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Consumer preferences for parcel delivery methods: the potential of parcel locker use in the Netherlands

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In the Netherlands, as in many other densely populated countries, home delivery is the dominant way of delivering online ordered parcels. This is mainly because big retail companies offer this delivery option for free. Due to the expansion of e-commerce, home delivery that typically makes use of diesel vans puts increasing pressure on logistics service providers, their employees, traffic, and the environment. Increased use of service points or parcel lockers could relieve some of this pressure, but these delivery alternatives are barely used by Dutch consumers. The goal of this paper is to better understand how consumers can be stimulated to use pick-up points and in particular parcel lockers. To achieve this goal, a stated choice experiment was conducted among Dutch e-commerce consumers, in which they made choices between home delivery, service point, and parcel locker alternatives that systematically varied in costs, delivery moment, and distance. The application of the model to predict choices under a number of scenarios makes clear that even a small increase in home delivery costs together with an expansion of parcel lockers that decreases the distance to the parcel lockers, could severely reduce the choice for home delivery: home delivery is predicted to reduce from 71% to only 7%. This suggests that there is potential for breaking through the dominance of home delivery.

Keywords: *Parcel Delivery, Parcel Lockers, Home Delivery, Consumer Preferences, Mixed Logit Model.*

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1. Introduction

E-commerce is changing the retail landscape worldwide. In 2015, roughly 7.5% of all retail sales were conducted online, while in 2024 this number is expected to increase to 21.8% (Statista, 2021). With the rise of e-commerce, the amount of home deliveries (HDs) has also increased. In 2020, under the strong influence of the Covid19-situation, the number of parcels delivered in the Netherlands rose to 334.9 million, which is a growth of 27% compared to 2019 (Thuiswinkel Markt Monitor, 2021). Consumers become increasingly accustomed to fast HD delivery. From a logistical and societal point of view, however, this development poses problems.

Logistically speaking, last-mile delivery, i.e. the last step of the logistical process aimed to bring the products to the consumers' homes, is inefficient for a number of reasons (Deutsch and Golany, 2018). First, the small parcel sizes and the high number of stops make it hard to efficiently use the loading space of delivery vehicles, as well as making it time and cost-consuming (Visser et al., 2014). According to Spiegler (2004) and Goodman (2005), the last mile entails up to 28% of the total delivery costs, partly traceable to the inefficient use of loading space in order to satisfy customers and reach delivery targets (Iwan et al., 2016). Another problem is the costs and emissions of delivery trips that are performed in vain due to consumers who are not at home (Gevaers et al., 2011). Researchers found that the amount of CO2 emissions rises on average by about 15% per extra delivery attempt (Edwards et al., 2009). Finally, the increased demand for deliveries has put a strain on employees, who have little time to deliver many parcels – especially during festive periods (Kuunders, 2019). Hence, the logistics service providers exploit their drivers at a maximum and force them to long working days and accept low wages.

The increasing number of home deliveries also causes societal problems, of which some are directly related to the aforementioned last-mile delivery issues and inefficiencies. First, last-mile deliveries form the most polluting part of the entire logistics chain, further exacerbated by failed and repeated deliveries (Gevaers et al., 2011; Visser et al., 2014). Second, last-mile deliveries cause congestion and space pollution due to "curbside parking" of delivery vehicles (Yuen et al., 2018). In the Netherlands, for example, inhabitants are annoyed by the increasing number of delivery vehicles in traffic (NOS, 2015). In 2019 alone, more than 1250 different complaints about dangerous driving, wrong parking, and other traffic-related problems with delivery vehicles were sent to the Dutch traffic safety organization (Kuunders, 2019). These issues are especially pertinent in densely populated urban areas already struggling with lack of space and noise and air pollution (Moroz & Polkowski, 2016; Lemke, Iwan & Korczak, 2016).

Several logistics solutions are being investigated to solve this so-called "last-mile problem" (Gevaers et al., 2011). The newest solutions are innovations like drone delivery (Zubin et al., 2020) and delivery by autonomous vehicles (Versluis, 2018). Other ideas like crowdsourcing or crowd shipping make use of existing traffic flows by allowing anyone to deliver a parcel on their journey from A to B (Marcucci et al., 2017). More contemporary ideas are urban consolidation centers (UCCs), manned service points (SPs), and parcel lockers (PLs) (Van Duin et al., 2020).

In the literature, much research attention is paid to UCCs (see for instance Quak et al., 2020; van Duin et al., 2017; Allen et al., 2012), which is much less the case for SPs and PLs, which are therefore the focus of this paper. SPs are often integrated with retail stores that offer the additional service of parcel drop-off and pick-up. Due to the increase of parcels, service point owners have indicated that the increased workload needed for handling and sorting the parcels is not reflected in the financial reward they receive from logistic service providers and some retailers have therefore stopped offering the service (Radar, 2020). Another disadvantage of SPs is that access is limited to shop opening hours. In contrast to manned collection points, PLs are unmanned and (in most cases) not constrained by opening hours (Deutsch and Golany, 2017; Lemke et al., 2016). PLs are groups of strategically situated lockers that can be both emptied by consumers and filled by logistics companies at any time of the day, making night deliveries possible (Deutsch and Golany, 2018, Van Duin et al., 2020). Furthermore, they are not bound to existing commercial structures and

therefore can be easily placed anywhere. They are often situated in apartment blocks, at petrol stations, near public transport nodes or at malls, but can also be placed near or within residential areas. They generally function with the help of electronic locks and opening codes received by mail or phone. Different customers can use them simultaneously, mainly depending on the number of lockers available in a locker station. A recent study by Van Duin et al. (2020) identified parcel lockers as one of the most promising options for more sustainable last-mile delivery. In addition, based on their simulation they concluded that if the infrastructure for PLs improves, operational efficiency can be increased as well (Van Duin et al., 2020). Hence, PLs can help in reducing the negative externalities of last-mile delivery, such as failed deliveries, inefficient use of vehicle loading space, and pollution, and can thereby be part of the solution dealing with the growth of e-commerce (Deutsch and Golany, 2018; Iwan et al., 2016).

Although the advantages of PLs are quite clear, they are still sparsely used in densely populated parts of Europe, such as the Netherlands. The number of parcel lockers currently is very limited and therefore e-commerce websites do not offer this option at check-out of ordered goods. On the other hand, logistic service providers are not inclined to considerably increase the number of PLs, because they believe that consumers will not use them: HD is often offered for free and is very convenient for consumers. This preference for HD can probably only be changed if HD is charged and PLs are offered at lower costs or free of charge. However, limited research attention has been given to the role of price in consumer choice for obtaining online ordered parcels. Moreover, the impact of distance to a pick-up point and the role of delivery times has received limited attention in the literature, hence, it is not clear how the use of pick-up points and in particular PLs can be stimulated.

The aim of this paper is to contribute to this insight and examine the trade-offs consumers make among the attributes of delivery alternatives. To that effect, a stated choice experiment is conducted, in which consumers make choices among HD, SP, and PL alternatives that vary in attributes delivery price, distance, and delivery time. A discrete choice model is estimated which indicates to which extent each of the assumed factors influences the observed choices.

The remainder of this paper is organized as follows. Section 2 contains a brief review of studies on consumer preferences for different parcel delivery options. Section 3 describes the methodology applied in this study. Section 4 presents and discusses the results of the estimated model. This model is then applied to predict consumer choices under a number of scenarios. The final section draws conclusions, discusses the implications, and provides some avenues for further research.

2. Literature review on Stated Choice Experiments using Parcel Lockers.

The enormous growth of e-commerce-activities has led to changes in the distribution systems and the shopping behavior of customers. For a proper understanding of shopping, behavior is good to take notice of previous research on the choice for parcel delivery methods and to identify the attributes included in those studies.

Collins (2015) found that price, quality, and locations of the self-collection points are important attributes that influence delivery method choice. More specifically, he found that "advanced notice of a delivery date", "ability to choose a delivery time window", the "width of this time window" and the "time of day" are the most important factors for choosing HD. For the use of PLs or SPs, opening hours, days the parcel can stay at the pick-up point, parking possibilities and distance contribute mostly to the choices. Furthermore, his results show that people are willing to pay more for delivery once the delivery time windows are known and more narrow.

De Oliveira et al. (2017) researched the shopping behavior of consumers with respect to home delivery or a delivery to an automatic delivery station (ADS) by looking at socio-demographics and e-commerce habits. The values that were used in this study for factors like delivery price or delivery time were not very explicitly defined making it impossible to acquire any insights into the

consumer preferences for specific delivery price ranges, delivery times, and willingness to pay (WtP). Likewise, the stated preference approach by Da Silva et al. (2019) between home delivery and a pick-up alternative had freight cost and delivery time as attributes that were not very precise. They didn't specify crisp price values but specified that costs for pick-up were 25% and 50% cheaper than the costs of home delivery. The results show that in terms of relative utility, the freight costs attribute was most important. Also, Rai et al. (2019) showed that delivery price was by far the most important attribute for the respondents. When delivery costs and return costs are free, consumers are also open to self-collection (pick-up) and more willing to wait longer for delivery (Rai et al., 2019). This study didn't consider socio-demographic variables.

Hofer et al. (2020) showed in their study 'Estimation of changes in customer's mobility behavior by the use of parcel lockers' that participants from Graz (Austria) are willing to use environmentally friendly transport modes (walk, bike, public transport) for a maximum travel distance of 1.9 km between a parcel locker and e.g. their home. Lachapelle et al. (2018) performed a study on parcel locker systems in a car-dominant city, considering attributes like location, characterization, and potential impacts on city planning and consumer travel access. They found that areas with higher shares of households with Internet access are also more likely to use lockers. Yuen et al. (2018) performed a survey and checked the five dimensions that influence the consumers' acceptance of an innovation (Baskerville et al., 2014): relative advantage, compatibility, complexity, trialability, and observability. They found that the dimensions have explained approximately 42% of consumers' intention to use self-collection services. They also suggested but didn't research it, that the stakeholders could also influence consumers' behavior by providing discount incentives or subsidization for the use of self-collection services or raising a price mark-up on home delivery services.

Based on the reviewed papers, we can conclude that shopping behavior has been analyzed regarding the preferences for different delivery options. Some of the studies lack precision in the specification of attribute levels, especially for delivery price and distance. Just a few works (Collins et al, 2015; De Oliveira et al., 2017; Da Silva et al., 2019; Rai et al., 2019) considered price or cost as decisive factors, however, they didn't make an explicit distinction between SPs and PLs. Using real values for prices and distances in the SCE could help in finding optimal price and distance values for making stimulating pick-up alternatives and discouraging home delivery and thereby help companies in locker placement decisions and e-retailers in setting their delivery prices. In addition, including socio-demographic variables gives an indication of which e-consumer groups are of most interest to target in order to realize a switch to more sustainable delivery alternatives.

3. Methodology

3.1 Stated choice experiment

In order to examine the preferences of e-commerce consumers for parcel delivery alternatives, a stated choice experiment is constructed. In this experiment, respondents have to imagine that they have purchased a product online, and they have to select a delivery alternative. To that effect, they are presented a series of choice sets that each describes three alternatives: an HD (home delivery), an SP (service point), and a PL (parcel locker) alternative.

Each of the three alternatives is described by a number of attributes. For the selection of the attributes, we consulted the literature, in particular the papers we reviewed before. A list of potential attributes was then discussed with 6 experts in semi-structured interviews. This group involved scientists in the field of logistics, logistic service provider (LSPs) employees, and a representative of an e-commerce lobby organization. The main attributes that were deemed important involved delivery price, delivery moment, distance to pick-up points, and weight and size of parcels. However, we believe that weight and size are far less important attributes as data on delivery of parcels in a period of one week in the city of Amsterdam revealed that the vast

majority of ordered parcels would fit into Parcel Lockers: 75% of all parcels weigh less than 2 kg, 85% had length smaller than 50 cm, 90% had a width smaller than 40 cm, and 80% had a height smaller than 20 cm (van Amstel, 2018). Hence, we decided not to vary weight and size in the experiment, but to fix this in the decision context as presented to the respondents. The decision construct was introduced to respondents as follows (translated from Dutch): "Imagine you buy a product online costing €65, which is not too big and not too heavy (for example, sunglasses, headphones, or clothes). During the order process, you will receive various options for the delivery of the parcel. Assume that the parcel is delivered the next day and does not fit into your mailbox". The fixed price of €65 is approximately the average price for online orders in the Netherlands (Thuiswinkel Markt Monitor, 2021). The products mentioned as an example are assumed to be gender-neutral and they fit into a parcel locker, but not in a mailbox.

The resulting list of attributes and their levels are used to construct the alternatives and the choice sets and tested in two pilot studies to ensure that the attributes were well understood and the attribute levels were well chosen.

- **Price**. For HD price a wide range of €0-6 was selected. Currently, many large retailers in the Netherlands offer free HD for orders over €20 or €25, while they charge around €2 to €4 for lower cost orders, whereas smaller retailers may charge higher costs. In one of the pilot studies, we used a wider price range: €0-9 for HD, which revealed that hardly anyone would then choose HD when the price was €9, so we reduced the range to €0-6. For both pick-up point deliveries, we selected only two levels: for free and a small charge of €2.
- **Delivery moment.** Currently, most parcels are delivered at weekday office hours, between 9:00 and 18:00 hours, which serves as a reference level for this attribute. The other levels gradually expand this delivery period with more delivery moments to choose from: first by evening delivery on working days, then by weekend day delivery and finally by delivery on weekend evenings. For the SP alternative, this attribute is called opening hours and because most shops are closed on Sundays in the Netherlands, we additionally make a distinction between Saturdays and Sundays. For PL only two levels are varied: either 24/7 or day and evening access, but not at night, with a smaller pick-up window on Sunday.
- **Distance to pick-up.** Obviously, distance is only varied for both pick-up options. Four distance levels are selected that increase by 250-meter steps, starting at 250 m. for PL and at 500 m. for SP.

Table 1 presents the list of attributes and their levels that were varied in the main experiment reported in this paper.

Table 1. Alternatives, Attributes & Attribute Levels

Attribute	Attribute levels
Home delivery	
Delivery price	€0 €2 €4 €6
Delivery moment	Day delivery on weekdays (09:00 - 18:00) You can choose from: day delivery on weekdays (09:00 - 18:00) or evening delivery on weekdays (18:00 - 22:00) You can choose from: day delivery on weekdays (9:00 - 18:00), evening delivery on weekdays (18:00 - 22:00) or day delivery on weekends (9:00 - 18:00) You can choose from: day delivery on weekdays (09:00 - 18:00), evening delivery on weekdays (18:00 - 22:00), day delivery on weekends (9:00 - 18:00) or evening delivery on weekends (18:00 - 22:00)
Service Point Delivery	
Delivery price	€0 €2
Distance / time to the SP	500m (approx. 6 minutes' walk) 750m (approx. 9 minutes' walk) 1000m (approx. 12 minutes' walk) 1250m (approx. 15 minutes' walk)
Opening hours	Mon – Fri: 07:00 – 18:00 Mon – Fri: 09:00–18:00, Sat: 09:00–17:00 Mon – Fri: 09:00 – 21:00, Sat: 08:00–18:00, Sun: 10:00–17:00 Mon – Sat: 08:00–22:00; Sun: 10:00–20:00
Parcel Locker Delivery	
Delivery price	€0 €2
Distance / time to the PL	250m (approx. 3 minutes' walk) 500m (approx. 6 minutes' walk) 750m (approx. 9 minutes' walk) 1000m (approx. 12 minutes' walk)
Opening hours	24/7 (open 24 hours a day) Mon - Sat: 08:00 - 22:00; Sun: 10:00 - 20:00

With the help of the software package Ngene (ChoiceMetrics, 2018), a balanced orthogonal fractional factorial design was generated that resulted in the construction of 16 choice sets. This design was blocked in two blocks of 8 choice sets each. Every respondent was randomly assigned to one of the two blocks and therefore responded to 8 choice sets. In each choice set, respondents were requested to indicate which of the three presented delivery options they preferred. An example of a choice set is presented in Figure 1.

	1. Home delivery	2. Service point	3. Parcel locker
Price	€4	€2	€2
Moment of delivery / opening hours	Day delivery on weekdays (09:00 - 18:00)	Mon - Fri: 09:00 - 18:00, Sat: 09:00 - 17:00	Mon - Sat: 08:00 - 22:00; Sun: 10:00 - 20:00
Distance to the service point or the parcel locker	-	1000m (approx. 12 minutes' walk)	750m (approx. 9 minutes' walk)
Choice	○	○	○

Figure 1. Example Choice Set

3.2 Sample

Data were collected by means of a sample from the Dutch population of consumers who order goods online. Respondents were recruited in three different ways. First, the authors spread the survey online in their own network. Second, the survey was posted on several online consumer forums. Third, posters and flyers were distributed among the TU Delft campus and several apartment buildings in Delft. This resulted in 530 persons that opened the online survey, of which 383 completely filled out the questionnaire. Of this group, 12 persons were excluded because they never bought a product online. An additional group of 28 persons was excluded because either they did not live in the Netherlands, or they completed the survey in an extremely short time period, or they did not provide serious responses. Hence, the results presented in this paper are based on the responses provided by 343 respondents.

The distribution of the personal characteristics of the sample is presented in Table 2. We refer to the appendix for an overview of the coding of the personal variables for inclusion in our models. There was an equal proportion of men (49%) and women. Most notably, persons with higher education were overrepresented (as compared to the Dutch population) while persons with education up to primary or secondary school were underrepresented. Also, there is an overrepresentation of people in the age group between 21 and 40 years old, while people under 20 and over 61 are underrepresented.

Table 2. Sample Characteristics (N=343)

Socio-Demographics	Category	Percentage
Gender	Male	49.0%
	Female	50.1%
	Did not specify	0.9%
Age	0-20	9.3%
	21-40	41.7%
	41-60	33.5%
	61-80	15.1%
	81+	0.3%
Education	Elementary school	0%
	Secondary school – low level	1.7%
	Secondary school – high level & middle vocational	20.4%
	Bachelor (both university and higher vocational)	39.1%
	Master & PhD.	38.8%
Household Income	Less than €10.000	11.7%
	€10.000 – €50.000	27.2%
	€50.000 – €100.000	22.4%
	More than €100.000	17.8%
	I'd rather not say	21%
Employment Status	Unemployed / Retired	9.6%
	Student	23.6%
	Part-time	18.9%
	Full-time	43.6%
	Entrepreneur	4.4%
Urbanity level	Rural	5.8%
	Village	15.4%
	Small City	31.2%
	Large City	47.5%

3.3 Model estimation

In this subsection, we describe the model estimation procedure. We adopt the random utility framework, which assumes that individuals choose the alternative with the highest utility (see e.g. Train 2003). Utility U for individual *n* and alternative *i* can be specified as:

$$U_{in} = X_{in}\beta + \varepsilon_{in} \quad (1)$$

Where X_{in} is a (1xK) vector of explanatory variables describing individual n and alternative i, including alternative-specific dummy variables as well as generic and alternative specific attributes and their interactions with the characteristics of individual n. β is a vector of parameters and ε_{in} is a random error component. We assume that the parameters are normally distributed across consumers $\beta_{xin} \sim N(\mu_{xi}, \sigma_{xi})$), which implies that a mean parameter μ and a standard deviation σ is estimated for each attribute. Since price and distance parameters are generally assumed to have a negative sign for all consumers, typically a lognormal distribution is assumed for these parameters. However, to avoid the possibility of long tails, we prefer normal distributions for these parameters and as will become clear in the results section and further discussed there, the estimated standard deviations were rather modest and consequently, the share of consumers with a positive parameter was negligible.

In addition, we estimate an additional error component η for the two pick-up alternatives (SP and PL), to test for a nesting effect. The reason is that we expect that these two pick-up alternatives share some unobserved characteristics, which results in correlations among the preferences for these two alternatives. The error component η is assumed to follow a normal distribution with zero mean and a standard deviation σ $\eta_{(SP,PL)} \sim N(0, \sigma)$). Finally, we assume the random error component ε_{in} follows a Gumbel distribution.

A mixed multinomial logit model was estimated to arrive at the parameters, which takes the panel structure of the data into account (this is related to the fact that every respondent made 8 choices and the tastes of each respondent apply to all 8 choices). In random parameter mixed logit, when the parameter for attribute j is considered random, the likelihood of observing a sequence of choices, i*, in choice situations, t, by an individual n is calculated as shown in Equation [2] (Note that for each random parameter, an additional integral is required). Since this model does not have a closed-form solution, it is estimated using maximum simulated log-likelihood (see e.g. Train 2003).

$$P_{i*nt}(\beta_j) = \frac{e^{V_{in}(\beta_j)}}{\sum_{i'}^{I} e^{V_{i'n}(\beta_j)}} \tag{2}$$

$$L_n = \int_{\beta_j} \left[\prod_t P_{i*nt}(\beta_j)\right] f(\beta_j) d\beta \tag{3}$$

The panel mixed logit model is estimated using the Apollo choice-modeling package (Hess and Palma, 2019). Different models were tried in which in addition to the attributes, the personal characteristics presented in Table 4 were included. Only statistically significant parameters at the conventional 95% reliability level were kept in the final model. The final model was estimated by using 1000 Halton draws. The number of draws was determined by constantly doubling the number of draws until the parameters became stable. This resulted in the following utility functions, the parameter values of which are presented in Table 5 and discussed in the next section (see Table 3 and 4 for an explanation of variable names and coding).

Table 3. Coding of attributes

ATTRIBUTES	coding of levels and labels			
Delivery costs (PR: price) HD (€)	0	2	4	6
Delivery Moment (DM) HD	DM1_HD	DM2_HD	DM3_HD	
Mon-Fri: 9-18	0	0	0	
Mon-Fri: 9-22	1	0	0	
Mon-Fri: 9-22, Sat-Sun: 9-18	0	1	0	
Mon-Fri: 9-22, Sat-Sun: 9-22	0	0	1	
Delivery costs (PR: price) SP (€)	0	2		
Distance (DIS) (km.) SP	0.50	0.75	1.00	1.25
Opening Hours (OH) SP	OH1_SP	OH2_SP	OH3_SP	
Mon-Fri: 07-18	0	0	0	
Mon-Fri: 9-18, Sat: 9-17	1	0	0	
Mon-Fri: 9-21, Sat: 8-18, Sun: 10-17	0	1	0	
Mon-Sat: 8-22; Sun: 10-20	0	0	1	
Delivery costs (PR: price) PL (€)	0	2		
Distance (DIS) (km.) PL	0.25	0.50	0.75	1.00
Opening Hours (OH) PL	OH			
24/7 (open 24 hours a day)	1			
Mon-Sat: 08:00 - 22:00; Sun: 10:00 - 20:00	0			

Table 4. Coding of personal characteristics

PERSONAL CHARACTERISTICS	coding of levels and labels	
Gender	FEM	
Male	0	
Female	1	
Age (years)	20-81	
Education (EDU)	EDU	
lowest (elementary school/VMBO/MAVO	0	
…	…	
highest (Master & PhD)	4	
Urbanity Level (UL)	UL	
lowest (rural periphery)	0	
…	…	
highest (center of a large city)	7	
Work status	PART	FULL
No work / student / retired	0	0
part-time work	1	0
full-time work	0	1
Income (INC) (gross annual household)	INC	
lowest (Less than €10,000)	1	
10,000 – 20,000…	2	
…	…	
More than 100.000	11	

$$U_{hd} = \left(\beta^{pr} + \beta_{hd+pl}^{age \cdot pr} \cdot AGE\right) \cdot PR_{hd} + \beta_{hd}^{dm_1} \cdot DM1_{hd} + \beta_{hd}^{dm_2} \cdot DM2_{hd} + \beta_{hd}^{dm_3} \cdot DM3_{hd} + \sigma^{pr} + \sigma_{hd}^{dm_3} + \varepsilon_{hd} \quad (4.1)$$

$$U_{sp} = \left(ASC_{sp} + \beta_{sp}^{inc} \cdot INC\right) + \left(\beta^{pr} + \beta_{sp}^{pr-shift} + \beta_{sp}^{age \cdot pr} \cdot AGE\right) \cdot PR_{sp} + \beta_{sp}^{oh_1} \cdot OH1_{sp} + \beta_{sp}^{oh_2} \cdot OH2_{sp} + \beta_{sp}^{oh_3} \cdot OH3_{sp} + \beta_{sp}^{dis} \cdot DIS_{sp} + \sigma^{pr} + \eta_{sp+pl} + \varepsilon_{sp} \quad (4.2)$$

$$U_{pl} = \left(ASC_{pl} + \beta_{pl}^{age} \cdot AGE + \beta_{pl}^{fem} \cdot FEM + \beta_{pl}^{ul} \cdot UL\right) + \left(\beta^{pr} + \beta_{hd+pl}^{age \cdot pr} \cdot AGE\right) \cdot PR_{pl} + \beta_{pl}^{oh} \cdot OH_{pl} + \beta_{dis}^{pl} \cdot DIS_{pl} + \sigma^{pr} + \eta_{sp+pl} + \varepsilon_{pl} \quad (4.3)$$

Note that in our model, the SP price parameter has a different value than that of the other two delivery alternatives. Although one may argue that this contradicts classical economic theory, we like to refer to Chorus (2014) who addresses this issue: "…Take the commensurability axiom, which suggests that a Euro spent for purpose A weighs as much as a Euro spent on purpose B. This axiom is extremely convenient for the development of economic models. However convenient, the axiom severely conflicts with empirical travel behavior research which finds that for many road users, a Euro spent on road pricing weighs much heavier than a Euro spent on petrol (e.g., Hensher et al., 2007)". Note further that Work Status and Education are not included in the final model as they did not have any statistically significant parameters at the conventional 95% reliability level.

4. Interpreting the estimates

4.1 Base preference

Each of the 343 respondents made 8 choices, so in total 2744 choices were observed. Of these choices, 37% were made for an HD alternative, 24% for an SP alternative, and 38% for a PL alternative. These choices are influenced by two main factors. First, by any differences in selected attribute levels among the alternatives. For example, the average price of the HD alternatives in our experiment is €3, while the average price of the two pick-up alternatives is only €1, which therefore negatively affects choosing an HD alternative. Second, the choices are influenced by all attributes that consumers associate with each of the delivery alternatives, but which are not varied in the experiment. Examples of the latter are the hassle of retrieving a parcel at a pick-up alternative and the relative unfamiliarity with the pick-up alternatives, in particular PL, compared to HD. Since our models also include various personal characteristics that have a non-zero mean, the estimated ASCs do not reflect the choice distribution presented above. The ASCs should be regarded as fixed correction factors that need to be added to the prediction based on the attributes and added variables.

In addition, a shared error component for SP and PL was estimated and found to be statistically significant and fairly large in magnitude (η = -2.369; note that the negative sign of the estimate should be ignored, hence, only the magnitude matters). Based on this estimate, the correlation between SP and PL can be calculated (Train, 2003, p.114) as follows: $\eta/(\eta + \pi^2/6) = 0.59$. This is relatively high, which indicates that if respondents have chosen SP in any of the choice situations, it is more likely that they also have chosen for PL in any of the other situations (and the other way around). Hence SP and PL are regarded as more similar to each other than to HD. In other words, SP and PL are more seen as substitutes of each other and therefore compete more with each other than they both do with HD. The reason is that both are pick-up alternatives and it is obvious that part of the consumers dislike the hassle of leaving their home to obtain a parcel instead of receiving this at home. On the other hand, part of the consumers may prefer pick-up because they dislike

HD, for example, because they don't like that a package is delivered to their neighbors when they are not at home, or they believe that HD is environmentally unfriendly.

The estimated main effects for the personal characteristics (see Table 4) indicate how the base preferences for the three delivery alternatives differ among the categories of these variables. The results indicate that SP becomes more attractive with decreasing income. The attractiveness of PL decreases with age, being female, but increases with higher urbanity levels. That PL attractiveness increases with urbanity level is good news for PL expansion because most likely this will first take place in the most urbanized environments.

Table 5. Estimates of the Panel Mixed Logit Model

Base preferences		**estimates**	***t*-value**
ref	*HD Alternative Specific Constant*	*0*	
ASC_{sp}	SP Alternative Specific Constant	0.877	2.962
β_{sp}^{inc}	SP Income	-0.097	-3.342
ASC_{pl}	PL Alternative Specific Constant	1.373	2.710
β_{pl}^{age}	PL Age	-0.024	-3.168
β_{pl}^{fem}	PL Female	-0.742	-3.367
β_{pl}^{ul}	PL Urbanity level	0.175	2.805
Attributes & interactions			
β^{pr}	HD_SP_PL_Price	-1.226	-11.210
$\beta_{sp}^{pr-shift}$	SP_shift_Price	-0.361	-2.149
$\beta_{hd+pl}^{age \cdot pr}$	HD_PL_Price * Age	0.009	4.142
$\beta_{sp}^{age \cdot pr}$	SP_Price * Age	0.018	4.524
HD Delivery Moment			
ref	*Mon-Fri: 9-18*	*0*	
$\beta_{hd}^{dm_1}$	Mon-Fri: 9-22	1.617	9.030
$\beta_{hd}^{dm_2}$	Mon-Fri: 9-22. Sat-Sun: 9-18	1.496	8.059
$\beta_{hd}^{dm_3}$	Mon-Fri: 9-22. Sat-Sun: 9-22	1.322	6.227
SP Opening hours			
ref	*Mon-Fri:7-18*	*0*	
$\beta_{sp}^{oh_1}$	Mon-Fri: 9-18. Sat: 9-17	0.297	1.874
$\beta_{sp}^{oh_2}$	Mon-Fri: 9-21. Sat: 8-18. Sun: 10-17	1.063	6.569
$\beta_{sp}^{oh_3}$	Mon-Sat: 8-22; Sun: 10-20	1.049	7.525
β_{pl}^{oh}	PL Opening hours (24/7)	0.402	4.304
β_{sp}^{dis}	SP Distance	-1.402	-7.702
β_{dis}^{pl}	PL Distance	-1.580	-8.017
Random parameters			
σ^{pr}	Sigma HD Price	0.321	5.322
$\sigma_{hd}^{dm_3}$	Sigma HD Delivery moment D3	0.927	3.086
η_{sp+pl}	Shared error component SP & PL	-2.369	-11.063
Final Log-Likelihood			-1983.12
Rho-square			0.3233
Number of parameters			22

ref: reference level (in italics): values not estimated but fixed to zero.

So far, we discussed only average utilities. We continue by discussing how preferences vary with changes in the varied attribute levels.

4.2 Price

A generic price parameter across all three alternatives is estimated, which has a negative sign, indicating that the utility of each of the delivery options decreases with increasing price, as expected. In addition to the generic price parameter, a shift price parameter is estimated for SP, which needs to be added to the generic price parameter to arrive at the price parameter for SP. This shift parameter is statistically significant and negative, indicating that consumers are more price-sensitive for this alternative than for the other two. The estimated interaction effects for price and age indicate that price sensitivity is related to age. Since age is positively correlated with income, this partly reflects an income effect, but since this effect is much stronger than income, which was not statistically significant, this also reflects a genuine age effect. The interaction effects are positive for all three delivery alternatives, which means that price sensitivity decreases with age: the younger one is, the stronger the dislike for paying for parcel delivery. This interaction effect with age is twice as strong for SP as for both HD and PL. To illustrate this effect, we calculate the price parameters for two different age groups. For a 20 year old consumer, the SP price parameter is equal to (-1.226 -0.3610 + 0.018*20 =) -1.227, while the price parameter for HD and PL for a 20-year old is -1.046. For a 70 year old consumer the price parameters are: SP= -0.327, HD and PL= -0.596. These results suggest that older consumers are willing to pay much more for the manned SP service than for the other two alternatives, while the opposite applies to younger consumers.

Furthermore, a significant sigma is found for price, which denotes the standard deviation of the assumed normal distribution in price tastes. This indicates that apart from what can be explained by age, there is additional heterogeneity in price sensitivity. The estimated standard deviation (0.321) is fairly small compared to the average price parameter (-1.226) earlier discussed. Based on this distribution, it can be calculated that only a very small part of the consumers have a positive price parameter. Finally, it should be mentioned that a quadratic component for HD price parameter was tested, but was found to be not statistically significant at the conventional 95% reliability level. This indicates that utility linearly decreases with increasing price in the €0-6 price range.

4.3 Delivery moment & opening hours

For HD, delivery during working day office hours serves as a reference. The results indicate that all expansions result in increased utility. Adding only a delivery option evenings of weekdays, increases utility the most. Further expansion to delivery during the day on the weekends does not further increase utility, but results in a somewhat lower increase of utility. This is even more so the case for expansion to evening delivery on the weekends. Furthermore, the estimated sigma for the latter option has a considerable value indicating that much heterogeneity exists in consumer utility derived from weekend evening delivery, ranging from strong like to strong dislike for adding weekend evenings to home delivery.

These findings are unexpected: we expected an increase for every additional expansion because the expansions of delivery moments were defined as possibilities for the consumer to choose from, hence, the delivery moment is chosen by the consumer. We can only speculate about possible reasons that explain this finding. Possibly, the attribute levels were not fully understood or believed by all respondents, because currently consumers are often not given the option to choose a delivery moment. Possible other reasons why consumers do not prefer weekends for home delivery may involve: they less prefer staying at home waiting for parcels in weekends than on (evening of) weekdays; they less prefer delivery vans in their streets on weekend days; they dislike the possibility of being disturbed in the weekends for receiving a parcel intended for their neighbors in case the neighbors are not at home; they regard weekend days, in particular Sundays, more as rest days, possibly for religious reasons.

For SP an increase from working day (shop) opening hours towards Saturdays increases utility, but the largest increase in utility is observed for a further expansion towards evenings of weekdays and Sunday opening. Again, a further expansion to evening of weekend days, does not further increase utility. This provides further evidence that parcel delivery on evenings of weekdays is valued to obtain parcels, but that delivery on weekend days and particular their evenings does not add much value on average.

Finally, with respect to parcel lockers: access also at night is valued above access during the day and evenings only.

4.4 Distance

As expected, the utility of SP and PL decreases with increasing distance to the pick-up location. Consumers seem to be somewhat more sensitive to distance to PL than to distance to SP. Possibly because pick-up at SP can be more easily combined with a trip to the shop in which the SP point is located, a trip consumers would make anyway.

Overall, we can conclude that estimated attribute parameters can be interpreted well. This gives confidence in the estimated parameters and provides face validity to the estimated model.

5. Predicting consumer choices

In this section, the model presented in the previous section is applied to predict consumers' choices for delivery options under various price and distance scenarios. Sample enumeration is applied, which entails that a synthetic population is constructed, which is based on our sample because personal characteristics of the population of e-consumers are largely missing. To that effect, first, parameters were adjusted for every respondent in the sample, based on his/her scores on the socio-demographic variables (see formulas 4.1, 4.2 and 4.3 and Table 4). Next, unobserved heterogeneity for price was taken into account by drawing from the estimated normal distribution. The same procedure is followed for the error component SP and PL share. This was repeated many times with the result that the predictions are based on simulated choices of 96,040 synthetic consumers. This number is arbitrarily chosen but it is sufficiently large to assure stable predictions. For each of these consumers, the choice probabilities are predicted for the three alternatives in each of the six scenarios. The averages across all these predicted probabilities are presented in Table 5, which are interpreted as the market shares of the delivery options under each scenario. Since current market shares of the three delivery alternatives are not available, we cannot adapt the estimated ASC's to assure that our predictions reflect true market shares. Hence, the predicted market shares reflect stated market shares as observed in our sample.

Scenario one probably most closely represents the current situation for many parcels delivered in the Netherlands. In this scenario, all delivery alternatives are for free, and parcel lockers, which are currently not widespread in the Netherlands, are located at a long distance for people's homes (2.5 km.). It should be noted that 2.5 km is beyond the distance values we have varied in the experiment and we have to assume that the estimated distance parameters are also valid beyond these values. The results presented in Table 6 indicate that as may be expected, HD dominates, while only a small share of consumers choose for SP and PL.

Scenario two assumes that PLs are located at bus stops and consequently, distance to PL has severely reduced: only 0.5 km. According to Goudappel Coffeng (2020), 90% of the inhabitants of the densely populated province Zuid-Holland could then reach a locker within 500 meters from their home. The results indicate that the share for PL then increases considerably. In this scenario, PLs are located closer to e-consumers' homes than SPs, therefore the share of PL exceeds the share of SP.

In scenario three, a possible future scenario is introduced that represents a situation in which e-retailers cooperate and agree on a small price increase of €2 for HD. All other attributes are kept at

the same values as in the previous scenario. The results indicate that even a small price increase for HD considerably decreases the share of HD.

In contrast to the first reference scenario, in which all delivery options are for free, in scenario four all delivery options are set to the maximum price levels as varied in the choice experiment. Because in this scenario, HD is substantially more expensive than the two pick-up alternatives, the choice for HD considerably decreases under this high price scenario compared to scenario one: the share of HD drops from 71% under scenario 1 to 29% under this scenario. SP is more used under this scenario, but 28% is willing to travel 2.5 kilometers to pick-up a parcel at a locker instead of paying more for HD.

In scenario five the price of PL is set to zero, while all other attributes are kept at the same values as in the previous scenario. Compared to the previous scenario, this considerably increases the share of PL, which largely substitutes from SP. This also illustrates that SP and PL more heavily compete with each other than both do with HD, which is due to the relatively large shared error component as earlier explained.

Finally, in scenario six, on top of the previous scenario, PLs are located at bus stops, hence at a short distance, as in scenarios 2 and 3. Under this scenario, the vast majority of e-consumers intends to use PL and only a small share remains using HD.

To summarize, these predictions suggest that if PLs are located at relatively short (walking) distances from e-consumers' homes and HD is no longer for free, a majority of e-consumers will use PL.

Table 6. Predicted shares of delivery options under six scenarios

Scenario	1.Reference scenario 1 – low prices	2.PL close by	3.PL close by & HD low price	4. Reference scenario 2 - high prices	5. PL for free	6. PL for free & close by
HD Price	€ 0	€ 0	€ 2	€ 6	€ 6	€ 6
SP Price	€ 0	€ 0	€ 0	€ 2	€ 2	€ 2
PL Price	€ 0	€ 0	€ 0	€ 2	€ 0	€ 0
HD Delivery moment	Weekdays: 9h-18h	Weekdays: 9h-18h	Weekdays: 9h-18h	Weekdays: 9h-18h	Weekdays: 9h-18h	Weekdays: 9h-18h
SP Opening hours	Mon - Sat: 8h-22h; Sun: 10h-17h	Mon - Sat: 8h-22h; Sun: 10h-17h	Mon - Sat: 8h-22h; Sun: 10h-17h	Mon - Sat: 8h-22h; Sun: 10h-17h	Mon - Sat: 8h-22h; Sun: 10h-17h	Mon - Sat: 8h-22h; Sun: 10h-17h
PL opening hours	24/7	24/7	24/7	24/7	24/7	24/7
SP Distance	1 km	1 km	1 km	1 km	1 km	1 km
PL Distance	2.5 km	0.5 km	0.5 km	2.5 km	2.5 km	0.5 km
HD	71%	43%	23%	29%	21%	7%
SP	18%	4%	6%	43%	20%	2%
PL	11%	53%	71%	28%	59%	91%

6. Conclusion

This paper examined consumers' preferences for receiving parcels that are ordered online. To that effect, a stated choice experiment was constructed in which respondents make choices among home delivery (HD), service point (SP), and parcel locker (PL) alternatives that are systematically varied in price, delivery moment, and distance. From these observed choices, a panel-mixed logit model was estimated that revealed the impact of attributes and personal characteristics on utility derived from the alternatives. All varied attributes have a statistically significant impact on utility and the effects were in expected directions. In addition, the results indicate that preferences vary with a range of personal characteristics.

The results indicate that variations in price have a considerable impact on utility. This is illustrated by predictions for various scenarios, which suggest that even a small increase in HD price decreases the choice for this option considerably. The simulations also indicated that if HD is considerably priced at €6, SP use is set at €2, while PL is for free and located close to consumers' homes, the far majority of e-consumers will use PL.

However, realizing such a dense locker network requires high investments, and to function properly they should have a white label, implying collaboration between the different competitors in the sector. While governments could stimulate this development by subsidizing the placement of white label lockers and assisting with providing suitable locations, it is not clear how more collaboration in this sector can be achieved. The complexity here is that the e-commerce sector is highly competitive and transcends national boundaries. In addition, price-fixing is often not permitted by law, so the question is how the e-commerce sector can legally cooperate in this respect. Possibly, savings due to the introduction of PLs may lead to a positive business case in the long run. From the research on PL from a Logistic Service Provider (LSP)- perspective (van Duin et al., 2020) it is known that application of a 70% PL share and just 10% evening deliveries can lead to a 20% reduction in both traveled distance and its related GHG emissions, while also a reduction of 45% of the operational time can be realized. Hence, further investigating this is an interesting avenue for continued research on PLs.

In addition, more research is required to better understand the complex interests within the sector and to find effective ways to stimulate cooperation among LSPs and e-retailers. Also, research towards optimal networks for parcel lockers is much needed. First promising steps are made based on principles from Physical Internet (Crainic and Montreuil, 2016), who have translated the PI vision to the context of city logistics as the ''Hyperconnected City''. This implies research on finding out which specific locations are suitable to help maximize the shared use of the lockers, while also keeping in mind efficient vehicle routes for delivery vans of the different LSPs.

A limitation of this research is that it is based on a convenience sample. Although a well-sized sample of 343 respondents was realized and all groups of interest are well presented, in particular, the lower educated were less represented in our sample. Although we cannot excluded the possibility that this under representation may have influenced the results to some extent, the fact the variation in the remaining categories was not related to any of our estimates, suggests that this did not heavily influenced the results of our research. Hence, it is advisable to repeat this research with a larger and especially, more representative sample. To validate the real choices of delivery it is important that in representative pilot projects such as in Spijkenisse and Goederee (Izipack, 2021) measurement of the choices is executed. A further limitation of this study is that consumers had to imagine that they ordered a consumer good of average price (€65), hence the results apply to consumer goods of moderate value. For consumer goods that are considerably more expensive, the ratio of delivery costs compared to the price decreases, which raises the question of whether consumers are then equally sensitive to the variation in delivery costs as varied in this experiment. This is an interesting topic for further research.

For many years free HD has been a sort of holy grail that could not be changed within the delivery service sector. As the sector itself is now running to its limits by exploiting their personnel with lower wages due to the enormous growth it is time for a change. This paper suggests that consumers are willing to use the parcel locker alternative as long a discriminating pricing strategy will be applied among HD, SP and PL. To facilitate the significant switch to PL also strong investments are needed in the positioning of PLs close to the vicinity of households.

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