parcel lockers by car are doing that on the way back from work, indicating that they are combining this with doing other errands. The people that pick up their parcel on foot just go to the locker to pick up their parcel. Lachapelle et al. (2018) researched the impacts of location, potential impacts on city planning and consumer travel access. At the micro level, sites are located in four major types of locations: urban commercial streets, diverse suburban sites with abundant parking, suburban arterial post locations and shopping centres. Sites are found in places that were chosen in all plausibility for their cost effectiveness. Sites are generally more favourable for car access. Zenezini at al. (2018) stress also the importance of location. The installation of parcel lockers on public land, in fact, suffers from legal constraints and the necessity for different permits. Companies, therefore, choose mainly to install them in private places such as shopping malls, where customers can easily access them and can combine different purposes into one trip.

2.3. Cost (perspective) of parcel lockers

Having discussed the consumer perspective and location of the lockers, the financial side of the parcel locker is important as well. Iwan et al. (2016b) have shown how efficient the use of a parcel locker is in relation to a standard delivery model. The comparison between a courier delivery and parcel locker delivery has been made and shows substantial differences as shown in Table 1 (Bilik, 2014).

Table 1. Comparison of courier delivery and parcel locker delivery on a daily basis (Bilik, 2014).

Indicators	Courier	InPost parcel lockers
Daily kilometres/ delivery driver	150	70
Parcels daily/delivery driver	60	600
CO_2 emission/parcel	300 g	14 g
Fuel consumption/parcel	0.23 l	0.01 l

In terms of cost-efficiency the most eye-catching number in Table 1 is the number of parcels that can be delivered in one day. At the same time the environmental gain in terms of CO_2-emmissions seems to be significantly lower for the InPost parcel lockers as well as the fuel consumption. Important to mention is that the research does not mention anything about the number of parcel lockers needed, the exact locations, the size and costs of a parcel locker. It only gives an indication of parcel locker prospects. Based on the interviews in the research of Zenezini at al. (2018) they state that they can provide better vehicle routing and decrease the delivery cost. These advantages reflect also on drivers, who do not suffer the problems of missed delivery and wrong addresses and therefore can work faster and better. However, nothing is said about the time a parcel can stay in the locker. This factor also has a strong influence on the efficiency.

2.4. Environmental economics

Looking at the paper of Giuffrida et al (2016) their analysis shows an environmental point of view of the use of parcel lockers in relation to home delivery and claim it can save up to two thirds of the emissions. This also includes the emissions of the customer who needs to travel towards the parcel locker. Important to mention is the fact that the courier time is the most significant factor that saves the money and emissions at most when using parcel lockers. This gain can be explained by the fact that the courier drops multiple packages in one trip instead of multiple drops with just one package per doorstep visited. The benefits mentioned in this research are based on a static change, meaning that the customers don't need to change their behaviour to collect the parcels. Giuffrida et al., (2016) conducted research involving sensitivity analysis to see the ranges where a parcel locker becomes more expensive. Looking at for example the economical part for the customer, a parcel locker shouldn't be located further than 3.5 km in an urban context. If it is further than 3.5 km, only the logistics provider will benefit.

3. The pilot project: parcel lockers in 'De Pijp' Amsterdam

The district of 'De Pijp' is a part of the overall district of Amsterdam Zuid. The district of De Pijp is as large as 149 hectares and has 35,525 inhabitants. Looking at the households more than 60% are single person households. Considering the potential customers for E-Commerce, 79% of the inhabitants are between the ages of 15 and 65, and more specifically 44% of the inhabitants has an age between 20 to 39. This group of young people is mostly working during the day, are quite flexible in their behaviour, and prefer to walk instead of using cars. De Pijp has relatively high neighbour nuisance due to the large number of bars, restaurants and retailers having severe problems with parking and (un)loading activities (Van Amstel, 2018).

Before introducing the new delivery model with usage of the parcel lockers it was crucial to analyse the current last mile delivery model. The current delivery model will also be used as a benchmarking scenario for the scenarios with the new delivery models.

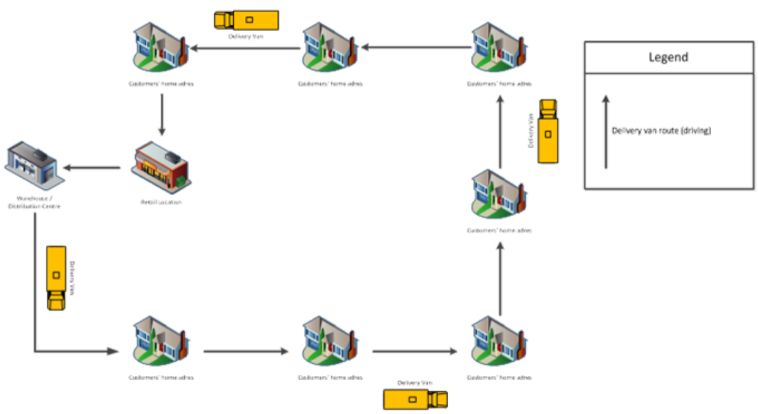

Fig. 1. Visualisation current delivery model

Figure 1 represents the standard home delivery. The black lines indicate a simplified route of the standard delivery van that drives from the distribution centre towards the drop off places and delivers the parcels. The person receiving the parcels doesn't need to get out of his home to receive the parcel. With this standard home delivery, three important last mile problems emerge that need to be taken into account (Gevaers et al., 2011). The first problem occurs when a parcel cannot be delivered and the delivery van needs to drive back to the warehouse with the undelivered parcel. This causes a next day delivery creating extra costs. From Van Duin et al. (2016) the first time hit percentage is on average 75%. The second problem is the density of the delivery area, the denser the area is the higher the efficiency. Together with density the length of the delivery window is the third problem, where the logistics provider wants a long-time window due to route efficiency. The customers prefer a small-time window. The better this time window is the smaller the chances of missed delivery and a high "first time hit rate".

3.1. Parcel lockers

Since there is no standard design for a parcel locker yet, the locker dimensions of former projects are used in this study. Parcel lockers have different sizes and integrated mailboxes and have been designed in such a way that 96% of all parcels intended to be sent to a parcel locker fits.

Table 2. Parcel Locker Sizes.

	Medium	Large	Extra-large
Width (mm)	410	410	410
Length (Depth) (mm)	525	525	525
Height (mm)	242	502	758

Fig. 2. Example of a Parcel locker

As can be seen in Table 2 the only thing that differs is the height of the lockers; the width and length are exactly the same. The current overall dimensions of the complete parcel locker are, 1610mm x 525mm x 1758mm. The parcel machine has a touchscreen and can be used to draw signatures. A camera is mounted in the locker as well for safety reasons and the machine is reasonably vandal proof. Consumers will receive an email/text when the parcel has arrived in the locker. The machine has a scanner as well, to be able to scan ID's when needed. The maximum storage in this machine is 3 days, where after the parcel will be transported to a nearby retail location.

3.2. Design alternatives

The design alternatives generated can be distinguished into three categories based on where parcels are delivered to (see Table 3). The first category is home delivery (the current situation), the second category is the delivery to retail locations, and the third category is the delivery to lockers. Each of the three categories has a separation between distribution and collection of parcels. Distribution is the delivery of parcels to a certain location, collection is the collection of parcels from a certain location, these are mainly C2C and C2B shipments. In total, there is one base alternative and three new alternatives.

Table 3. Design alternatives future delivery model.

Alternative	Description		Home	Retail	Parcel Locker
Alternative 0	Current parcel delivery	Distribution	Yes	Yes	No
		Collection	No	Yes	No
Alternative 1	Substitution of retail locations with parcel	Distribution	Yes	No	Yes
	lockers	Collection	No	No	Yes
Alternative 2	Parcel lockers as substation for current	Distribution	Yes	Yes	Yes
	parcel delivery model including collection	Collection	No	Yes	Yes
Alternative 3	Parcel lockers as substitution for current	Distribution	Yes	Yes	Yes
	parcel delivery model distribution only	Collection	No	No	No

For every alternative three variations can be distinguished. These variations are based on the percentage of fit of the parcels in the parcel lockers. The first fit is the standard percentage of the current parcel locker, this fit is 88% and is based on the various dimensions of the lockers available. Differing in Medium, Large and Extra-Large, since the number of large parcels is relatively small in comparison with the smaller parcels no distinctions will be made based on 16 parcel lockers. The second fit is 66%, this fit is based on reducing the size of the lockers. The size of this locker is a S sized locker and has 38 lockers. The third fit is 50%, this fit is based on taking the same width and depth of the medium locker but reducing the height by half, having a capacity of 50 lockers.

4. Applied methods for evaluation

For selecting the right delivery alternative Dym et al., (2014) suggest the usage of an evaluation matrix. This evaluation matrix will compare the different methods of evaluating alternatives with each other, which can be found in the literature. The three methods used in this research are the Cost Effectiveness Analysis (CEA), Multi Criteria Analysis (MCA) and simulation. CEA will be used to define the cost in as much detail as possible. It allows the costs of the different alternatives to be evaluated and compares the alternatives financially. The MCA will be used to value the alternatives by PostNL experts and transport experts from TU Delft. The CEA has more of a quantitative nature and the MCA more of a qualitative nature. Finally, simulation will be used to simulate the alternatives and validate whether the chosen variables such as the number of lockers, unloading times are chosen correctly. Simulation also considers the occupancy rates of the lockers and occupancy rates of the drivers. Together the three methods give a completely integrated and accurate overview of the best alternative on different levels and substantiate the final conclusion of the research question.

4.1. Cost Effectiveness Analysis

One of the methods used to compare alternatives on costs is Cost Effectiveness Analysis (CEA). CEA is a tool that uses the costs of a program and relates it to the key outcomes or benefits. Looking at the literature, several methods are mentioned for calculating costs. One that comes forward and is particularly suited for this research starts with a standard transportation cost function (Blauwens et al., 2010).

$$TC = T \cdot t + D \cdot d + Z \qquad (1)$$

$$\frac{(T \cdot t + D \cdot d \cdot v)}{(\frac{STOP}{w} \cdot ip \cdot ad \cdot cp \cdot P)} \cdot (1 + r) + (C_s + C_d) \cdot r + R_1 \cdot C_{rt} + (R_1 + ip) \cdot C_p \qquad (2)$$

Where

TC = Total transportation costs (€)
T = Time/duration of the transport (hour)
T = Time/hour coefficient (€/hour)
D = Distance driven for transport (km)
d = Distance coefficient (€/km)
Z = Extra costs, like transhipment costs (€)
V = Vehicle type coefficient
P = Parcel multiplication coefficient
STOP =Average number of stops per delivery route per driver

ad = Area density coefficient
C_p = Collection point coefficient
R_1 = Percentage sent to retailers (%)
r = Return logistics coefficient
C_s = Evening sorting costs per parcel (€)
C_d = Debrief costs per parcel (€)
C_p = Parcel compensation cost (€)
C_{rt} = Retailer costs per parcel (€)
W = Time window coefficient
Ip = First time hit rate coefficient

Table 4. Total cost in a standard- & growth scenario

Alternative	Total delivery cost	# of drivers	Total delivery cost	# of drivers
0	*€3,210.49*	*7*	*€3,210.49*	*7*
1 M,L,XL	€2,840.55	7	€2,840.55	7
1 S	€2.522.88	7	€2,522.88	7
1 XS	€2.428,58	7	€2,428.58	7
2 M,L XL	**€4,012.71**	7	€3,137.09	4
2 S	**€3,361.92**	8	€2.704,85	6
2 XS	**€3,312.26**	8	€2,814.50	6
3 M,L,XL	**€3.588,64**	7	€2,716.37	4
3 S	€3,204.72	8	€2,550.17	6
3 XS	**€3,220.56**	8	€2,724.71	6

In the standard scenario five alternatives are more expensive than the current delivery model. In the growth scenario the number of drivers for the locker routes is reduced to half. All these alternatives are cheaper to operate than the current delivery model. This includes purchasing the parcel lockers. This means that the alternatives with the separate locker route are able to cut labour and therefore become more cost efficient than the current delivery model. Another thing which can be concluded as it is shown in Table is the fact that the daily delivery costs of all the alternatives are relatively close to each other in the growth scenario. However, in the standard scenario the difference in costs between the alternatives is larger (see the bold cost numbers).

4.2. Multi-Criteria Analysis (MCA)

A well-known evaluation method is Multi-Criteria Analysis (MCA). Usage of multi criteria decision analysis is particularly useful in situations where consideration of different choices or courses/actions creates a certain number of conflicts to a substantial extent. MCA has different ways of being used, i.e. one of the most important parts is determining the weights. The weights of the criteria will be determined using Saaty's principle (Saaty, 2008). This principle is used for the analysis of complex decisions. It uses the relative importance of criteria. This is done to determine the final weights for each criterion. In order to do so, the goal is to have multiple individuals compare the criteria to each other. Each individual gives a score ranging from 1 to 10 for each combination of criteria to address which criteria is assumed to be more important. The outcome of the criterion weights are normalised in the MCA. The scores on the criteria applied are shown in Table 5.

Table 5. Overall scores on the (MCA) criteria

Alternative	Accessibility	Customer Service	Efficiency	Feasibility	Safety	Sustainability	Reliability
0	*5*	*5*	*5*	*5*	*5*	*5*	*5*
1 M,L,XL	6.826	6.565	5.913	5.826	**4.957**	5.174	5.739
1 S	5.609	5.565	5.783	5.739	**4.870**	5.261	5.261
1 XS	**4.739**	**4.826**	5.522	5.870	**4.826**	5.478	5.000
2 M,L,XL	7.913	6.391	6.565	**4.391**	**4.783**	**4.696**	6.130
2 S	6.652	5.652	6.522	5.043	**4.652**	5.391	5.913
2 XS	5.652	5.087	6.087	5.217	**4.652**	5.739	5.913
3 M,L,XL	7.609	6.087	6.348	**4.826**	**4.435**	**4.717**	5.739
3 S	6.196	5.152	5.674	**4.804**	**4.370**	5.217	5.630
3 XS	5.022	**4.413**	5.413	5.239	**4.283**	5.500	5.457

4.3. Simulation modelling

The goal of the simulation is to see how the delivery models work with the specifications that have been set. The simulation model is a discrete event simulation model specified in Simio (van Amstel, 2018). The simulation will validate in detail the assumptions needed and validates whether the number of lockers is sufficient and if the delivery drivers are able to operate within their working day of 8.5 hours. Therefore, the model output consists of the occupancy rate of the lockers, the occupancy rate of the delivery drivers shifts, and the delivery times (see Table 6).

Table 6. Simulation results.

Alternative	Shift Occupancy Rate Normal Route (%)	Total Delivery Time AVGNormalRoute (h)	Total Delivery Time MinNormalRoute (h)	Total Delivery Time MaxNormalRoute (h)	Shift Occupancy Rate Locker Route (%)	Total Delivery Time AVG Locke Route (h)	Total Delivery Time Min Locker Route (h)	Total Delivery Time Max Locker Route (h)	Locker Occupance Rate (%)	Parcels loaded in van at Depot (#)	House Delivery (#)	Locker Delivery (#)	Retail (#)	Undelivered (#)
0	64.83	5.51	2.49	6.41	x	x	x	x	x	9263	7777	x	1115	371
1 M,L,XL	64.55	5.49	2.37	6.34	x	x	x	x	66.50	8893	7464	1428	x	x
1 S	67.14	5.71	2.74	6.47	x	x	x	x	65.95	9344	7846	1038	x	460
1 XS	68.83	5.85	3.15	6.53	x	x	x	x	59.10	9634	8084	779	x	771
2 M,L,XL	80.68	6.86	6.62	7.10	45.47	3.86	3.77	3.95	68.78	8833	1054	7576	203	x
2 S	66.52	5.65	2.59	6.53	40.55	3.45	2.42	3.74	60.92	8862	2822	5546	494	x
2 XS	66.39	5.64	2.61	6.53	40.53	3.44	2.42	3.76	64.37	8836	3779	4431	626	87
3 M,L,XL	80.68	6.86	6.62	7.10	45.47	3.86	3.77	3.95	99.66	8833	1054	7576	203	x
3 S	66.52	5.65	5.65	6.53	40.55	3.45	2.42	3.74	92.37	8862	2822	5546	494	x
3 XS	66.39	5.64	5.64	6.53	40.53	3.44	2.42	3.76	96.56	8836	3779	4431	626	87

5. Conclusion

All detailed results can be found in van Amstel (2018). Overall alternative 2 S lockers performs better considering unforeseen circumstances (see Table 6), such as having a higher unloading time than expected and/or having a lower number of drivers (based on sensitivity analysis). Since this research is focused on designing a delivery model that can operate more cost efficiently and more sustainably than current deliveries, alternative 2 S lockers performs the best of all alternatives and the current situation. It is also possible to deliver at a retail location when necessary.

Parcel lockers are distributed evenly in De Pijp. Walking distance on average is less than 5 minutes. The number of assumed parcel lockers located in De Pijp is 47. These parcel lockers are delivered by 3 delivery drivers and the other parcels are delivered by 3 delivery drivers. Instead of having a total of 1475 stops for the whole delivery of 1770 parcels, this alternative delivery model has 430 stops for the normal delivery route, and only 47 stops for the parcel locker route. The related daily delivery costs are €2,704.85 per day, instead of €3,210.49 per day. On a yearly basis, this could save up to €121,356 for the area of De Pijp. Our results confirm the findings of Bilik (2014) in terms of parcel delivery efficiency. Based on our research findings the usage of parcel lockers is beneficial. However the size and locations need to be determined more precisely by the use of simulation modelling.

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