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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 the 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 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.

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 cost are relatively high. Most important reason for these high cost 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

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leg, such as drones, AGV's and bikes (van Kaauwen & van Duin, 2018). One of the methods with the highest potential is delivery with 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 chances of missed delivery. More and more parcels are being delivered to collection points due the fact that people are not 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.

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.

Customer perspective of parcel locker use. The research of Iwan et al. (2016a) has 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 the parcel locker 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 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

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characteristic as well, although people perceive home delivery as being safer than delivery in 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 improving and optimizing the performance of their parcel locker networks.

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 the parcel lockers more often if their location is more close (Iwan et al., 2016). 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 the parcel lockers by car are doing that on the way back from work, indicating that they are combining 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 Australia?? Post location and shopping centres. Sites are found in places that were chosen in all plausibility for their cost effectiveness. Sites are generally more favourable to auto access, given bicycle racks, CityCycle stations, taxi ranks and nearby public transport are present in less than a third of the cases. Zenezini at al. (2018) stress also the importance of location. The installation of parcel lockers on the public soil, in fact, suffers from legal constraints and the necessity for different permits. Companies, therefore, chose mainly to install them in private places such as shopping malls, where customers can easily access it and can combine different purposes for one trip.

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)

	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-emmission 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,

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nothing is said about the time a parcel can stay in the locker. This factor also has a strong influence on the efficiency.

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 that 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 in their behaviour to collect the parcels. The research (Giuffrida et al., 2016) conducted a sensitivity analysis to see the ranges if 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's further only the logistics provider will benefit.

THE PILOT PROJECT: PARCEL LOCKERS IN 'DE PIJP' AMSTERDAM

The district of 'De Pijp' is a part of the overall district Amsterdam Zuid. The district of De Pijp is as large as 149 hectares and has 35525 inhabitants. Looking at the households more than 60% is a single person household. Considering the potential customers for E-Commerce, 79% of the inhabitants is between the age of 15 and 65, and more specifically 44% of the inhabitants has an age of 20 to 39. This group of young people are 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 is crucial to analyze the current last mile delivery model. The current delivery model will also be used as a benchmarking scenario to the scenarios with the new delivery models.

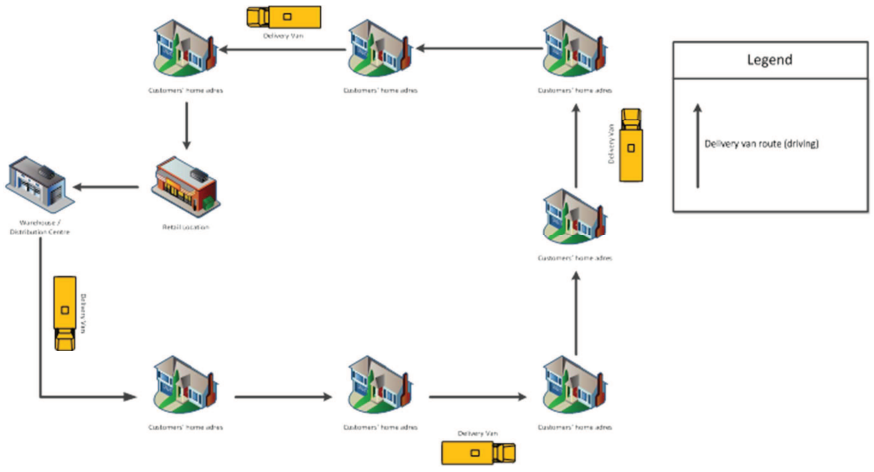

Figure 1. Visualization current delivery model

Figure 1 represents the standard home delivery. The black lines indicate a simplified route of the standard delivery van that drives from the distribution center 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

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problems come forward 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 changes of missed delivery and a high "first time hit rate".

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

Table 3. Parcel Locker Sizes

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

Figure 3. Example of a Parcel locker

As can be seen in Table 3 the only things that differs is the height of the lockers the width and length are exactly the same. Giving good prospects of easy changeable lockers, replacing for example one extra-large locker for three medium sized lockers. 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 vandalism 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.

Design alternatives. The design alternatives generated can be distinguished in three categories based on where parcels are delivered to (see Table 4). 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 4. Design alternatives future delivery model

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

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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 in half, having a capacity of 50 lockers.

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 literature. The three methods used in this research are the Cost Effectiveness Analysis (CEA), Multi Criteria Analysis (MCA) and simulation. The CEA will be used to define the cost in detail as much as possible. It allows to evaluate the costs of the different alternatives 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 will be of quantitative nature and the MCA more of a qualitative nature. Finally, the simulation will be used to simulate the alternatives and validate whether the chosen variables such as number of lockers, unloading time are chosen correctly. Simulation also considers the occupancy rates of the lockers and occupancy rate 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.

Cost Effectiveness Analysis. One of the methods used to compare alternatives on costs is a 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 literature several methods are being mentioned to calculate costs. One that comes forward and is particular suited for this research starts with a standard transportation cost function (Blauwens et al., 2010).

$$TC = T \cdot t + D \cdot d + Z \tag{1}$$

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

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

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Table 5. Total cost in standard situation and a growth scenario

Alternative	Total daily delivery costs (CEA) (standard alternative)	# of drivers	Total daily delivery costs (CEA) (drivers change)	#of drivers
Alternative 0	€3,210.49	7	€3,210.49	7
Alternative 1 M, L, XL	€2,840.55	7	€2,840.55	7
Alternative 1 S	€2,522.88	7	€2,522.88	7
Alternative 1 XS	€2,428.58	7	€2,428.58	7
Alternative 2 M, L, XL	€4,012.71	7	€3,137.09	4
Alternative 2 S	€3,361.92	8	€2,704.85	6
Alternative 2 XS	€3,312.26	8	€2,814.50	6
Alternative 3 M, L, XL	€3,588.64	7	€2,716.37	4
Alternative 3 S lockers	€3,204.72	8	€2,550.17	6
Alternative 3 XS lockers	€3,220.56	8	€2,724.71	6

In the standard situation 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 the purchasing of the parcel lockers. This means that the alternatives with the separate locker route need to cut labour force to be able to be more cost efficient than the current delivery model. Another thing that can be concluded is in the growth scenario the daily delivery costs of all the alternatives are relatively close to each other. However, in the standard situation the difference in costs between the alternatives is larger (see the red marked areas).

Multi-Criteria Analysis (MCA). A well-known evaluation method is a Multi-Criteria Analysis (MCA). The usage of multi criteria decision analysis is particularly useful in the situation where the consideration of different choices or courses/actions creates a certain number of conflicts to a substantial extent. The 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 being 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 was 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 6.

Table 6. Overall scores on the criteria

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

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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.

Table 7. Simulation results

	ShiftOccupancyRate Normal Route (percentage)	TotalDeliveryTimeAVG Normal Route (hours)	TotalDeliveryTimeMIN Normal Route (hours)	TotalDeliveryTimeMAX Normal Route (hours)	ShiftOccupancyRate Locker Route (percentage)	TotalDeliveryTimeAVG Locker Route (hours)	TotalDeliveryTimeMIN Locker Route (hours)	TotalDeliveryTimeMAX Locker Route (hours)	LockerOccupancyRate (percentage)	Parcels loaded in delivery van at the depot	House Distribution	Locker Distribution	Retail Distribution	Undelivered
Alternative 0	64.83%	5.51	2.49	6.41	X	X	X	X	X	9263	7777	X	1115	371
Alternative 1 M, L, XL lockers	64.55%	5.49	2.37	6.34	X	X	X	X	66.50%	8893	7464	1428	X	X
Alternative 1 S lockers	67.14%	5.71	2.74	6.47	X	X	X	X	65.95%	9344	7846	1038	X	460
Alternative 1 XS lockers	68.83%	5.85	3.15	6.53	X	X	X	X	59.10%	9634	8084	779	X	771
Alternative 2 M, L, XL lockers	80.68%	6.86	6.62	7.10	45.47%	3.86	3.77	3.95	68.78%	8833	1054	7576	203	X
Alternative 2 S lockers	66.52%	5.65	2.59	6.53	40.55%	3.45	2.42	3.74	60.92%	8862	2822	5546	494	X
Alternative 2 XS lockers	66.39%	5.64	2.61	6.53	40.53%	3.44	2.42	3.76	64.37%	8836	3779	4431	626	87
Alternative 3 M, L, XL lockers	80.68%	6.86	6.62	7.10	45.47%	3.86	3.77	3.95	99.66%	8833	1054	7576	203	X
Alternative 3 S lockers	66.52%	5.65	2.59	6.53	40.55%	3.45	2.42	3.74	92.37%	8862	2822	5546	494	X
Alternative 3 XS lockers	66.39%	5.64	2.61	6.53	40.53%	3.44	2.42	3.76	96.56%	8836	3779	4431	626	87

CONCLUSION

All detailed results can be found in van Amstel (2018). Overall alternative 2 S lockers performs better considering unforeseen circumstances (see Table 7), 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 to design a delivery model that can operate more cost efficient and more sustainable than current delivery, 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.

The 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 Pijpis 47. These parcel lockers are delivered by 3 delivery drivers and the 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 €2704.85 per day, instead of €3210.49 per day. On a yearly basis, this could save up to €121,356.00 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 precisely by the use of simulation modelling.

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